Species Status Assessment Report for the White-tailed Prairie Dog (*Cynomys leucurus*)

Photo credit: Rhonda Foley/USFWS

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Executive Summary

This report summarizes the results of a species status assessment (SSA) that the U. S. Fish and Wildlife Service (Service) completed for the white-tailed prairie dog (*Cynomys leucurus*). One of five prairie dog species in North America, the white-tailed prairie dog lives in a variety of habitats, including sagebrush steppe, grasslands, and semiarid canyonlands and ranges from southern Montana, through central and southern Wyoming, into northeastern Utah and northwestern Colorado. Like other prairie dog species, the white-tailed prairie dog is colonial (live in colonies) and is distributed across its range as a system of colony complexes. This SSA report summarizes the current and future condition of the white-tailed prairie dog to assess the species’ overall viability now and into the future. For the purposes of this SSA, we define viability as the ability of the white-tailed prairie dog to sustain populations in the wild into the future.

To assess the white-tailed prairie dog’s current and future statuses, we used the three conservation biology principles of resiliency, redundancy, and representation (together, the 3Rs). Specifically, we identified the species’ ecological requirements at the individual, population, and species levels, and described the stressors influencing the species’ viability. The white-tailed prairie dog needs multiple, resilient populations distributed across its range in a variety of ecological settings to persist into the future and to avoid extinction. For our analyses, we divided the species’ range into three populations and nine analysis units. We specifically measured three habitat and demographic factors to determine the species’ current condition and predict its future condition as a means to assess the species’ viability. We evaluated precipitation amount, precipitation variability, and population trends in the nine analysis units to assess the resiliency of white-tailed prairie dog populations in the face of several stressors, including the introduced disease sylvatic plague. In our assessment, a large number of populations in high condition spread across a variety of habitats within the species’ range equates to high overall viability for the white-tailed prairie dog.

The historical condition of the white-tailed prairie dog is difficult to quantify due to a lack of reliable historical data. In the present, the species remains distributed across its historical geographic range, but at decreased abundances because of widespread poisoning campaigns and the introduction of plague in the 20th century.Using the best available data and expert input, we evaluated the three habitat and demographic factors mentioned above and determined that six analysis units are currently in high overall condition (high resiliency) and three analysis units are in moderate overall condition (moderate resiliency). Within the analysis units in high condition, white-tailed prairie dog complexes have maintained stable occupancy in recent years despite frequent plague epizootics and a long-term drought in the western United States. The analysis units in moderate condition have experienced population declines or are exposed to less favorable habitat conditions, but they have also demonstrated stable population trends or recovery after declines. Currently, the white-tailed prairie dog continues to occupy a variety of
habitat types across all of its historic range, and the species continues to exhibit redundancy and representation in the face of multiple stressors.

Table ES-1. Summary of the current condition of the white-tailed prairie dog. Moderate and High refer to the levels of resiliency, or population health or condition, we determined for each analysis unit in our current condition analysis.

<table>
<thead>
<tr>
<th>Population</th>
<th>Analysis Unit</th>
<th>Current Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Montana</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Wyoming</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Northern Utah</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>North Central Colorado</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Northeast Utah</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Northwest Colorado</td>
<td>High</td>
</tr>
<tr>
<td>North Park</td>
<td>North Park</td>
<td>Moderate</td>
</tr>
<tr>
<td>Southern</td>
<td>Southeast Utah</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Grand Junction</td>
<td>High</td>
</tr>
</tbody>
</table>

We predicted the future viability of the white-tailed prairie dog by forecasting the conditions of the three habitat and demographic factors for each analysis unit under five potential future scenarios. Our future scenarios varied based on two main stressors, drought and plague outbreaks, and levels of conservation efforts. We forecast each scenario to two time periods, approximately 30 and 60 years into the future. The projected future conditions of each analysis unit varied based on the forecasted scenario, but we predict that all of the analysis units will remain in moderate to high overall condition in three out of five future scenarios. In our most pessimistic scenario, where we predict the intensities of both drought and plague to increase, we predicted that two analysis units, Montana and Southeast Utah, will be in low condition, and thus at a higher risk of extirpation. Overall, we predict the white-tailed prairie dog will continue to exhibit similar levels of resiliency, redundancy, and representation up to 60 years into the future.

We acknowledge that our assessment is a prediction and may not accurately forecast future events. However, we used the best available science for our analyses and acknowledged any key assumptions and uncertainties throughout this SSA report.
Table E-S 2. Summary of the predicted future conditions of the white-tailed prairie dog under five scenarios. We predicted that analysis units will be in low (L), moderate (M), or high (H) condition (population health or resiliency) for each future scenario 30 and 60 years into the future.

<table>
<thead>
<tr>
<th>Analysis Units</th>
<th>Scenario 1 30 Years</th>
<th>Scenario 1 60 Years</th>
<th>Scenario 2 30 Years</th>
<th>Scenario 2 60 Years</th>
<th>Scenario 3 30 Years</th>
<th>Scenario 3 60 Years</th>
<th>Scenario 4 30 Years</th>
<th>Scenario 4 60 Years</th>
<th>Scenario 5 30 Years</th>
<th>Scenario 5 60 Years</th>
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<td>Montana</td>
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<td>L</td>
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<tr>
<td>Wyoming</td>
<td>H</td>
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<td>H</td>
<td>M</td>
<td>M</td>
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<tr>
<td>Northern Utah</td>
<td>H</td>
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<tr>
<td>North Central Colorado</td>
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<td>Northeast Utah</td>
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<td>North Park</td>
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<td>Southeast Utah</td>
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<td>L</td>
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<td>M</td>
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<tr>
<td>Grand Junction</td>
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Chapter 1. Introduction

This report summarizes the results of a Species Status Assessment (SSA) conducted by the U. S. Fish and Wildlife Service (Service) for the white-tailed prairie dog (Cynomys leucurus). The white-tailed prairie dog is a small rodent found in Colorado, Montana, Utah, and Wyoming.

We used the SSA framework to conduct an in-depth review of the species’ biology and the stressors that impact it, to evaluate its current biological status, and to predict the future status of resources and conditions as a means of assessing the white-tailed prairie dog’s viability. This SSA report summarizes the results of our analysis using this framework. As new information becomes available, we intend to update this SSA report as needed so that it can support all functions of the Endangered Species program, if merited, such as candidate assessments, listing, consultation, and recovery.

The purpose of this SSA report is to provide the biological and scientific foundation for the Service’s decision on whether to list the white-tailed prairie dog as a threatened or endangered species under the Endangered Species Act of 1973, as amended (Act) (16 U.S.C. 1531 et seq.). If the Service determines that listing the white-tailed prairie dog is warranted, the SSA report may also be used by the Service to propose designating critical habitat for the species as required by the Act. Importantly, this SSA report does not result in a decision document, but instead provides the biological information and scientific analysis needed to support future decisions made by the Service under the Act. The listing decision for the white-tailed prairie dog will be made by the Service after reviewing this SSA report and all relevant laws, regulations, and policies, and the Service will announce any policy decision independently in the Federal Register.

1.1 Petition History and Previous Federal Actions

On July 15, 2002, we received a petition from the Center for Native Ecosystems, Forest Guardians, Biodiversity Conservation Alliance, and Terry Tempest Williams requesting that the white-tailed prairie dog be listed as endangered or threatened across its entire range. On November 9, 2004, we announced our 90-day finding that the petition did not present substantial scientific or commercial information indicating that listing may be warranted (69 FR 64889). Following internal review and a settlement agreement with the petitioners, we initiated a 12-month status review for the white-tailed prairie dog on May 6, 2008 (73 FR 24910). On June 1, 2010, we completed our status review and determined that the white-tailed prairie dog was not warranted for listing as a threatened or endangered species under the Act (75 FR 30338). On September 29, 2014, a court remanded the 12-month not-warranted finding back to us for reconsideration. This SSA will inform our new 12-month finding for the white-tailed prairie dog, which we expect to publish in the Federal Register before the end of Federal Fiscal Year 2017.
1.2 The Species Status Assessment (SSA) Framework

This SSA report summarizes the results of our in-depth review of the white-tailed prairie dog’s biology and stressors, an evaluation of the species’ biological status, and an assessment of the resources and conditions needed to maintain long-term viability. For the purposes of this assessment, we define viability as the ability of the species to sustain populations in the wild into the future in a biologically meaningful timeframe, which is 60 years for our analyses (explanation for our timeframes given in Chapter 4. Future Condition).

Using the SSA Framework (Figure 1), we considered what the white-tailed prairie dog needs to be viable into the future by characterizing the current and future statuses of the species using the concepts of resiliency, redundancy, and representation (the “3Rs”) from conservation biology (Shaffer and Stein 2000, pp. 308–311; USFWS 2016, p.12).

- **Resiliency** is the ability of populations to tolerate natural, annual variation in their environment and to recover from periodic or random disturbances, known as stochastic events. Resiliency can be measured using metrics like vital rates, such as annual births and deaths, and population size. In general, populations with high abundance and stable or increasing population trends are more resilient than those with limited resources or declining populations. Populations with high resiliency can better withstand stochastic changes in demography or their environment due to natural or anthropogenic disturbances.

- **Redundancy** is the ability of a species to withstand catastrophic events, such as a rare, destructive natural event that affects multiple populations. Redundancy is measured by the duplication and distribution of populations across the range of the species. The more redundant a species, or the greater number of populations a species has distributed over a larger landscape, the better able it is to recover from catastrophic events. Redundancy helps “spread the risk” and ensures all populations are not extirpated at once due to a catastrophic event.

- **Representation** is the ability of a species to adapt to changing physical (climate, habitat) and biological (diseases, predators) conditions. Representation can be measured by looking at the genetic, morphological, behavioral, and ecological diversity within and between populations across a species’ range. The more representation, or diversity, a species has, the more likely it is to adapt to and persist with natural or human-caused changes to its environment.
Figure 1. The three phases (blue boxes) of the SSA Framework used to guide this analysis. To assess the viability of the white-tailed prairie dog, we evaluated the species’ needs, the current availability and condition of those needs, and the species’ current condition. We then predicted the species’ future condition based on the future availability and condition of the species’ needs.

For the purpose of this SSA, viability is defined as the ability of a species to sustain populations in the wild over time. Viability is not a single state; rather, there are degrees of viability. In other words, we do not conclude that a species is or is not viable upon completion of a Species Status Assessment. Instead, we characterize the resiliency, redundancy, and representation a species currently presents and predict how these characteristics may change into the future. Generally speaking, species with higher resiliency, redundancy, and representation are more protected from the vagaries of the environment, can better tolerate stressors and adapt to changing conditions, and are thus more viable than species with low levels of the 3Rs.

To assess the viability of the white-tailed prairie dog, we analyzed the species’ ecology, historic and current conditions, and projected the viability of the species under a number of future scenarios, all in the context of the 3Rs and using the best scientific data available. Chapter 2 of this SSA report summarizes the biology, ecology, and needs of the white-tailed prairie dog at the individual, population, and species levels. Chapter 3 examines the stressors (and conservation measures) which impact the resiliency of white-tailed prairie dog populations and analyzes the historical and current conditions of the species. Chapter 4 predicts the future condition of the species under five potential scenarios. In Chapter 5, we summarize all of the information presented in this SSA and analyze the viability of the white-tailed prairie dog.

1.3 Summary of New Information

Since our 2010 review of the white-tailed prairie dog’s status, we studied new peer-reviewed literature and solicited data and new information from partner agencies in all four states across the range of the white-tailed prairie dog (Colorado, Montana, Utah, and Wyoming) including,
but not limited to, state Natural Heritage programs, state wildlife management agencies, tribes, and the Bureau of Land Management (BLM). Specifically, we requested new information (after 2010) on:

- The species’ distribution, population sizes, population trends, and any updates to the species’ range or mapped colonies;
- The magnitude and severity of sylvatic plague in the agency’s area;
- Other potential threats to the species, including, but not limited to, energy development, agricultural conversion, recreational shooting, wildfire, and poisoning;
- Updates to laws, regulations, or policies that may apply to the species; and
- Any ongoing conservation for the species and its habitats.

Our literature review and data solicitation resulted in new information on sylvatic plague dynamics and management, conservation efforts on BLM-managed public lands, and white-tailed prairie dog population trends. Several peer-reviewed papers have been published since 2010 investigating the application and efficacy of deltamethrin, an insecticide, and oral Sylvatic Plague Vaccine (SPV) to manage the non-native pathogen that causes deadly epizootics of sylvatic plague in prairie dog colonies. BLM field offices throughout the range of the white-tailed prairie dog have updated their Resource Management Plans (RMPs) to comply with the 2007 Statewide Programmatic White-tailed Prairie Dog Biological Evaluation published in Wyoming, which describes several conservation measures which can be implemented to protect colonies on BLM-managed lands. One of the most important new sources of data for our analysis were statewide white-tailed prairie dog occupancy surveys coordinated by the Western Association of Fish and Wildlife Agencies (WAFWA) conducted in Colorado, Utah, and Wyoming in 2016. Until recently, state wildlife agencies in all four states within the species’ range monitored populations using different methods and varying levels of effort. Although there are still small differences in the way the states now collect and analyze this occupancy data, this represents a significant improvement in available information that has allowed us to complete a more robust analysis of the white-tailed prairie dog’s viability.

We incorporated these data, which include spatial data, peer-reviewed literature, reports, and personal communications, into various parts of the SSA, including the analysis of the current distribution of the white-tailed prairie dog and the severity of stressors and related conservation actions. If we lacked specific data for some aspect of our analysis, we used information from other prairie dog species including the black-tailed prairie dog (Cynomys ludovicianus), the Gunnison’s prairie dog (C. gunnisoni), and the Utah prairie dog (C. parvidens).
Chapter 2. Species Ecology and Needs

In this chapter, we provide basic biological information about the white-tailed prairie dog, including its taxonomic history and relationships, morphological description, physical environment, and reproductive and other life history traits. We then outline the needs of the white-tailed prairie dog at the individual, population and species levels. This is not an exhaustive review of the species’ natural history; rather, it provides the ecological basis for the SSA analyses conducted in this report.

2.1 Life History

2.1.1 Taxonomy and Description

The white-tailed prairie dog is one of five prairie dog species that inhabit western North America (Clark et al. 1971, p. 1; Pizzimenti 1975, pp. 62-63). Prairie dogs are in the squirrel family, Sciuridae, and belong to the genus *Cynomys* (Hollister 1916, p. 5). The genus is split into two subgenera (Clark et al. 1971, p. 1; Pizzimenti 1975, pp. 15-16). Utah (*C. parvidens*), Gunnison’s (*C. gunnisoni*), and white-tailed prairie dogs are included in the subgenus *Leucocrossuromys* (Hollister 1916, p. 5, Clark et al. 1971, p. 1). Although Burt and Grossenheimer (1964 in Knowles 2002, p. 3) considered all members of the subgenus *Leucocrossuromys* to be a single species, based on Pizzimenti’s (1975) work, it is doubtful that the single species concept for the subgenus *Leucocrossuromys* is valid (Knowles 2002, pp. 3-4). According to Knowles (2002, p. 4), there is sufficient genetic and morphological evidence to conclude that there are three separate species within the white-tailed prairie dog subgenus. The *Leucocrossuromys* prairie dogs have short tails with white tips and exhibit weaker social structures than the *Cynomys* subgenus (Hollister 1916, pp. 1, 6). The subgenus *Cynomys* includes black-tailed (*C. ludovicianus*) and Mexican prairie dogs (*C. mexicanus*). Chromosomal and biochemical data suggest Utah prairie dogs and white-tailed prairie dogs are very closely related (Pizzimenti 1975, p. 16).

White-tailed prairie dogs are between 340 to 370 millimeters (mm) (13.4 to 14.6 inches (in)) in length with a 40 to 65 mm (1.6 to 2.6 in) long tail (Clark et al. 1971, p. 1). The tail has a grayish white tip and is white on the terminal half. The coat is generally yellow-tan with distinctive dark brown or black cheek patches that extend above the eye with a lighter black stripe that extends below the eye onto the cheek (Clark et al. 1971, p. 1) (Figure 2).
2.1.2 Habitat

The white-tailed prairie dog occurs at elevations ranging from 1,150 meters (m) (3,773 feet (ft)) (Flath 1979, p. 63) to 3,200 m (10,500 ft) in parts of Wyoming, Utah, Montana, and Colorado (Tileston and Lechleitner 1966, p. 295; Seglund et al. 2006, p. 4). Unlike the grass-dominated habitats of black-tailed prairie dogs, white-tailed prairie dogs generally inhabit drier landscapes with shrub land vegetation, such as the high desert scrub community of Utah and sagebrush steppe of western Wyoming (Tileston and Lechleitner 1966, p. 295; Clark 1977, pp. 3-5; Collins and Lichvar 1986, pp. 88-91; Gadd 2000, pp. 15-16; Lupis et al. 2007, p. 7). Colonies can also be found adjacent to highly productive agricultural areas (Seglund et al. 2006, p. 44). Plants associated with white-tailed prairie dog colonies include a variety of shrubs, forbs, and grasses, including saltbush (*Atriplex* spp.), sagebrush (*Artemisia* spp.), and western wheatgrass (*Pascopyrum smithii*) (Seglund et al. 2006, p. 5, and references within). Unlike other prairie dog species, white-tailed prairie dogs do not actively ‘clip’ vegetation within colonies to alter habitat structure (Tileston and Lechleitner 1966, p. 302). Their habitats are generally flat with slopes less than 30 degrees (Collins and Lichvar 1986, p. 92; Forrest et al. 1985 in Andelt et al. 2009, p. 36).
White-tailed prairie dogs prefer areas with lower vegetation heights to facilitate predator surveillance (Collins and Lichvar 1986, p. 92), but they also may use dense brush adjacent to grassier areas to avoid predators (Tileston and Lechleitner 1966, p. 314; Hoogland 1981, pp. 266-268; Gadd 2000, pp. 24-26). White-tailed prairie dogs dig their own burrows, which require deep, well-drained soils. Preferred soils are derived from sandstone or shale and may be clay-loam, silty clay, or sandy loam (Lupis et al. 2007, p. 6). Burrows are used throughout the year for hibernation, cover from temperature extremes, predator avoidance, and birthing and raising young (Clark 1977, p. 9; Hoogland 1981, pp. 258-264). During winter, burrows must be available that extend below the frost line to prevent freezing during hibernation (Wagner and Drickamer 2004, pp. 188, 194; Underwood 2007, p. 3). Burrow complexes are usually widespread with numerous entrances, tunnels, and chambers. These extensive burrow systems provide numerous refugia for prairie dogs to escape from predators, which include ferruginous hawks, eagles, badgers, coyotes, bobcats, rattlesnakes, and black-footed ferrets (Seglund et al. 2006, p. 58; MFWP and BLM 2010, p. 2). The number of burrows in an area varies greatly from location to location, ranging from 0.3 to 118 per acre (0.12 to 47.75 per hectare) with a mean of 0.8 to 16.8 per acre (0.32 to 6.79 per hectare) (Tileston and Lechleitner 1966, p. 314; Menkens and Anderson 1989, p. 84; Seglund and Schnurr 2010, p. 94).

2.1.3 Feeding Habits

Prairie dogs are primarily herbivorous and mainly eat grasses and forbs (Kelso 1939, pp. 7-11). However, the white-tailed prairie dog’s selection of plants is somewhat dependent on site-specific conditions and seasonality. For example, they have been found to eat sagebrush and saltbush during early spring, grasses in the summer, and seed heads and rabbitbrush flowers in the fall (Kelso 1939, p. 10; Tileston and Lechleitner 1966, p. 302). White-tailed prairie dogs also eat insects (Stockard 1929, p. 476; Crocker-Bedford 1976, p. 25) and will occasionally consume small parts of Wyoming ground squirrels killed during territorial interactions (Hoogland and Brown 2016, p. 4). A laboratory study of black-tailed prairie dogs determined one prairie dog consumes about 0.93 kilograms (kg) of food per month (Hansen and Cavendar 1973 in Miller et al. 2007, p. 2804). Prairie dogs obtain most of their water from the vegetation they eat and can persist without free water (Clark 1977, p. 26; Knowles 2002, p. 7), but they can become water-stressed if sufficient succulent vegetation is unavailable (Seglund et al. 2006, p. 7). Individual white-tailed prairie dogs need sufficient vegetation surrounding their burrows to meet their nutritional needs throughout the active season, which includes energetically expensive activities like breeding and whelping of pups (Garrett et al. 1982, pp. 54-57; Beck 1994, p. 25).

2.1.4 Life Cycle and Reproduction

Adult sex ratios are approximately one male to two females (Clark 1977, p. 76; Hoogland 2010, pers. comm.). Breeding occurs from late March to mid-April (Tileston and Lechleitner 1966, p. 303) (Figure 3). White-tailed prairie dogs can reproduce at one year of age, and they have a
single litter once a year averaging four to six pups (Bakko and Brown 1967, pp. 110-111). Females practice polyandry, which is copulation with two or more males (Hoogland 2013, p. 731). Polyandry improves the reproductive output of white-tailed prairie dog females by increasing the probability of conception and parturition and the number of surviving yearlings (Hoogland 2013, pp. 734-735). Pups are born in burrows after a gestation period of approximately 30 days (Tileston and Lechleitner 1966, p. 304) and emerge from the burrow for the first time four to six weeks after birth (Bakko and Brown 1967, p. 103) (Figure 3). Juveniles begin to disperse from the colony in June and July when population densities are the highest (Clark 1977, p. 72) (Figure 3). Some adults, mainly yearling males, will disperse during the spring (Clark 1977, p. 70). Although the average longevity of white-tailed prairie dogs in the wild is unknown, it is believed to only be a few years (Clark 1977, p. 86; Pauli et al. 2006, p. 18).

<table>
<thead>
<tr>
<th>Life Stage</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult (&gt;1 year old)</td>
<td>Hibernation</td>
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<td></td>
<td></td>
<td></td>
<td>Active Season</td>
<td></td>
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<td></td>
<td></td>
<td>Hibernation</td>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Pup (&lt;3 months old)</td>
<td></td>
<td></td>
<td>In Burrow</td>
<td></td>
<td></td>
<td>Emerge from Burrow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juvenile (&gt;3 months old)</td>
<td></td>
<td></td>
<td>Dispersal</td>
<td>Active Season</td>
<td></td>
<td>Hibernation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 3. Gant timeline chart for one year in the life cycle of a white-tailed prairie dog adult, pup, and juvenile.

Vital rates, such as annual births and deaths, are difficult to discern for the white-tailed prairie dog across its range. Rates of birth and death in the species seem to be highly variable and dependent on a variety of factors, including body condition as a consequence of annual changes in habitat quality, colony size and density, and sylvatic plague cycles (an exotic disease caused by the bacterium Yersinia pestis) (Hoogland et al. 1987, p. 19; Montana Prairie Dog Working Group 2002, p. 28; Facka et al. 2010, entire; Seglund 2016, p. 11). Highly variable vital rates can lead to drastic increases and decreases in population numbers within a white-tailed prairie dog colony, even within the same year (Pauli et al. 2006, p. 19; Seglund et al. 2006, p. 28). The
number of reproductive females in a colony can vary greatly from year to year (Menkens and Anderson 1989, p. 344), and increased reproduction has been observed in colonies after disasters like plague epizootics, which may help compensate for large declines (Cully 1997 in Knowles 2002, p. 14). One theoretical model concluded juvenile survival is the main factor that drives population growth in prairie dog populations (Pauli et al. 2006, p. 19), but juvenile mortality rates are high (Pauli et al. 2006, p. 18; Hoogland 2001, pp. 919-920). Reported annual mortality rates for prairie dogs range from 30 to 60 percent (Knowles 2002, p. 7), but they may not incorporate population declines due to plague, which can cause colony mortality rates of 85 to 100 percent (Clark 1977, p. 73; Cully and Williams 2001, entire). In a three year study of a colony in Wyoming, the majority of adult prairie dogs died or disappeared (possibly dispersed) after their first year (Clark 1977, p. 86).

2.1.5 Activity

White-tailed prairie dogs are diurnal, meaning they are active during the day (Tileston and Lechleitner 1966, p. 200). They are active approximately 5 to 7 months per year from early spring to fall (March to October) and hibernate during late fall and winter (Clark 1977, pp. 59-60; Cooke 1993, p. 11). In years with unfavorable conditions, such as drought, adults may become dormant and begin hibernating as early as July (Tileston and Lechleitner 1966, p. 301; Clark 1977, p. 55; Andelt et al. 2009, p. 43). White-tailed prairie dogs are sensitive to heat and will avoid high midday temperatures during the summer by foraging in the cooler morning and evening hours (Clark 1977, p. 58).

2.1.6 Social System and Metapopulation Dynamics

Although they are still colonial, white-tailed prairie dogs have the least cohesive social structure of all the prairie dog species. They are also less territorial than other species, with aggressive behavior being mostly confined to the breeding season (Tileston and Lechleitner 1966, p. 312; Clark 1977, p. 31-32). Adult white-tailed prairie dogs spend little time displaying social behavior and most of their time feeding or in alert postures (Clark 1977, p. 44). Their social system is organized around family groups or ‘clans,’ comprised of several reproductive females, one or two males of reproductive age, and dependent young (Clark 1977, p. 62; Cooke 1993, p. 22). Multiple clans grouped together comprise a ‘colony’, and multiple grouped colonies comprise a ‘complex’ (Hoogland 2006 in Baker et al. 2013, p. 230). Within the colony, white-tailed prairie dogs occur in low densities (Hoogland 1981, p. 252). This, in addition to the species’ decreased sociality, make the borders of white-tailed prairie dog colonies less discernible than those of other prairie dog species (Tileston and Lechleitner 1966, pp. 297, 314; Hoogland 1981, p. 252). Home range sizes of white-tailed prairie dogs in Wyoming averaged 5.9 acre (2.4 hectare) for adults and 6.9 acre (2.8 hectare) for juveniles. Although the location of an individual’s home range may shift between years, the size was found to be relatively constant (Clark et al. 1971, p. 3).
A metapopulation represents a system of neighboring populations connected by dispersing individuals, or, a “population of populations” (Levins 1970 in Hanski and Gilpin 1991, p. 7). The metapopulation structure of white-tailed prairie dogs has received little study and is not well defined (Keinath 2004, p. 13). However, emigration and immigration are common in white-tailed prairie dogs (Clark 1977, p. 66), and migration is recognized as an important factor influencing the species’ population dynamics (Clark 1977, p. 80). Juveniles begin to disperse from the natal burrow in June and July, and some adults, mainly yearling males, will disperse in the spring (Clark 1977, p. 70-72). Plague in this species often results in near extirpation of colonies. Rapid recolonization of some areas post-plague with few or no surviving reproductive adults suggests the species is highly mobile (Seglund et al. 2006, p. 10), and this reestablishment process is necessary for the persistence of white-tailed prairie dog colonies across the landscape (Nistler 2009, p. 18). To facilitate this reestablishment, as well as gene flow, large areas of white-tailed prairie dog colonies with dispersal corridors of appropriate habitat are necessary (Clark 1977, p. 80; Nistler 2009, p. 73). With the exception of one female with a recorded dispersal distance of 8 kilometers, reported white-tailed prairie dog dispersal distances range from less than 50 meters to 2.4 kilometers (reviewed by Seglund et al. 2006, p. 10).

2.1.7 Status as a Keystone Species

Prairie dogs are often referred to as keystone species because of their effects on grassland ecosystems (Miller et al. 1994, p. 678; Stapp 1998, p. 1253; Kotliar et al. 1999, p. 178; Davidson et al. 2012, entire). A keystone species is one that influences the composition and function of an ecological system in a way that is disproportionately higher than its relative abundance (Kotliar et al. 1999, p. 178). While defenders of keystone species status for prairie dogs point to their extensive effects as prey, grazers, and burrowers (Miller et al. 1994, entire; Miller et al. 2000, entire; Forrest 2005, entire; Davidson et al. 2012, entire), some others contend that current studies are too limited in scope and that these effects have been overstated without sufficient proof (but still state that prairie dog conservation is important) (Stapp 1998, entire; Kotliar et al. 1999, entire). It is not within the scope of this SSA to determine whether or not the white-tailed prairie dog is a keystone species, especially since this debate is generally focused on black-tailed prairie dogs, which are more wide-ranging, more densely populated, and better studied than white-tailed prairie dogs. However, we do think it is important to acknowledge the diversity of species associated with prairie dog colonies in this document.

The black-footed ferret (Mustela nigripes) is a federally endangered mammal that is an obligate prairie dog predator. Because black-footed ferrets depend on prairie dogs for food, declines in ferrets are directly linked to declines in prairie dogs across North America (reviewed by Kotliar et al. 1999, p. 182). Burrowing owls (Athene cunicularia) and mountain plovers (Charadrius montanus) are highly facultative associates (but not obligates) of prairie dog colonies that also have documented declines in concert with decreasing prairie dog numbers (reviewed by Kotliar et al. 1999, p. 182). Predators associated with prairie dog colonies include ferruginous hawks
(Buteo regalis), golden eagles (Aquila chrysaetos), badgers (Taxidea taxus), swift foxes (Vulpes velox), and rattlesnakes (Crotalus spp.) (Miller et al. 1994, pp. 678-697; Kotliar et al. 1999, p. 177; Knowles 2002, p. 23). Native pronghorn (Antilocapra americana) and bison (Bison bison) and introduced cattle sometimes preferentially graze on the nutritious forage found on prairie dog colonies (Coppock et al. 1983, p. 12; Krueger 1986, pp. 762-763; Sierra-Corona et al. 2015, p. 6).

2.2 White-tailed Prairie Dog Needs

A species can only be viable if its basic ecological needs are met. In this section, we translate our knowledge of the white-tailed prairie dog’s biology and ecology into its needs at the individual, population, and species levels. For individual white-tailed prairie dogs, we describe the habitat resources or conditions that adults, pups, and juveniles need to complete each stage of their life cycle. We then describe the habitat and demographic conditions that white-tailed prairie dog populations need to be resilient. Finally, we describe what the species needs in order to be viable, in terms of resiliency, redundancy, and representation (Figure 4).

![Figure 4. General overview illustration of how resiliency, redundancy, and representation influence what a species needs for viability.](image)

2.2.1 Individual Needs

Individual needs for white-tailed prairie dogs vary somewhat by life stage (Figure 5). Adult prairie dogs need abundant succulent vegetation and friable soils for their breeding and sheltering needs (Seglund et al. 2006, pp. 4, 6). Succulent vegetation, such as grasses and forbs, supports their caloric and hydration requirements throughout the active season (breeding, whelping, metabolic maintenance) (Tileston and Lechleitner 1966, pp. 302-202; Seglund et al. 2006, p. 6). Adults also need friable soils for digging and maintaining well-developed burrow systems that protect them from predators and temperature extremes and provide shelter during
whelping and hibernation (Seglund et al. 2006, p. 4). Adult prairie dogs also need to find mates every year so they can complete their life cycle. Like adults, juvenile prairie dogs need access to succulent vegetation for growth. Friable soils allow them to dig new burrows, or occupy abandoned burrows, once they disperse. Prairie dog pups are completely reliant on a female to provide them nutrition during the whelping period. They also need the well-developed burrow systems provided by friable soils for shelter during this vulnerable stage. Once pups are weaned, they need succulent vegetation to feed upon.

Figure 5. Life cycle diagram with the resource needs of individual white-tailed prairie dog adults, juveniles, and pups. An individual prairie dog needs these resources to breed (B), feed (F), shelter (S), and disperse (D) and thus complete its life cycle.

2.2.2 Population Needs

For the purposes of this SSA, we define a population of white-tailed prairie dogs as a complex of colonies. To remain ecologically functional, these populations need high levels of fecundity and juvenile survival as well as connectivity between colonies within the complex (Clark 1977, p. 80; Pauli et al. 2006, p. 19; Nistler 2009, p. 73). High levels of fecundity and juvenile survival can drive population growth and allow colonies to recover from stochastic disasters, such as extreme weather events or plague epizootics (resiliency) (Pauli et al. 2006, p. 19). Given the short
longevity of adults (Hoogland 2001, p. 919), annual recruitment of juveniles is imperative to replace the loss of reproductive individuals every year (Pauli et al. 2006, p. 19). White-tailed prairie dogs are known to be highly mobile (Tileston and Lechleitner 1966, p. 315), and connectivity between colonies encourages dispersal of individuals and maintains gene flow, which prevents extirpation due to low genetic diversity and accelerated genetic drift (Clark 1977, p. 80; Lacy 1987, p. 148; Lomolino et al. 2003, pp. 116-119; Nistler 2009, p. 73). Immigration increases abundance within populations and allows for recolonization of extirpated colonies following a disaster (Knowles 1987, p. 54; Sackett et al. 2013, p. 2450). Larger, less fragmented colonies are more resilient and less likely to be extirpated by a stochastic event (Miller et al. 1994, p. 678).

It is important for us to note there may be times when high connectivity could be detrimental for white-tailed prairie populations because it can lead to increased rates of plague transmission. Studies have shown that smaller, more fragmented populations experience decreased rates of plague transmission and thus may exhibit more resilience than their larger, more connected counterparts (Cully and Williams 2001, p. 901; Johnson et al. 2010, p. 365). However, smaller, more fragmented populations are more vulnerable to other stochastic events, and the decrease in connectivity associated with fragmentation means extirpated colonies are less likely to be recolonized. Recent research suggests connectivity may not actually be the main driver of the plague cycle (Stapp et al. 2004, p. 238; Gage and Kosoy 2005, p. 519; Biggins et al. 2010, pp. 21-24; Matchett et al. 2010, pp. 30, 33), and a fragmented metapopulation structure on its own is not enough to protect prairie dogs from the threat of plague (George et al. 2013, p. 1580), so we maintain that connectivity is important to support gene flow after epizootics and to promote viability of the species (Knowles 2002, p. 24; Lomolino et al. 2003, pp. 116-119; Nistler 2009, p. 73).

2.2.3 Species Needs

As a species, the white-tailed prairie dog needs multiple, resilient, connected populations that display a breadth of ecological and genetic diversity across its range (Knowles 2002, p. 24). Well-connected complexes of prairie dog colonies with high levels of immigration and emigration across the landscape ensure gene flow and allow for recolonization following extirpation of individual colonies (Clark 1977, p. 80; Knowles 1987, p. 54; Nistler 2009, p. 73). Although information on genetic variability of white-tailed prairie dogs is limited, it is likely that genetic exchange is occurring throughout the species’ range between inter-connected populations (A. Seglund, CPW, pers. comm.; K. Hersey, UDWR, pers. comm.). Habitat types utilized by white-tailed prairie dogs across the range include intermountain basins, agricultural fields, open shrublands, grasslands, and sage-steppe (Tileston and Lechleitner 1966, p. 295; Clark 1977, pp. 3-5; Collins and Lichvar 1986, pp. 88-91; Gadd 2000, pp. 15-16; Seglund et al. 2006, p. 44; Lupis et al. 2007, p. 7). In order to adapt to changing physical and biological conditions, the species needs to maintain its genetic and ecological diversity
(representation) and a certain number and distribution of resilient populations across its range (redundancy).

2.2.4 Summary of Species Needs in terms of the 3Rs

When individual prairie dogs have access to ample food and habitat, reproductive rates increase and colonies expand (Garrett et al. 1982, pp. 54-57; Seglund et al. 2006, p. 7). These conditions create large, resilient populations that are able to withstand periodic natural disturbances, such as drought or disease outbreaks (resiliency). At the population level, juvenile survival drives population growth (Pauli et al. 2006, p. 19) and connectivity maintains dispersal and gene flow between colonies (Clark 1977, p. 80; Knowles 1987, p. 54; Lomolino et al. 2003, pp. 116-119; Nistler 2009, p. 73). The duplication and distribution of colonies across the landscape, as well as the high potential for migration, create a population that is able to recover from catastrophic events (redundancy) (Knowles 1987, p. 54; Knowles 2002, p. 24). At the species level, connectivity facilitates a network of multiple (redundant), self-sustaining (resilient) populations distributed across the white-tailed prairie dog’s range that display a breadth of genetic and ecological diversity (representation). This increases the ability of the species to adapt to changing physical and biological conditions (representation) (Table 1).
Table 1. Summary of individual, population, and species’ needs for the white-tailed prairie dog in terms of the 3Rs.

<table>
<thead>
<tr>
<th>Level</th>
<th>Need</th>
<th>Function of Need</th>
<th>Association with 3 Rs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual</td>
<td>Friable soils</td>
<td>Digging burrows and creating interconnected burrow systems for protection from predators and weather; shelter for hibernation and whelping; habitat for dispersing juveniles</td>
<td>Resiliency</td>
</tr>
<tr>
<td></td>
<td>Abundant succulent vegetation</td>
<td>Meet caloric and hydration needs throughout the active season including breeding, whelping, and juvenile growth</td>
<td>Resiliency</td>
</tr>
<tr>
<td>Population</td>
<td>High fecundity and juvenile survival</td>
<td>Drive population growth</td>
<td>Resiliency</td>
</tr>
<tr>
<td></td>
<td>Connectivity between colonies</td>
<td>Provides for dispersal of juveniles and young adults; increases genetic diversity and allows for immigration following catastrophic events, which increases abundance within populations and the number of populations across the range (in the case of recolonization)</td>
<td>Resiliency, Redundancy</td>
</tr>
<tr>
<td>Species</td>
<td>Multiple, connected, resilient populations across the species’ range</td>
<td>Improves the viability of the species by spreading the risk associated with catastrophic events</td>
<td>Redundancy</td>
</tr>
<tr>
<td></td>
<td>Maintenance of the full breadth of ecological and genetic diversity within the species’ range</td>
<td>Preserves diversity and provides for adaptability in the face of changing environmental conditions</td>
<td>Representation</td>
</tr>
</tbody>
</table>
Chapter 3. Historical and Current Condition

In this chapter, we summarize the historical and current conditions of the white-tailed prairie dog at the population and species levels. To do this, we introduce the stressors that have and continue to influence the species’ condition as well as current conservation efforts which buffer against these stressors. We then detail how prairie dog abundance has changed over time. Finally, we put the species’ historical and current conditions in the context of the 3Rs to assess the species’ current viability. At the species level, the white-tailed prairie dog needs multiple, connected, resilient populations in a breadth of ecological settings across its range to be viable (Chapter 2).

We used ESRI ArcMap v. 10.4.1 for the spatial analyses conducted in this chapter. The data sources for these analyses can be found in U. S. Fish and Wildlife Service 2017 (entire).

3.1 Range of the White-tailed Prairie Dog

For the purposes of this SSA, we compiled spatial data from Colorado Parks and Wildlife (CPW), the Montana Natural Heritage Program, Utah Division of Wildlife Resources (UDWR), the Wyoming Game and Fish Department (WGFD), and the Wyoming Natural Diversity Database (WYND) to create an updated range map for the white-tailed prairie dog (Figure 6). A detailed description of this process is described in U.S. Fish and Wildlife Service 2017 (pp. 4-9). We present the species’ range at two scales, the gross range and the predicted range. The gross range encompasses all areas of known occurrence and potential habitat, so it represents the outer, approximate boundary of where white-tailed prairie dogs occur or could occur. We do not expect that all of the areas within the gross range are occupied by white-tailed prairie dogs or that they necessarily provide suitable habitat. The predicted range is a subset of the gross range that represents a more spatially-refined estimate of where white-tailed prairie dogs may occur. It includes areas of known occurrence and areas that are potentially capable of supporting the species based on assessments of habitat characteristics such as vegetation, soils, slope, and elevation. These areas were identified by synthesizing white-tailed prairie dog range data, occurrence data, modeling efforts, and expert knowledge.

Whenever possible, we used the predicted range for our spatial analyses because it more accurately reflects the core of the white-tailed prairie dog’s distribution. However, there were a few analyses where it was more appropriate to use the gross range; we explicitly identify these cases in the text to prevent confusion. Historical range maps (Hollister 1916, p. 24; Clark et al. 1971, p. 2) more closely reflect the species’ gross range by our definition and are discussed in section 3.3 Historical Condition.

The white-tailed prairie dog’s gross range extends from a small part of southern Montana into central and southern Wyoming, northwest Colorado, and northeast Utah (Clark et al. 1971, p. 1).
In Montana, the species is only found in southern Carbon County. The white-tailed prairie dog’s gross range encompasses 52,146,521 acres (21,102,948 hectares), and the predicted range encompasses 34,277,527 acres (13,871,623 hectares). The vast majority of the species’ range is in Wyoming; 76 percent of the predicted range and 63 percent of the gross range occurs in the state (Table 2). Approximately half of the gross and predicted ranges are on public land administered by the Bureau of Land Management (BLM), and about a third is privately-owned (Figure 7, Table 3).

Figure 6. The gross and predicted ranges of the white-tailed prairie dog. The gross range represents the outer boundary of areas where the white-tailed prairie dog occurs or could occur, but not all areas within the gross range are occupied or provide potentially suitable habitat. The predicted range is a more refined subset of the gross range modeled on habitat attributes to more accurately predict areas where the white-tailed prairie dog may occur. Although it represents a more accurate spatial representation of the range of the white-tailed prairie dog, we also do not expect that all areas within the predicted range are occupied or provide suitable habitat. The gross range encompasses 52,146,521 acres (21,102,948 hectares), and the predicted range encompasses 34,277,527 acres (13,871,623 hectares).
Table 2. Acres of the white-tailed prairie dog’s predicted and gross ranges in Colorado, Montana, Utah, and Wyoming. The gross range encompasses 52,146,521 acres (21,102,948 hectares) and represents the outer boundary of areas where the white-tailed prairie dog occurs or could occur, but not all areas within the gross range are occupied or provide potentially suitable habitats. The predicted range encompasses 34,277,527 acres (13,871,623 hectares) and represents a more refined subset of the gross range modeled on habitat attributes to more accurately predict areas where the white-tailed prairie dog may occur. Although it represents a more accurate spatial representation of the range of the white-tailed prairie dog, we also do not expect that all areas within the predicted range are occupied or provide suitable habitat.

<table>
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<th>State</th>
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<th>Acres in Gross Range</th>
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<td>16.27%</td>
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<tr>
<td>Wyoming</td>
<td>26,295,015</td>
<td>76.71%</td>
<td>32,691,098</td>
<td>62.69%</td>
</tr>
</tbody>
</table>
Figure 7. Landownership types across the predicted range of the white-tailed prairie dog. Since spatial data of the proper resolution were available, we used the predicted range for this analysis because it is a subset of the gross range that represents a more spatially-resolved estimate of where the white-tailed prairie dog may occur.
Table 3. Land ownership types across the predicted and gross ranges of the white-tailed prairie dog. The gross range encompasses 52,146,521 acres (21,102,948 hectares) and represents the outer boundary of areas where the white-tailed prairie dog occurs or could occur, but not all areas within the gross range are occupied or provide potentially suitable habitats. The predicted range encompasses 34,277,527 acres (13,871,623 hectares) and represents a more refined subset of the gross range modeled on habitat attributes to more accurately predict areas where the white-tailed prairie dog may occur. Although it represents a more accurate spatial representation of the range of the white-tailed prairie dog, we also do not expect that all areas within the predicted range are occupied or provide suitable habitat.

<table>
<thead>
<tr>
<th>Land Ownership Type</th>
<th>Percent of Predicted Range</th>
<th>Percent of Gross Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bureau of Indian Affairs</td>
<td>3.53%</td>
<td>3.92%</td>
</tr>
<tr>
<td>Bureau of Land Management</td>
<td>51.63%</td>
<td>48.50%</td>
</tr>
<tr>
<td>Bureau of Reclamation</td>
<td>1.29%</td>
<td>0.92%</td>
</tr>
<tr>
<td>U.S. Forest Service</td>
<td>0.35%</td>
<td>5.01%</td>
</tr>
<tr>
<td>U.S. Fish and Wildlife Service</td>
<td>0.38%</td>
<td>0.26%</td>
</tr>
<tr>
<td>National Park Service</td>
<td>0.22%</td>
<td>0.67%</td>
</tr>
<tr>
<td>Local Government</td>
<td>0.09%</td>
<td>0.26%</td>
</tr>
<tr>
<td>State Government</td>
<td>6.25%</td>
<td>6.19%</td>
</tr>
<tr>
<td>Private</td>
<td>35.83%</td>
<td>33.94%</td>
</tr>
<tr>
<td>Other</td>
<td>0.43%</td>
<td>0.35%</td>
</tr>
</tbody>
</table>

3.2 Stressors Affecting the Species’ Condition and Related Conservation Measures

In this section, we discuss the external factors (stressors) that may influence the 3Rs, and thus the viability, of the white-tailed prairie dog (Figure 8). Through careful review of available literature on white-tailed prairie dog, we chose to evaluate stressors for which there is broad consensus of the potential to impact the species. These stressors include sylvatic plague, drought, agricultural land conversion, shooting, poisoning, overgrazing, invasive weeds, wildfire, urbanization, and energy development. This collection of pertinent stressors is supported by other seminal reports on white-tailed prairie dog conservation (Seglund et al. 2006, pp. 44-66). There are certainly other possible stressors that we considered in the course of our analysis, such as off road vehicle use, toxic chemical leakage associated with hydraulic fracturing and oil and gas reserve pits, interspecies competition, predation, solar energy development, tar sands, inadequate management practices, that have been mentioned in the context of white-tailed prairie dogs (75 FR 30338, Rocky Mountain Wild v. U.S. Fish and Wildlife Service 2014, case 9:13-cv-
00042-DWM, pp. 15-17), but we found no credible support that effects from these stressors, either individually or cumulatively, could lead to population-level effects. We largely excluded these inconsequential stressors from further analysis in this SSA Report. For those stressors considered further, we include a description, a current quantification of the magnitude of the stressor (if possible), an influence diagram modeling the potential impacts of the stressor on population resiliency, and a summary of ongoing and/or potential conservation measures that may lessen these impacts.
Figure 8. A general influence diagram modeling how stressors can impact the viability of the white-tailed prairie dog. The stressor (orange box) decreases the availability (represented by orange arrows) of habitat factors (blue boxes) the white-tailed prairie dog needs, including friable soils, abundant vegetation, and connectivity between colonies. The three habitat factors positively influence (represented by blue arrows) the demographic characteristics of a population, including abundance, fecundity, and juvenile survival (red boxes), which then positively impact (blue arrows) population resiliency. The number and spatial distribution of populations across the species’ range characterize its redundancy. Any differences in the genetic, ecological, morphological, or behavioral features of these populations influence the species’ representation. Together, the 3Rs (yellow boxes) describe the species’ viability, or ability to maintain populations in the wild into the future.
3.2.1 Sylvatic Plague (Yersinia pestis)

Description
Sylvatic plague (plague) is an exotic disease foreign to the evolutionary history of North American prairie dogs. Plague was first observed in wild rodents in North America near San Francisco, California, in 1903 (Eskey and Haas 1940, p. 1) and was first confirmed in white-tailed prairie dogs in 1936 (Eskey and Haas 1940, pp. 14-15). The disease is now endemic throughout the species’ range (Biggins and Kosoy 2001, p. 906; Pauli et al. 2006, p. 3). Plague is caused by a bacterium (Yersinia pestis), which fleas acquire by biting infected animals and subsequently transmit via a bite to other animals (Gage and Kosoy 2005, pp. 516-517). The disease can also be transmitted through pneumonic (airborne) or septicemic (blood) pathways from infected to disease-free animals (Barnes 1993, p. 28; Ray and Collinge 2006, p. 203; Cully et al. 2006, p. 158; Rocke et al. 2006, p. 243; Webb et al. 2006, p. 6236). Prairie dogs are highly susceptible to plague, likely because of their dense populations, social nature, abundant flea vectors, and low resistance to the bacterium (Biggins and Kosoy 2001, p. 913).

Plague outbreaks do not erupt within all populations throughout the range of the white-tailed prairie dog at the same time. Instead, plague is maintained in populations across the range in either an enzootic state or as an epizootic event. Enzootic plague is characterized by low rates of infection and mortality within a prairie dog population (Gage and Kosoy 2005, pp. 506-509; Biggins et al. 2010, p. 18). Hypothesized mechanisms for the maintenance of this low-level infection in a population include factors such as other, more resistant host species, resistant prairie dogs, differences in the efficiency and survival of flea vectors, or the retention of plague bacteria in the soil (Gage and Kosoy 2005, pp. 510, 513-518; Matchett et al. 2010, pp. 30, 33). The factors that cause a change from an enzootic period to an epizootic event are not fully understood, but may include host density, flea density, and climatic conditions (Cully 1989, p. 49; Parmenter et al. 1999, p. 814; Cully and Williams 2001, pp. 899-903; Enscore et al. 2002, p. 186; Lomolino et al. 2003, pp. 118-119; Stapp et al. 2004, p. 237; Gage and Kosoy 2005, p. 509; Ray and Collinge 2006, p. 204; Stenseth et al. 2006, p. 13110; Adjemian et al. 2007, p. 372; Snäll et al. 2008, p. 246). Epizootic plague occurs when the disease rapidly amplifies within the host population (prairie dog colonies), resulting in swift, large-scale die-offs (Barnes 1993, p. 29; Biggins and Kosoy 2001, pp. 63-64; Cully and Williams 2001, pp. 900-901; Gage and Kosoy 2005, pp. 506-508). Total colony mortality can range from 85 to 100 percent (Lechleitner et al. 1962, pp. 190-192; Cully 1993, pp. 40-42; Cully and Williams 2001, p. 901). Larger, more closely located colonies have been found to be more susceptible to plague epizootics (Cully and Williams 2001, p. 903). Therefore, smaller, more fragmented colonies may slow the spread of plague across a landscape (Cully and Williams 2001, p. 901; Johnson et al. 2010, p. 365). However, recent research has contributed to the idea that connectivity does not drive the plague cycle. Plague may be maintained within populations during enzootic periods, so an epizootic could erupt without the need for an outside host transmitting infected fleas (Stapp et al. 2004, p. ...
Plague cycles (i.e., epizootic, recovery, enzootic) can result in successive population peaks that are progressively lower than the previous peak, leading to overall population decline (Knowles 2002, p. 13; Augustine et al. 2008, p. 260; Hartley et al. 2009, p. 864). Reestablishment of a colony extirpated by plague depends on survivors or the immigration of individuals from neighboring colonies (Cully and Williams 2001, p. 902; Nistler 2009, p. 18; Jones et al. 2012, p. 189). In addition to bolstering abundance, migrants provide crucial genetic diversity to populations (Jones et al. 2012, p. 193; Sackett et al. 2013, p. 2448). The plague cycle has resulted in prairie dogs exhibiting a metapopulation structure with populations “blinking in and out” as populations are extirpated by plague and subsequently recolonized (Cully and Williams 2001, p. 902; Knowles 2002, p. 18, 20; George et al. 2013, p. 1573). While still very susceptible, white-tailed prairie dogs have lower colony mortality rates than other prairie dog species because of their decreased sociality and lower intra-colony densities (Cully and Williams, pp. 898-901). White-tailed prairie dog colonies have been documented rebounding from plague as quickly as one or two years in some instances (Cully and Williams 2001, pp. 898-899).

**Impacts to Population Resiliency**

![Influence diagram modeling how sylvatic plague impacts the resiliency of white-tailed prairie dog populations. In the model, the orange box represents the stressor, and the orange arrows represent the negative impacts the stressor can have on crucial habitat (blue box) and demographic (red boxes) factors. The blue arrows represent the positive influences of the habitat and demographic factors on population resiliency (population health; yellow box). The black arrow represents the unknown impacts of plague on fecundity.](image-url)

Figure 9. Influence diagram modeling how sylvatic plague impacts the resiliency of white-tailed prairie dog populations. In the model, the orange box represents the stressor, and the orange arrows represent the negative impacts the stressor can have on crucial habitat (blue box) and demographic (red boxes) factors. The blue arrows represent the positive influences of the habitat and demographic factors on population resiliency (population health; yellow box). The black arrow represents the unknown impacts of plague on fecundity.
In addition to direct mortality of individuals (reduced abundance, reduced juvenile survival), plague affects the white-tailed prairie dog across its range by decreasing connectivity and creating a network of smaller, more fragmented populations (Clark 1977, p. 63; Cully and Williams 2001, p. 903). Immediately following a plague epizootic, surviving individuals can exhibit increased reproduction (higher fecundity) to compensate for the loss of individuals within a colony (Hoogland 2001, p. 923; Knowles 2002, p. 14). However, reproduction slows as colony size increases, and populations affected by plague may show decreasing peaks in maximum abundance (reduced fecundity; Hoogland et al. 1987, p. 19; Knowles 2002, p. 13; Augustine et al. 2008, p. 260; Hartley et al. 2009, p. 864).

**Summary of Impacts to the 3Rs**

In general, larger populations (spatially and abundance) exhibit higher resiliency and are more able to withstand annual, stochastic events. In a landscape affected by plague, smaller, more fragmented prairie dog populations are less resilient and are more vulnerable to other stochastic events like drought (Clark 1977, p. 63; Miller et al. 1994, p. 678; Cully and Williams 2001, p. 903; Knowles 2002, p. 24; Seglund et al. 2006, p. 60). Additionally, the loss of populations across the range decreases the redundancy and representation of the species. The loss of populations from across the range, in different ecological settings, makes the whole species more susceptible to a wide-scale, catastrophic event and less adaptable to other changes in the biological environment. This change in population structure has decreased the species’ ecological function, or its role in community ecology, across its range (Jones et al. 2012, p. 183, and references within; Miller et al. 2007, p. 2807, and references within).

As discussed in **Section 2.2.2 Population Needs**, it is important for us to mention that smaller, more fragmented populations may experience decreased rates of plague transmission and thus may exhibit more resiliency than their larger, more connected counterparts (Cully and Williams 2001, p. 901; Lomolino et al. 2003, p. 116; Johnson et al. 2010, p. 365). However, smaller, more fragmented populations are more vulnerable to other stochastic events, and the decrease in connectivity associated with fragmentation means extirpated colonies are less likely to be recolonized, decreasing the species’ redundancy. Recent research suggests a fragmented metapopulation structure on its own is not enough to protect prairie dogs from the threat of plague (George et al. 2013, p. 1580), and that connectivity may not actually be a key driver of plague epizootics (Stapp et al. 2004, p. 238; Gage and Kosoy 2005, p. 519; Biggins et al. 2010, pp. 21-24; Matchett et al. 2010, pp. 30, 33). Therefore, we maintain that connectivity is important to maintain gene flow after epizootics and to promote viability of the species (Knowles 2002, p. 24; Nistler 2009, p. 73).

**Current and Suggested Conservation Measures**

Current plague management efforts aim to minimize the impacts of plague by either reducing flea loads on prairie dogs or immunizing individual prairie dogs against the disease. Applying
the insecticide deltamethrin on prairie dog burrows (“dusting”) effectively reduces fleas and increases prairie dog survival rates from plague (Biggins et al. 2010, p. 21; Abbott et al. 2012, p. 244). In one study, dusting reduced fleas by 96 percent 25 days post-application and 63 percent 10 months post-application in white-tailed prairie dogs (Biggins et al. 2010, p. 20). A Population Viability Analysis (a model for predicting extinction risk) for white-tailed prairie dogs in Colorado also found that dusting could dramatically decrease extinction risk in colonies exposed to epizootics (Seglund and Schnurr, pp. 111-112). Drawbacks to burrow dusting include effects to non-target invertebrates and high labor and financial costs (Jachowski et al. 2011, p. 100, and references within). Fleas have also been documented developing resistance to deltamethrin in less than 10 years (Boyer et al. 2014, p. 3), so long-term plague management efforts should not rely on deltamethrin alone (Z. Walker, WGFD, pers. comm.). An insecticide-treated bait (Imidacloprid), which reduces effects to non-target species and has lower labor costs, also reduces prairie dog flea loads, but not to the same extent as dusting (Jachowski et al. 2011, p. 100-106).

The sylvatic plague vaccine (SPV) is a preventative measure administered to prairie dogs through treated baits (Abbott et al. 2012, p. 246). In laboratory experiments, 94 percent of vaccinated prairie dogs survived plague exposure when treated with SPV (Rocke et al. 2010, p. 53; Abbott et al. 2012, p. 247). A recent broad-scale experiment to test the effectiveness of SPV in four prairie dog species (including white-tailed prairie dogs) found that SPV increased survival on colonies infected with plague (Rocke et al. 2017, p. 7). However, some prairie dogs on these colonies still died from plague because researchers were unable to attain either a 100% vaccination rate or a sufficient vaccination rate to impart community immunity (Rocke et al. 2017, p. 10). In a black-tailed prairie dog population in Colorado, the effectiveness of SPV was found to be highly influenced by temporal variation in treatment, as well as temporal variation in the eruption of plague epizootics (Tripp et al. 2017, p. 14). The authors found that neither dusting nor SPV provided colonies with complete protection, but repeated distribution of SPV well in advance of a plague epizootic (>30 days) stabilized survival rates in adult prairie dogs exposed to an epizootic (Tripp et al. 2017, pp. 14-16). To be effective at controlling plague, the authors suggested that SPV should be given well in advance of any observed plague epizootics, should be administered repeatedly over large areas, and should be administered in late summer or fall to ensure the vaccination of juveniles (Tripp et al. 2017, pp. 15-17; Rocke et al. 2017, p. 11).

Dusting and SPV use in conjunction with vigilant plague epizootic monitoring may provide the most effective way to reduce the range-wide impacts of plague on the white-tailed prairie dog (Antolin et al. 2002, p. 122; Abbott et al. 2012, p. 248; Tripp et al. 2016, pp. 559-560; Tripp et al. 2017, p. 17). However, the widespread use of these prophylactics across the species’ range may be logistically and financially challenging (Boulerice 2016, p. 8). That being said, a new method of manufacturing has made SPV bait production quicker and more cost effective (Corro
et al. 2017, pp. 2-4), and recent tests have explored the utility of using drones and all-terrain vehicles to distribute SPV over larger areas (USFWS 2016). Information provided by recent studies on plague management techniques may help managers gain the most benefit from limited, but targeted, conservation efforts. SPV vaccination rates of 50 to 80 percent of individuals in a colony may be necessary to control plague epizootics (Tripp et al. 2014, p. 232). Broadcasting SPV-laden baits at high densities during the fall, as opposed to the spring, may be the best way for managers to reach these vaccination goals (Tripp et al. 2014, pp. 229-230; Tripp et al. 2017, p. 17). Additionally, insecticide dusting in the fall may actually provide longer-term protection than dusting in the spring (8 months versus 5 months, Tripp et al. 2016, p. 557). While the goal should be to dust whole colonies for maximum plague prevention, dusting even a portion of a colony can buffer it against the effects of a plague epizootic for some time (Tripp et al. 2016, p. 559; Tripp et al. 2017, p. 15). Flea abundance rebounded to high levels 12 months after dusting treatment on plots that were adjacent to large blocks of untreated habitat, so managers may consider dusting more frequently or at least annually to effectively suppress plague on small, disjunct colonies in larger habitat areas. A single dusting event on an entire colony would theoretically suppress flea abundance for a longer period of time (D. Tripp, CPW, pers. comm.). Preventative dusting is also more effective than dusting in response to an observed plague epizootic (Tripp et al. 2016, p. 559).

The recovery of the federally endangered black-footed ferret depends on the management of plague in prairie dog colonies where ferrets have been reintroduced. Recovery actions in black-footed ferret management areas include supporting research on plague dynamics, monitoring and managing plague in prairie dog colonies, and developing and implementing SPV (U.S. Fish and Wildlife Service 2013, pp. 76, 80-81, 92-93). Therefore, colonies within black-footed ferret management areas, such as the Meeteetse reintroduction site in Wyoming, likely receive some of the highest levels of prophylactic treatment for plague within the white-tailed prairie dog’s range. Therefore, white-tailed prairie dog colonies where ferrets have been reintroduced may benefit from increased levels of plague management.

Plague management activities including dusting and SPV distribution are ongoing within the white-tailed prairie dog’s range (Table 4). SPV distribution currently occurs in black-footed ferret management areas in Utah, and is likely to continue in the future (K. Hersey, UDWR, pers. comm.). Managers from Colorado Parks and Wildlife (CPW), the BLM, and the National Park Service (NPS) are currently working on an intensive plague management plan for white-tailed prairie dog complexes in the Little Snake and Wolf Creek Black-footed Ferret Management Area of northern Colorado (Amy Seglund, CPW, pers. comm.). Rather than focusing solely on benefits to black-footed ferrets, the main motivation of the program is the management of white-tailed prairie dogs and associated species, such as burrowing owls and ferruginous hawks. Colonies in Little Snake have remained small since a plague epizootic in the 1980s, while
colonies in Wolf Creek have exhibited recovery. Managers will map colonies in 2017 and use those results to target annual SPV distribution starting in 2018.

Table 4. Acres of plague management efforts (dusting and SPV distribution) across the white-tailed prairie dog’s range from 2013 to 2017 at two sites. These values are based on information provided to us by managers from certain agencies, so all of the plague management efforts across the species’ range are not captured here. Because of this, blank cells are given a value of (--) rather than zero.

<table>
<thead>
<tr>
<th>Site</th>
<th>Year</th>
<th>Number of Acres Dusted</th>
<th>Number of Acres with SPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Park IPA and Arapaho National Wildlife Refuge, Colorado&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2015</td>
<td>2,465</td>
<td>--</td>
</tr>
<tr>
<td>Meeteetse, Wyoming&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2013</td>
<td>--</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>2014</td>
<td>--</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>2015</td>
<td>--</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>2016</td>
<td>5,021</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>2017</td>
<td>2,200*</td>
<td>2,200*</td>
</tr>
</tbody>
</table>

<sup>a</sup> Source: J. Hughes, USFWS, pers. comm.

<sup>b</sup> Sources: Boulerice and Grenier 2014, pp. 433-434; Boulerice 2015, pp. 308-309; Boulerice 2016, pp. 4-5; Boulerice 2017, pp. 4-5; Z. Walker, WGFD, pers. comm.

* These values represent anticipated efforts for Meeteetse in 2017, and they represent a minimum number of acres that may receive treatment. Biologists at WGFD are currently seeking more funding to possibly expand these efforts (Z. Walker, WGFD, pers. comm.).

Despite these conservation efforts, plague remains the main driver of white-tailed prairie dog population dynamics across the entirety of the species’ range (Knowles 2002, p. 13; Pauli et al. 2006, p. 3; Seglund and Schnurr 2010, p. 104). Populations are now smaller, more fragmented, and more vulnerable to stochastic events (less resilient) than they were historically (Clark 1977, p. 63; Knowles 2002, p. 24; Augustine et al. 2008, pp. 260-262; Hartley et al. 2009, p. 864). However, the white-tailed prairie dog has demonstrated one of the most robust responses to plague of all the prairie dog species, and some colonies have been documented rebounding from an epizootic in as quickly as one to two years (Cully and Williams 2001, pp. 898-899). That being said, frequent, successive plague outbreaks over time may prevent a population from fully recovering to its pre-plague state (Augustine et al. 2008, p. 260; Hartley et al. 2009, p. 864). Ameliorating the effects of plague on white-tailed prairie dog populations will require the range-wide, strategic use of dusting and SPV (Tripp et al. 2017, p. 17).
3.2.2 Drought

Description

Drought is defined as a deficiency in precipitation over an extended period, which reduces water supply, water quality, and range productivity, and impacts social and economic activities (Woodhouse and Peck 1998, p. 2693; National Weather Service 2008, p. 1). Although drought is recognized as a normal process, the western United States has been in what is characterized as a significantly harsh drought for the last 17 years (Woodhouse and Peck 1998, p. 2693; National Oceanic and Atmospheric Administration (NOAA) 2017). The last time the western United States experienced a “megadrought” of this magnitude was in the latter half of the 16th century (Woodhouse and Peck 1998, p. 2699). Recent studies of Gunnison’s prairie dog and black-tailed prairie dog colonies have attributed observed decreases in body condition, reproductive rates, and adult and juvenile survival to the current drought period (Facka et al. 2010, entire; Davidson et al. 2014, entire).

Reduced precipitation due to drought decreases a site’s primary productivity and limits the amount of succulent vegetation available to prairie dogs. White-tailed prairie dog population dynamics and survival are closely tied to the quality of their habitat (Lomolino et al. 2003, p. 116; Facka et al. 2010, entire; Davidson et al. 2014, entire). Increased primary productivity at a site leads to higher prairie dog densities, increased mating success, and larger litters (Crocker-Bedford and Spillett 1981 in Holmes 2008, p. 5; Hoogland 2001, p. 920). Additionally, abundant vegetation allows white-tailed prairie dogs to accumulate the large amounts of fat they need to survive hibernation (Seglund et al. 2006, p. 6). Prairie dogs may become dormant or enter hibernation as early as July in dry years, extending the time they spend underground (Tileston and Lechleitner 1966, p. 301; Clark 1977, p. 55; Andelt et al. 2009, p. 43). If they do not have access to high quality forage and do not build sufficient fat stores prior to hibernation, they may emerge from their burrows during the winter and die from starvation (Seglund et al. 2004, p. 46).

The effects of drought on the plague cycle in prairie dogs are complex and difficult to assess. Researchers have hypothesized contradictory effects of drought on plague epizootics, with studies concluding that drought may contribute to decreased (Parmenter et al. 1999, pp. 816-817; Stapp et al. 2004, pp. 237-238; Snäll et al. 2008, pp. 244-245; Snäll et al. 2009, p. 501) or increased incidences of plague (Eads and Hoogland 2016, pp. 7-8; Eads et al. 2016, p. 1050). In wet years or areas, flea abundance can increase due to higher primary productivity, leading to increased plague risk for a prairie dog colony (Parmenter et al. 1999, pp. 816-817; Snäll et al. 2008, pp. 239-240). In contrast, low primary productivity associated with dry years or areas can lead to decreased prairie dog body condition, increased flea loads, and higher plague risk (Eads and Hoogland 2016, p. 6; Eads et al. 2016, pp. 1046-1047, 1050). The complex interplay of annual precipitation variability over multiple years, primary productivity, and prairie dog densities may ultimately explain colony vulnerability to plague epizootics (Eads and Biggins
More research is needed to better understand how precipitation, or lack thereof, affects the plague cycle (Eads and Biggins 2017, p. 16).

**Impacts to Population Resiliency**

Figure 10. Influence diagram modeling how drought impacts the resiliency of white-tailed prairie dog populations. In the model, the orange box represents the stressor, and the orange arrow represents the negative impacts the stressor can have on crucial habitat factors (blue boxes). The blue arrows represent the positive influences of the habitat and demographic factors (red boxes) on population resiliency (population health; yellow box). The black arrow represents the unknown impacts of drought on connectivity.

Drought reduces the amount of succulent vegetation available to prairie dogs. In the absence of abundant vegetation, white-tailed prairie dogs experience decreases in abundance, fecundity, and juvenile survival. Drought may also negatively affect connectivity between colonies by removing dispersal corridors with suitable habitat. However, the effects of drought on connectivity between white-tailed prairie dog colonies have not been directly studied, and other prairie dog species have been observed dispersing through sub-optimal habitat (Sackett et al. 2012, pp. 415-416).

**Summary of Impacts to the 3Rs**

Prairie dog populations affected by drought exhibit lower abundance, reproduction, and survival. This makes them less resilient and more vulnerable to other stochastic events. White-tailed prairie dogs are considered to be well-adapted to xeric habitats (Clark 1977, p. 2; Knowles 2002, p.7; Pizzimenti and Nadler 1972 in Seglund et al. 2006, p. 3), and they may exhibit more resiliency to drought than other prairie dog species. If drought decreases the availability of suitable dispersal corridors and limits connectivity, populations will also exhibit decreased resiliency through the limitation of immigration and gene flow. This could lead to the loss of populations across the range and decrease the redundancy of the species, making it more susceptible to a wide scale, catastrophic event. However, only a few migrants per generation are needed to prevent a loss of genetic diversity within a colony (representation), and prairie dogs have been observed dispersing through sub-optimal habitat (Jones et al. 2012, p. 193; Sackett et
The effects of drought may be amplified if it occurs in concert with other stressors, such as a plague epizootic (Seglund et al. 2006, pp. 64-65; Lupis et al. 2007, p. 35; Eads et al. 2016, p. 1050).

Current and Suggested Conservation Measures

We are not aware of any ongoing conservation measures involving the white-tailed prairie dog and drought. Ensuring that white-tailed prairie dog habitat is in high condition may help buffer colonies from additional vegetation losses due to drought (Seglund et al. 2006, p. 70). High condition habitat is free from invasive weeds like cheatgrass, has minimal woody shrub encroachment, and is not overgrazed. In non-drought years, moderate grazing and prescribed burns may help achieve these habitat conditions (Pauli et al. 2006, p. 31, and references within). In extreme cases, supplemental feeding by managers may help colonies persist during periods of extended drought (Davidson et al. 2014, p. 433).

Intense drought has impacted the western U. S. for the last 17 years (NOAA 2017), and it is widespread throughout the white-tailed prairie dog’s gross range. Drought limits the amount of succulent vegetation available to prairie dogs as forage, reducing reproductive rates and densities within colonies. This makes populations less resilient and more vulnerable to other stochastic events. Recent research suggests drought also has the potential to increase the prevalence of plague within prairie dog populations (Eads et al. 2016, p. 1050).

3.2.3 Agricultural Land Conversion

Description

Agricultural land conversion is the change in land use from a previous use to an agricultural use, including cropland and pastureland. At a large scale, agricultural land conversion represents a permanent loss of prairie dog habitat (Knowles 2002, p. 2; Ceballos et al. 2010, p. 8). In some instances, agricultural lands can benefit prairie dogs by providing a source of highly nutritious forage (Crocker-Bedford 1976, pp. 73-74; Seglund 2002, p. 7; Seglund and Schnurr 2010, p. 95). Roads and fences associated with agricultural conversion can fragment contiguous prairie dog habitat (Seglund and Schnurr 2009, p. 95), but it is possible that agricultural lands sometimes facilitate prairie dog dispersal (Sackett et al. 2012, p. 408). Agricultural conversion is at least partially responsible for the decrease of white-tailed prairie dogs in Montana (Montana Prairie Dog Working Group 2002, p. 27), and colonies near crops may be subjected to more lethal control efforts than those that are not (Hoogland 2001, p. 917; Knowles 2002, p. 12).

Although cropland and pastureland in the United States increased from 2007 to 2012, there has been a large decrease in the amount of land being used for agricultural production since 1980 (NRCS 2015, pp. 2-2, 3-3; numbers do not include Federally-owned lands). This decrease occurred across the range of the white-tailed prairie dog, with all states within the species’ distribution showing a decrease in the number of acres being used for cultivated crops and
pastureland/hay production since 2010 (Table 5). Approximately 8 percent of the white-tailed prairie dog’s predicted range is currently used as agricultural land (Table 5).

Table 5. Acres of cultivated crops and pastureland/hay production within the white-tailed prairie dog’s predicted range in 2010 and 2015. We used the predicted range for this analysis because it represents a more spatially-resolved estimate of where the white-tailed prairie dog may occur and because data on land use type was available at the proper scale. The change in each land type is the acres in 2010 subtracted from the acres in 2015. Cultivated crops and pastureland/hay production has decreased across the range since 2010 (information on data available in USFWS 2017, p. 3). For reference, the white-tailed prairie dog’s predicted range encompasses 34,277,527 acres (13,871,623 hectares), and approximately 8 percent of the predicted range is currently used for agriculture.

<table>
<thead>
<tr>
<th>State</th>
<th>Cultivated Crops 2010</th>
<th>Cultivated Crops 2015</th>
<th>Change in Cultivated Crops acreage</th>
<th>Pasture/Hay 2010</th>
<th>Pasture/Hay 2015</th>
<th>Change in Pasture/Hay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado</td>
<td>93,669</td>
<td>89,068</td>
<td>-4,601</td>
<td>482,961</td>
<td>244,035</td>
<td>-238,926</td>
</tr>
<tr>
<td>Montana</td>
<td>8,287</td>
<td>7,880</td>
<td>-407</td>
<td>42,729</td>
<td>21,591</td>
<td>-21,139</td>
</tr>
<tr>
<td>Utah</td>
<td>75,118</td>
<td>71,428</td>
<td>-3,690</td>
<td>387,310</td>
<td>195,703</td>
<td>-191,607</td>
</tr>
<tr>
<td>Wyoming</td>
<td>583,228</td>
<td>554,579</td>
<td>-28,650</td>
<td>3,007,137</td>
<td>1,519,472</td>
<td>-1,487,666</td>
</tr>
</tbody>
</table>
Impacts to Population Resiliency

Figure 11. Influence diagram modeling how agricultural land conversion impacts the resiliency of white-tailed prairie dog populations. In the model, the orange box represents the stressor, and the black arrows represent the unknown impacts the stressor can have on crucial habitat factors (blue boxes). The blue arrows represent the positive influences of the habitat and demographic factors (red boxes) on population resiliency (population health; yellow box).

Agricultural conversion of land occupied, or potentially occupied, by white-tailed prairie dogs reduces available habitat and can fragment remaining habitat. However, if sufficient, undisturbed prairie dog habitat is available on the margins of converted land, prairie dogs may disperse into these areas. For instance, prairie dog colonies in urban areas still persist on roadsides and near the edges of development (Johnson and Collinge 2004, p. 488). In some instances, prairie dogs may benefit from the increased availability of high quality forage in agricultural areas. In other words, if prairie dogs can breed, feed, and shelter in areas converted to croplands, agricultural areas may actually increase the availability of abundant vegetation, which would increase abundance, fecundity, and juvenile survival. However, the intrusion of prairie dogs into cropland or pastureland may make them more vulnerable to lethal control, thus directly reducing abundance and juvenile survival. Conversion of habitat into agricultural land may also reduce the availability of friable soils for creating burrows, but appropriate soils would likely still be available on the margins of the converted area. While agricultural conversion may fragment continuous prairie dog habitat and decrease connectivity, there is the possibility of prairie dogs utilizing agricultural lands as dispersal corridors in fragmented landscapes (Sackett et al. 2012, p. 416).

Summary of Impacts to the 3Rs

If agricultural conversion presents a true barrier to dispersal, such that individual prairie dogs are unable to disperse and colonize new habitats or join other colonies, fragmented white-tailed prairie dog colonies could exhibit less resilience and be more vulnerable to stochastic events. Conversely, if prairie dogs are able to exploit the abundant vegetation provided by agricultural
lands, populations would experience higher reproduction and abundance, which could improve the population’s resiliency. However, if more lethal control targets populations near agricultural lands, local extirpations will decrease the species’ redundancy by reducing the number of populations found across the landscape. If large numbers of colonies are extirpated across the range in a variety of ecological settings, the species could exhibit less representation.

Current and Suggested Conservation Measures
In the Colorado Gunnison’s and White-tailed Prairie Dog Conservation Strategy, managers identified two conservation objectives to decrease the impacts of agricultural land conversion on prairie dogs (Seglund and Schnurr 2010, p. 98). The first stated objective is to “minimize the perceived negative effects of prairie dogs on agricultural lands.” Strategies to meet this objective include developing alternatives to poisoning to minimize prairie dog damage on croplands, seeking funding for landowner incentive programs that maintain prairie dog colonies on private lands (such as easements and Candidate Conservation Agreements with Assurances), educating landowners about the potential for selling prairie dog hunts, rather than poisoning, in areas of high densities, and developing and implementing an outreach program. The second objective is to “minimize the adverse impacts on Gunnison’s prairie dogs and white-tailed prairie dogs of habitat fragmentation caused by current agricultural practices.” Strategies to meet this objective include identifying areas that can serve as dispersal corridors and areas for colony reestablishment, developing recommendations for agricultural practices that address or recognize habitat needs, and creating/using available incentives to fund cooperative agreements that can be used to develop movement corridors. To date, the only one of these conservation strategies that has come to fruition is the securement of a 15,156 acres (6,133 hectares) perpetual conservation easement for black-footed ferret conservation in Moffat County, which encompasses a large white-tailed prairie dog complex (A. Seglund, CPW, pers. comm.). The Utah Gunnison’s Prairie Dog and White-tailed Prairie Dog Conservation Plan does not include specific conservation strategies for prairie dogs and agricultural land conversion, but it does state that a high priority conservation strategy is to “develop outreach/education tools to enhance communication, information dissemination, and community involvement in conservation,” which could apply to private landowners with prairie dogs occupying their lands (Lupis et al. 2007, p. 40). The Wyoming Game and Fish Department’s draft 2017 State Wildlife Action Plan does not include specific goals addressing the effects of agricultural land conversion on prairie dogs, but it does recognize the importance of better understanding how different habitats and stressors influence the abundance and distribution of prairie dogs in the state (WGFD 2017, p. 4). White-tailed prairie dog occupancy surveys in Wyoming in 2016 revealed the highest occupancy probabilities in the state occurred on private lands, which includes some agricultural areas (Ceradini et al. 2017, p. 12; J. Ceradini, WYNDD, pers. comm.). We are not aware of any current conservation efforts concerning the effects of agricultural land conversion on prairie dogs in Montana. It is possible there could be some future white-tailed prairie dog habitat loss and/or fragmentation in Montana due to agricultural land conversion (L. Hanauska-Brown, MFWP, pers. comm.). If a
landowner is looking to convert white-tailed prairie dog habitat into cropland or pastureland, managers may suggest relocating the prairie dogs to other suitable habitat rather than employing lethal control.

Overall, it is difficult to assess the current impacts of agricultural land conversion on the white-tailed prairie dog because of a lack of species-specific studies and precise spatial data on the confluence of prairie dog complexes and agricultural lands. The data that are available to us indicate that agricultural land use has decreased since 2010 and currently only impacts approximately eight percent of the white-tailed prairie dog’s predicted range. Further, both positive and negative responses to agricultural conversion have been reported, so the net response of white-tailed prairie dogs to this stressor is equivocal. This leads us to conclude that agricultural land conversion does not exhibit a measureable negative impact on white-tailed prairie dog population resiliency across the species’ range.

3.2.4 Shooting

Description

White-tailed prairie dogs are subjected to shooting as recreation and as a form of pest management. The effects of shooting on white-tailed prairie dogs have not been specifically studied, but the effects of shooting on black-tailed prairie dog populations are well-researched and may provide insight into how white-tailed prairie dog populations may respond to this stressor. Colonial behavior makes prairie dogs vulnerable to shooting by providing shooters with easy access to many individuals at once (Pauli and Buskirk 2007, p. 1220). Previous studies have estimated that hunters can shoot up to 60 prairie dogs per day, and an average of 15,000 black-tailed prairie dogs were shot per year at one site in South Dakota (Knowles and Vosburgh 2001 and Reeve and Vosburgh 2003 in Seglund et al. 2006, p. 55). Black-tailed prairie dogs in colonies subjected to hunting spent more time in alert behaviors and less time foraging, although this effect decreased a year after shooting (Pauli and Buskirk 2007, p. 1223). Recreational shooting reduced black-tailed prairie dog densities at specific sites (Vosburgh and Irby 1998, pp. 366-367; Knowles 2002, p. 14) and may also negatively affect reproductive rates (Pauli and Buskirk 2007, p. 1228), but reproduction may increase following a lethal event like shooting to compensate for lost individuals (Hoogland 2001, p. 923, and references within). One study reports an instance where shooting rendered a colony functionally extinct, with only one juvenile prairie dog surviving. However, the colony was reestablished the following year by migrants (Knowles 1987, p. 54).

The long-term impacts of recreational shooting on prairie dog populations are unknown, but a PVA suggests it is unlikely to lead to extinctions of even small white-tailed prairie dog populations (Seglund and Schnurr 2009, p. 167). The less colonial nature and less discernable colony boundaries of white-tailed prairie dogs make them less vulnerable to shooting than other prairie dog species (Knowles 2002, p. 15; Seglund et al. 2006, p. 55). It is important to note that
the effects of shooting may contribute to the plague cycle in prairie dogs. Shooting temporarily reduces prairie dog densities within the affected colony until the colony is repopulated by migrants or through increased reproduction (Vosburgh and Irby 1998, pp. 366-367; Hoogland 2001, p. 923; Knowles 2002, p. 14; Nistler 2009, p. 18). As prairie dog densities decrease, flea vectors on the shot prairie dogs will seek out new hosts, leading to higher flea densities on the surviving prairie dogs (Tripp et al. 2017, p. 17). The higher flea loads, and the accompanying increase in number of flea bites, then make the surviving prairie dogs more susceptible to plague (Lorange et al. 2005, pp. 1909-1910). Therefore, colonies subjected to shooting may be at higher risk for an epizootic. Research has shown that being subjected to shooting does not detectably affect stress levels in adult black-tailed prairie dogs, but it does increase stress in juvenile prairie dogs (Gordon et al. 2003, pp. 19-20; Pauli and Buskirk 2007, p. 1224). Increased stress could lower immune function in juvenile prairie dogs, also making them more susceptible to plague (Pauli and Buskirk 2007, p. 1227).

The intensity and extent of shooting of white-tailed prairie dogs, either for recreation or control, has not been quantified. Shooting of white-tailed prairie dogs is allowed without a permit across much of the species' range; only Colorado requires a general hunting license. Regulations for shooting prairie dogs in black-footed ferret management areas vary from seasonal to full closures, based on management agency (USFWS 2013, p. 27). Shooting prairie dogs on public lands in Colorado is allowed from June 15 to February 28 with no bag limits; there are no seasonal restrictions for shooting prairie dogs on private lands (Colorado Parks and Wildlife 2016, p. 3). In Utah, white-tailed prairie dogs may be shot on public lands without bag limits from June 16 to March 31, and no certificate of registration is required (Utah Division of Wildlife Resources 2016, Regulation R657-19-6). The seasonal shooting restriction from April 1 to June 15 does not apply to private lands (Utah Division of Wildlife Resources 2016, Regulation R657-19-6). In Wyoming, the white-tailed prairie dog is classified as both nongame wildlife by the Wyoming Game and Fish Department (N. Bjornlie, WGFD, pers. comm.) and as an agricultural pest by the Wyoming Department of Agriculture (Wyoming Weed and Pest Control Act, W.S. 11-5-102 (a)(xii)), and there are no regulations governing the shooting of prairie dogs in the state. White-tailed prairie dogs are also regulated in this manner in Montana (L. Hanauska-Brown, MFWP, pers. comm.). State natural resource agencies do not currently monitor white-tailed prairie dog harvest numbers, so there is no information on the extent of shooting pressure experienced by white-tailed prairie dog populations. Colorado Parks and Wildlife previously included harvested prairie dogs in their general small game survey, but they are excluded from more recent reports (2006 +) because the data yielded high levels of error and wide confidence intervals (A. Seglund, CPW, pers. comm.). Although recreational shooting of white-tailed prairie dogs is widely permitted, they are most likely subjected to lower shooting pressure than other prairie dog species (Knowles 2002, p. 15; Seglund et al. 2006, p. 55).
Impacts to Population Resiliency

Figure 12. Influence diagram modeling how shooting impacts the resiliency of white-tailed prairie dog populations. In the model, the orange box represents the stressor, and the orange arrows represent the negative impacts the stressor can have on crucial demographic factors (red boxes). The blue arrows represent the positive influences of the demographic factors on population resiliency (population health; yellow box). The black arrow represents the unknown impacts of shooting on fecundity.

Shooting affects crucial white-tailed prairie dog demographic factors. It directly kills individuals, decreasing abundance. Reports state that peak shooting occurs in May and June when female prairie dogs are whelping pups (Gordon et al. 2003, p. 10; Seglund et al. 2006, p. 55), or from June to August after pups have emerged from burrows and become vulnerable to shooters (observations in Wyoming; Z. Walker, WGFD, pers. comm.). Pups that are not weaned cannot survive without a female, so the shooting of reproductive females results in decreased juvenile survival. Fecundity may increase following a shooting event as reproduction increases to compensate for the loss of individuals in a colony. However, a colony subjected to long-term, intensive shooting may not be able to compensate for population declines and fecundity may decrease over time. Additionally, prairie dogs on colonies subjected to shooting may spend less time foraging and experience reductions in body condition, decreasing fecundity (Pauli and Buskirk 2007, p. 1227).

Summary of Impacts to the 3Rs
Small colonies with low abundance and low juvenile survival exhibit decreased resiliency and are vulnerable to stochastic events, suggesting that white-tailed prairie dog populations subjected to shooting have less resiliency than those that are not. If colonies are locally extirpated due to high shooting pressure, there will be fewer white-tailed prairie dog populations across the species’ range, and the species will exhibit lower redundancy. If populations in a variety of ecological settings are extirpated by shooting, or if individual prairie dogs with characteristic behaviors or morphologies are targeted, the representation of the species will be reduced.
However, a model has suggested there is a low likelihood of even small white-tailed prairie dog colonies being extirpated by shooting (Seglund and Schnurr 2009, p. 167). Therefore, the data available to us indicate limited, localized negative responses to shooting most likely do not lead to species-level impacts.

Current and Suggested Conservation Measures

Colorado and Utah implement white-tailed prairie dog shooting closures on public lands from March 1 to June 14 and April 1 to June 15, respectively (Colorado Parks and Wildlife 2016, p. 3; Utah Division of Wildlife Resources 2016, Regulation R657-19-6). These shooting closures encompass the prairie dog’s breeding and whelping seasons, as well as the peak time for prairie dog shooting (Seglund et al. 2006, p. 55). These closures provide protection to white-tailed prairie dog populations during a crucial period and may reduce the demographic impacts of shooting on colonies (Seglund and Schnurr 2009, p. 165). Instituting shooting closures like these across the species’ range would have a positive conservation benefit and could decrease the contribution of shooting to any cumulative effects of stressors on the species’ viability (Seglund et al. 2006, pp. 69-70).

Wildlife on public lands managed by the BLM are, at a minimum, subjected to regulations created by state wildlife agencies. In addition to the state regulations described above, several BLM field offices have instituted protections for white-tailed prairie dogs on their lands, (summarized in Appendix A). As an agency, the BLM does not encourage the shooting of prairie dogs on public lands, but it is not forbidden (BLM 2007, p. 3-17). Although shooting may have localized impacts on the resiliency of certain populations on both public and private lands, the white-tailed prairie dog is probably subjected to less shooting than other prairie dog species (Knowles 2002, p. 15; Seglund et al. 2006, p. 55). It is unlikely that shooting impacts white-tailed prairie dog populations on a range-wide scale.

3.2.5 Poisoning

Description

The U.S. Department of Agriculture’s Bureau of Biological Survey and the Agricultural Appropriations Act of 1915 planned and authorized the elimination of prairie dogs across the western United States, mainly to reduce perceived competition with grazing livestock (Oakes 2000; Pauli et al. 2006, p. 25; Bergstrom et al. 2014, p. 134). Poisoning usually targeted black-tailed prairie dogs due to their visibility on the landscape, but Gunnison’s and white-tailed prairie dogs were also poisoned, leading to their decline (Knowles 2002, pp. 1-2; Seglund and Schnurr 2010, p. 140). Effects of these poisoning campaigns included a reduction in occupied habitat, extirpation from local areas, and fragmentation and isolation of colonies. The effects of poisoning also may contribute to the plague cycle in prairie dogs. If poisoning is not 100 percent effective at exterminating a colony, it will temporarily reduce prairie dog densities within the
targeted colony until the colony is repopulated by migrants or through increased reproduction (Hoogland 2001, p. 923; Nistler 2009, p. 18). As prairie dog densities decrease, flea vectors on the dead prairie dogs will seek out new hosts, leading to higher flea densities on the surviving prairie dogs (Tripp et al. 2017, p. 17). The higher flea loads, and the accompanying increase in number of flea bites, then make the surviving prairie dogs more susceptible to plague (Lorange et al. 2005, pp. 1909-1910). Therefore, colonies subjected to poisoning may be at higher risk for an epizootic.

Data specifically related to the historical poisoning of white-tailed prairie dogs are unavailable; published estimates encompass all four species of prairie dog in the western United States (Pauli et al. 2006, p. 11). 21.5 million acres (8.7 million hectares) of prairie dogs were poisoned by one agency alone by 1936 (Robinson 2005 in Bergstrom et al. 2014, p. 134). Poisoning in all states became less common after federal regulations of pesticides were enacted in the 1970s (Knowles 2002, p. 12; Pauli et al. 2006, p. 11). There is evidence of prairie dog populations rebounding after a poisoning campaign, at least partially due to increased reproductive rates within a colony following a catastrophic mortality event (Hoogland 2001, p. 923, and references within; Seglund et al. 2006, p. 55, and references within).

White-tailed prairie dogs are regulated as vertebrate pests in Wyoming (Wyoming Weed and Pest Control Act, W.S. 11-5-102 (a)(xii)) and Montana (L. Hanauska-Brown, MFWP, pers. comm.), and poisoning is legal in all four states within the species’ range. Poisoning today most likely occurs on a local scale without the goal of widespread extirpation (Seglund et al. 2006, p. 65). Poisoning of prairie dogs is not allowed on public lands administered by the Bureau of Land Management, except in the incidence where colonies present a threat to human health or safety (Appendix A). In 2015, the only white-tailed prairie dogs removed by the U. S. Department of Agriculture’s Wildlife Services branch were in Colorado; 667 burrows/dens were removed in response to a sheep rancher’s request (M. Lowney, USDA APHIS Wildlife Services, pers. comm.).

Pesticides used for controlling prairie dogs include zinc phosphide, aluminum phosphide, and fumigant gas cartridges (Pauli et al. 2006, p. 11). Entities (private or business) wishing to poison prairie dogs must obtain a Restricted Use Pesticide (RUP) Applicator’s or Dealer’s License. While the number of licensed applicators and dealers within each state can be obtained, the amount of control performed by these licensees is not tracked (Table 6). Additionally, RUP licenses are not species-specific to white-tailed prairie dogs, or even prairie dogs in general. Therefore, we cannot quantify the level of poisoning experienced by the white-tailed prairie dog across its range. Current poisoning efforts are most likely focused on the control of black-tailed prairie dogs due to their more discernible colonies (L. Wheat, Albany County Weed and Pest Control District, pers. comm.).
Table 6. Number of licensed Restricted-Use Pesticide (RUP) dealers and applicators within the states that comprise the white-tailed prairie dog’s gross range*. Other than Montana, these numbers represent statewide totals and are not restricted to counties within the species’ range. Additionally, these licenses are not specific to prairie dog control and are applicable to a variety of vertebrate species.

<table>
<thead>
<tr>
<th>State</th>
<th>Number of Licensed RUP Dealers</th>
<th>Number of Licensed RUP Applicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado</td>
<td>220</td>
<td>7,400</td>
</tr>
<tr>
<td>Montana (Carbon County)</td>
<td>6</td>
<td>107</td>
</tr>
<tr>
<td>Utah**</td>
<td>121</td>
<td>11,725</td>
</tr>
<tr>
<td>Wyoming</td>
<td>110</td>
<td>340</td>
</tr>
</tbody>
</table>

*Data sources: (Colorado) provided by Colorado Department of Agriculture on request; (Montana) https://mtplants.mt.gov/PesticideApplicator/ApplicationExternalSearch.aspx; (Utah) http://webapp.ag.utah.gov/LicenseLookup/index.jsp; (Wyoming) http://agriculture.wy.gov/component/content/article/50-technical-services/289-pesticide-applicator-license-list
**These numbers include both active and expired licenses. A large number of expired licenses are expected to be renewed (S. Jensen, Utah Department of Agriculture, pers. comm.).

Impacts to Population Resiliency

![Figure 13. Influence diagram modeling how poisoning impacts the resiliency of white-tailed prairie dog populations. In the model, the orange box represents the stressor, and the orange arrows represent the negative impacts the stressor can have on crucial demographic factors (red boxes). The blue arrows represent the positive influences of the demographic factors on population resiliency (population health; yellow box). The black arrow represents the unknown impacts of poisoning on fecundity.](image)
By killing individuals, poisoning may affect crucial white-tailed prairie dog demographic factors that populations need to be resilient. Poisoning decreases abundance and juvenile survival. The fecundity of survivors or immigrants may increase following a poisoning event, but a population subjected to long-term, intensive poisoning campaigns may not produce enough individuals reaching sexual maturity to compensate for the number of individuals lost to poisoning.

**Summary of Impacts to the 3Rs**
Small populations with low abundance and juvenile survival, such as those subjected to long-term poisoning campaigns, exhibit low resiliency and are vulnerable to stochastic events. If individual colonies or complexes are locally extirpated due to poisoning campaigns, there will be fewer, more fragmented white-tailed prairie dog populations across the species’ range. This leads to a decrease in redundancy, or the ability of the species to withstand catastrophic events. If poisoning is widespread, this could lead to the extirpation of populations in a variety of ecological settings and a reduction in genetic diversity across the white-tailed prairie dog’s range, resulting in a reduction of the species’ representation.

**Current and Suggested Conservation Measures**
Unlike historically, poisoning of white-tailed prairie dogs today most likely occurs on a local scale without the goal of widespread extirpation and does not result in species-level impacts (Seglund et al. 2006, p. 65). The more dispersed, less discernible colonies of white-tailed prairie dogs lead to lower levels of poisoning than other prairie dog species (L. Wheat, ACWPCD, pers. comm.). Within black-footed ferret management areas, poisoning is restricted to private/public land interfaces in certain situations, and use of the anticoagulant poison Rozol is prohibited (U.S. Fish and Wildlife Service 2013, pp. 70-71). Poisoning of prairie dogs is not allowed on public lands administered by the BLM, except in the incidence where colonies pose a threat to human health or safety (Appendix A). The placement of poisonous baits on BLM lands by a private citizen is prohibited (43 CFR 4140.1 (C) (2) (i)).

3.2.6 Overgrazing

**Description**
Grazing has always been a component of the sagebrush-steppe region of the western United States, and prairie dogs co-evolved with native herbivores such as pronghorn (*Antilocapra americana*), mule deer (*Odocoileus hemionus*), and bison (*Bison bison*) (Osborne 1953, p. 267; Miller et al. 1994, p. 111). In addition to native herbivores, domestic livestock grazing began in the intermountain west with the arrival of European settlers in the 1800s. The effects of grazing on ecosystems are influenced by stocking rate, livestock species, and grazing timing and rotation, and differences in these factors can lead to positive or negative effects on prairie dog populations (Fleischner 1994 p. 630). For our analysis, we defined well-managed grazing as grazing that positively, rather than negatively, alters plant communities to increase the quality of prairie dog habitat. In contrast, overgrazing degrades prairie dog habitat and occurs when grazing pressure
is so high that forage plants are unable to recover from the disturbance (Vallentine 1990, p. 329). Moderate, well-managed grazing can maintain productivity in semi-arid grasslands like those of the western U. S. and can actually increase forage quality in prairie dog areas (Lauenroth et al. 1994 in Pauli et al. 2006, p. 31; Miller et al. 2007, p. 2803). Grazing also reduces vegetation height, facilitating predator detection (Uresk et al. 1981, p. 200; Cable and Timm 1987, p. 46), and can be used as a management tool for increasing the availability of open habitat preferred by white-tailed prairie dogs (Buys and Associates Inc. 2005 in Seglund and Schnurr 2010, p. 158). In contrast, overgrazing can negatively affect white-tailed prairie dog habitat. Domestic livestock may preferentially remove the herbaceous vegetation preferred by prairie dogs, causing shrubs and unpalatable plants to flourish. This reduces the forage available to prairie dogs and may promote the establishment of invasive weeds, such as cheatgrass (*Bromus tectorum*; see section 3.1.7 below) (Masters and Sheley 2001, p. 503). Overgrazing can also increase soil compaction and damage microbiotic soil crusts, reducing the friability of soils (Mack 1981, pp. 148-149; Fleischner 1994, pp. 633-634). Fencing and roads associated with grazing may cause habitat fragmentation and may directly or indirectly cause increased mortality of prairie dogs by increasing prairie dog-vehicle collisions, creating perch sites for raptors, and providing access corridors for predators (Call and Maser 1985, p. 3; Connelly et al. 2000, p. 974; Connelly et al. 2004, pp. 1-2). Mismanaged grazing may amplify the impacts of other stressors such as plague and drought (Seglund et al. 2006, pp. 64-65; Lupis et al. 2007, p. 35).

One study mimicking moderate and heavy rates of livestock grazing in Utah prairie dog colonies found that grazing significantly improved forage quality, but juvenile prairie dogs were also found to have lower growth rates in the grazed plots (Cheng and Ritchie 2006, pp. 549-550). Prairie dogs in poor body condition, like those affected by overgrazing, may have higher flea loads and be more susceptible to plague (Eads and Hoogland 2016, p. 7; Eads et al. 2016, pp. 1046, 1047). The negative effects of even moderate grazing seen in the Utah prairie dog study contrast with the results of other studies and are likely due to the low productivity habitat of the study area (Cheng and Ritchie 2006, p. 551). Some portions of the white-tailed prairie dog’s range are also arid, low productivity habitats which may not respond well to any level of grazing (Seglund et al. 2006, p. 50).

Unregulated domestic livestock grazing peaked in the early 1900s (Oliphant 1968, p. vii; Young et al. 1976, pp. 194-195, Carpenter 1981, p. 106; Donahue 1999, p. 15; Seglund et al. 2006, pp. 49, 51) with an estimated 19.6 million cattle and 25 million sheep on ranges in the western United States (BLM 2009, pp. 1-2). While domestic livestock grazing remains one of the most widespread influences on western North American ecosystems (Fleischner 1994, p. 630; Seglund et al. 2006, p. 49), the intensity of grazing on all federal lands has declined since the early 1900’s, and the BLM now encourages the development of grazing plans that promote plant growth and benefit wildlife (Laycock et al. 1996, p. 3; Seglund et al. 2004, p. 37; Seglund et al. 2006, p. 24). Current data on grazing levels across the range of the white-tailed prairie dog...
are unavailable. Nationwide, the BLM reports a 53 percent decrease in grazing allotments since 1954, with 8.6 million animal unit months (AUMs) grazed on BLM lands in 2015 (BLM 2016, pp. 2-3). This also represents a 25 percent increase from 2003, which was a year characterized by decreased forage due to drought and other factors (6.9 million AUMs; Seglund et al. 2006; p. 51).

Overgrazing has the potential to impact white-tailed prairie dogs by degrading the quality and quantity of forage; decreasing forage availability during important breeding, rearing, and pre-hibernation periods; and decreasing reproductive success and overwinter survival (Seglund et al. 2006, p. 49). It is likely that overgrazing impacts white-tailed prairie dog colonies in localized areas across the species' range. However, we do know white-tailed prairie dog colonies can persist in areas grazed by cattle (Clark 1977, p. 6) and that well-managed grazing can benefit prairie dogs by creating open habitat with short-stature vegetation (Lauenroth et al. 1994 in Pauli et al. 2006, p. 31; Miller et al. 2007, p. 2803). Additionally, white-tailed prairie dogs are diet generalists adapted to dry environments that persisted during historic periods of high grazing pressure.

**Impacts to Population Resiliency**

![Influence diagram modeling how overgrazing impacts the resiliency of white-tailed prairie dog populations.](image)

Figure 14. Influence diagram modeling how overgrazing impacts the resiliency of white-tailed prairie dog populations. In the model, the orange box represents the stressor, and the orange arrows represent the negative impacts the stressor can have on crucial habitat factors (blue boxes). The blue arrows represent the positive influences of the habitat and demographic factors (red boxes) on population resiliency (population health; yellow box). The black arrow represents the unknown impacts of overgrazing on connectivity.

Friable soil is an essential component of white-tailed prairie dog habitat because it allows prairie dogs to create burrow systems for shelter (Seglund et al. 2006, p. 4). Overgrazing may reduce the availability of friable soils through compaction (Fleischner 1994, pp. 633-634), but prairie
dogs have been observed burrowing in extremely compacted soils (B. Van Pelt, WAFWA, pers. comm.; J. Ceradini, WYNDD, pers. comm.). Overgrazing also reduces the availability of abundant vegetation (Cheng and Ritchie 2006, p. 550; Seglund et al. 2006, p. 49), which could lead to reductions in abundance, fecundity, and juvenile survival (Beck 1994, p. 25; Lomolino et al. 2003, p. 116; Facka et al. 2010, pp. 1755-1759; Davidson et al. 2014, pp. 434-435). The roads and fences associated with grazing operations fragment contiguous prairie dog habitat and may make them more vulnerable to predation (Call and Maser 1985, p. 3; Connelly et al. 2000, p. 974; Connelly et al. 2004, pp. 1-2). Additionally, overgrazing can promote the spread and incursion of invasive plants like cheat grass (Mack 1981, pp. 148-152), which has the potential to create corridors of unsuitable habitat that may fragment prairie dog populations and reduce connectivity.

Summary of Impacts to the 3Rs
Larger, more connected white-tailed prairie dog populations are more resilient and able to withstand annual, stochastic events. Reductions in friable soils and vegetation can lead to reduced abundance, fecundity, and juvenile survival, and thus, a decrease in the resilience of populations exposed to overgrazing (Beck 1994, p. 25; Lomolino et al. 2003, p. 116; Seglund et al. 2006, pp. 4, 50; Facka et al. 2010, pp. 1755-1759; Davidson et al. 2014, pp. 434-435). Reduced connectivity between populations may lead to a decrease in the white-tailed prairie dog’s redundancy, or the ability of the species to recover from catastrophic events. If overgrazing is widespread, this could lead to the extirpation of white-tailed prairie dog populations in a variety of ecological settings and thus a reduction in the species’ representation.

Current and Suggested Conservation Measures
Prairie dogs have co-evolved with native grazers, and well-managed grazing can positively influence prairie dog habitat. The following best practices for grazing management were presented in the most recent White-tailed Prairie Dog Conservation Assessment compiled by the Western Association of Fish and Wildlife Agencies (Seglund et al. 2006, p. 52):

- Limit (or prohibit) grazing during periods of critical plant growth
- Fence off high priority areas of prairie dog habitat (although this would preclude any of the benefits provided by well-managed grazing)
- Include considerations of timing and intensity in grazing management plans to maintain sufficient vegetation in prairie dog habitat
- Be cognizant of confounding stressors, such as drought, when creating annual grazing management plans
- Control and eradicate invasive weeds

In contrast to the early 20th century, overgrazing today is likely localized, and we expect that it impacts only a small portion of the white-tailed prairie dog’s range. While overgrazing can decrease population resiliency (Call and Maser 1985, p. 3; Connelly et al. 2000, p. 974; Connelly

Managers should work with ranchers in areas still subjected to heavy grazing to create grazing management plans that will minimize negative effects on prairie dog colonies, following the best practices outlined above.

3.2.7 Invasive Weeds

Description

Invasive plants are promoted by intense levels of disturbance to the environment (Masters and Sheley 2001, p. 504), such as oil and gas development, agriculture, and urbanization. Invasive plant species alter ecological processes by displacing native species, increasing the vulnerability of communities to more invaders, and reducing wildlife habitat quality (Masters and Shelley 2001, p. 503). They can be particularly damaging in areas of low moisture, including shrub-steppe habitats, because they reduce water infiltration of the soil and possess deeper roots than native species, allowing them to use more water and reduce nutrient availability over time (DiTomaso 2000, p. 257).

Cheatgrass (*Bromus tectorum*) is an invasive annual grass that is widely distributed across the gross range of the white-tailed prairie dog, especially in Utah (Seglund et al. 2004, p. 46). Cheatgrass creates an altered fire regime, increasing the amount of fire and reducing native grasses and shrubs (Masters and Sheley 2001, p. 503). Due to the plant’s early spring growth and rapid senescence, cheatgrass monocultures leave prairie dogs with very little nutritious forage in late summer and early fall. This can prevent prairie dogs from building the sufficient fat stores necessary for hibernation and lead to decreased overwinter survival and reproductive rates the following year (Seglund et al. 2004, p. 46). These effects may be amplified in drought years if cheatgrass germination is limited by low spring precipitation, leaving prairie dogs with very little to eat throughout the entire active season (Van Horne et al. 1997, p. 313; Seglund and Schnurr 2010, p. 157). In addition to cheatgrass, native juniper species began invading sagebrush habitats after European settlement due to land use changes (Miller and Rose 1999, pp. 551, 555). While some amount of shrubs are helpful for escaping from predators (Hoogland 2001, pp. 265-266), white-tailed prairie dogs prefer open habitats with short stature vegetation to facilitate predator surveillance (Seglund et al. 2006, p. 5). The large-scale encroachment of juniper represents a degradation of habitat and may ultimately make prairie dogs more vulnerable to predators.
It is estimated that cheatgrass affects at least 56 million acres (approximately 23 million hectares) in the United States (Duncan et al. 2005 in Mealor et al. 2012, p. 427). In Utah, almost 300,000 acres (121,400 hectares) of BLM land are considered cheatgrass monocultures, and over 1 million acres (approximately 405,000 hectares) have cheatgrass as a major understory component (Zouhar 2003, p. 3). Every county within the range of the white-tailed prairie dog has reported cheatgrass invasions (Early Detection and Distribution Mapping System 2017), but specific data regarding the intensity of invasions within the species’ range are not available. Range-wide data regarding juniper encroachment on white-tailed prairie dog habitat are also unavailable (USFWS 2015, p. 59914), but one modeling effort to quantify canopy cover in greater sage-grouse management areas in Utah did identify high levels of conifer canopy cover in some areas of the white-tailed prairie dog’s gross range in the state (Falkowski et al. 2014). This mapping effort was not specific to juniper species, but some extensive juniper encroachment has occurred in areas of northeastern Utah, within the white-tailed prairie dog’s range (USFWS 2013b, pp. 19-22; K. Hersey, UDWR, pers. comm.). Other areas within the white-tailed prairie dog’s gross range are also impacted by juniper encroachment, but the levels of invasion in these areas are much lower than that seen in Utah (USFWS 2013b, pp. 14-29).

**Impacts to Population Resiliency**

![Figure 15. Influence diagram modeling how invasive weeds impact the resiliency of white-tailed prairie dog populations. In the model, the orange box represents the stressor, and the orange arrow represents the negative impacts the stressor can have on crucial habitat factors (blue boxes). The blue arrows represent the positive influences of the habitat and demographic factors (red boxes) on population resiliency (population health; yellow box). The black arrow represents the unknown impacts of invasive weeds on connectivity.](image)

Invasive weeds like cheatgrass alter native plant communities and reduce the amount of abundant vegetation available to white-tailed prairie dogs throughout the active season, which can decrease abundance and juvenile survival (Seglund et al. 2006, pp. 49-50; Lupis et al. 2007, p. 29). If prairie dogs do not have access to abundant succulent vegetation and cannot build
sufficient fat stores for hibernation, overwinter survival and fecundity the following year decrease (Seglund et al. 2006, pp. 49-50; Lupis et al. 2007, p. 29; Facka et al. 2010, pp. 1755-1758; Davidson et al. 2014, pp. 434-435). The effect of cheatgrass on colony connectivity may have a temporal component. Prairie dogs dispersing in the spring may not be hindered by cheatgrass since it is a nutritional forage source early in the year. However, cheatgrass senesces early in the season and may create corridors of unsuitable habitat between colonies for juvenile prairie dogs dispersing in the fall.

**Summary of Impacts to the 3Rs**

When white-tailed prairie dogs do not have access to sufficient amounts of vegetation throughout the active season, they may experience reductions in survival and fecundity (Facka et al. 2010, pp. 1755-1758; Davidson et al. 2014, pp. 434-435). This can lead to a decrease in population resiliency, and populations become more vulnerable to stochastic events. The effects of invasive weeds on connectivity are difficult to assess. Cheatgrass may facilitate dispersal in the spring and hinder it in the fall, and the magnitude of either of these effects is unknown. If invasive weeds reduce connectivity, populations will become more fragmented and the species will exhibit less redundancy across its range. If invasive weeds sometimes facilitate dispersal, this could increase connectivity and redundancy.

**Current and Suggested Conservation Measures**

Managers should seek to prevent and control invasive weeds to maintain the integrity of white-tailed prairie dog habitat. Cheatgrass can be controlled through physical (hand pulling, tillage, mowing), biological (grazing), and chemical (herbicides) means as well as prescribed fire (U. S. Forest Service 2014, pp. 2-5). Since 2005, Utah’s Watershed Restoration Initiative has completed projects resulting in the removal of 25,026 acres of juniper and the control of 6,591 acres of cheatgrass within the white-tailed prairie dog’s predicted range (K. Hersey, UDWR, pers. comm.). Grazing in white-tailed prairie dog habitat should be managed properly to prevent cheatgrass invasion and juniper encroachment (Fleischner 1994, pp. 632-633, and references within). On public lands administered by the BLM, grazing is managed with the intent to restore, maintain, or improve plant communities for the conservation of white-tailed prairie dogs (BLM 2007, pp. 4-1–4-3).

In Wyoming, oil and gas developers are directed to minimize disturbance and control cheatgrass in Greater Sage-grouse (*Centrocercus urophasianus*) Core Areas (State of Wyoming Executive Department Executive Order 2015-4, pp. 4, B-10). Similar protections are afforded in Greater Sage-grouse Core Areas in Montana. Developers are required to control invasive weeds, and agencies are directed to follow a “no net conifer expansion” policy and to make cheatgrass control a priority (State of Montana Office of the Governor Executive Order No. 10-2014, pp. 7-8, 16-17). White-tailed prairie dogs in these states may receive these benefits where the species’
range overlaps Greater Sage-grouse Core Areas. This overlap accounts for 35.2 percent of the white-tailed prairie dog’s predicted range (Figure 16).

Figure 16. Overlay of Greater Sage-grouse Core Areas on the white-tailed prairie dog’s predicted range. This overlap accounts for 35.2 percent of the white-tailed prairie dog’s predicted range, and prairie dog colonies in these areas may tangentially receive conservation benefits afforded to greater sage-grouse.

Cheatgrass is widespread throughout the white-tailed prairie dog’s gross range and likely has localized impacts on population resiliency, especially in drought years (Seglund and Schnurr 2010, p. 157). However, range-wide data are not available to assess the impacts of cheatgrass on the white-tailed prairie dog at a range-wide scale, so we cannot conclude if it is one of the main drivers of the species’ viability (Seglund and Schnurr 2010, p. 157; Lupis et al. 2007, pp. 29-30). Juniper encroachment likely degrades white-tailed prairie dog habitat in some localized areas, especially in certain regions of Utah. However, we have not seen evidence of juniper encroachment causing large impacts to population resiliency across the white-tailed prairie dog’s range. For local conservation efforts, managers should prevent invasion and remove cheatgrass and other invasive weeds from white-tailed prairie dog habitat so colonies will have access to high quality forage year-round. This will improve resiliency and make populations less vulnerable to other stochastic events, such as a plague epizootic or drought.
3.2.8 Wildfire

Description

The shrub-steppe habitat occupied by the white-tailed prairie dog evolved with infrequent fire frequency intervals of 100 to 450 years, depending on the dominant species of sagebrush (Baker 2006, pp. 180-181). Fire suppression activities also were infrequent (Baker 2006, p. 182) and probably had little effect on sagebrush landscapes (Baker 2011, p. 199). Fire ecology of sagebrush habitats has changed since European settlement of the American West. In general, fire frequencies have increased in lower elevation sagebrush habitats due to (and resulting in further) invasion of nonnative annual grasses, such as cheatgrass (Baker 2006, p. 178; Crawford et al. 2004, p. 8). In areas dominated by cheatgrass, historic fire cycles have significantly shortened, resulting in more frequent fires (Whisenant 1990 in Mealor et al. 2012, p. 427; Balch et al. 2013, pp. 177-178). In contrast, fire frequencies have declined in higher elevation sagebrush habitats, resulting in the expansion of shrubs and trees (Miller and Rose 1999, p. 557; Baker 2006, p. 178; Crawford et al. 2004, p. 8).

The specific effects of wildland fires on white-tailed prairie dogs are unknown. Evidence suggests wildfire can have either positive or negative impacts on prairie dog populations. Wildfire has the potential to positively influence white-tailed prairie habitat by reducing shrubs and increasing visibility for predator detection, releasing plant nutrients, stimulating production and quality of herbaceous vegetation, and removing vegetative litter (Seglund and Schnurr 2010, pp. 156-157; Milne-Laux and Sweitzer 2006, p. 299). In North Dakota, black-tailed prairie dog colonies expanded into areas treated with prescribed burns and mechanical vegetation removal because the treatments created more suitable open prairie dog habitat (Milne-Laux and Sweitzer 2006, p. 299). CPW biologists in northwest Colorado have observed fire positively affecting white-tailed prairie habitat in climax shrub communities by creating openings in the dense cover that allows colonies to expand. However, these same positive effects may not be seen in other white-tailed prairie dog habitat types like shortgrass prairie (B. Holmes, CPW, pers. comm.). Altered fire regimes and the positive feedback loop between fire and cheatgrass likely contribute to some level of habitat degradation across the species’ range (Lupis et al. 2007, p. 29). If a wildfire sweeps through prairie dog habitat in late summer or early fall, forage reductions may prevent prairie dogs from building enough fat stores for hibernation. However, prairie dogs are adapted to become dormant or begin hibernating early in years with low quality forage (Clark 1977, p. 55; Andelt et al. 2009, p. 43). Retreating to burrows may reduce direct mortality from fire. In contrast to high intensity wildfire, low intensity prescribed fires can be used to control invasive weeds and restore habitat, thus benefitting white-tailed prairie dogs (Pauli et al. 2006, p. 31, and references within).

Table 7 presents the acreage burned by wildland fires within the states that make up the white-tailed prairie dog’s gross range from 2010-2016. A large spike in wildfires was
recorded in 2012, corresponding with an abnormally warm and dry year in the intermountain west (National Interagency Coordination Center 2012, pp. 4-7).

Table 7. Acres burned by wildland fires within the states making up the white-tailed prairie dog’s gross range from 2010 to 2016. These data are statewide estimates of burned acreage and are not specific to areas where the white-tailed prairie dog occurs. Data were retrieved from the National Interagency Coordination Center website (https://www.nifc.gov/fireInfo/fireInfo_statistics.html; accessed 1 March 2017).

<table>
<thead>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado</td>
<td>44,020</td>
<td>161,167</td>
<td>246,445</td>
<td>195,145</td>
<td>24,949</td>
<td>22,602</td>
<td>129,495</td>
</tr>
<tr>
<td>Montana</td>
<td>56,711</td>
<td>168,010</td>
<td>1,220,655</td>
<td>124,209</td>
<td>38,118</td>
<td>351,264</td>
<td>114,594</td>
</tr>
<tr>
<td>Utah</td>
<td>64,781</td>
<td>62,783</td>
<td>415,267</td>
<td>70,282</td>
<td>28,255</td>
<td>10,203</td>
<td>101,096</td>
</tr>
<tr>
<td>Wyoming</td>
<td>80,382</td>
<td>135,878</td>
<td>357,117</td>
<td>44,016</td>
<td>7,836</td>
<td>35,652</td>
<td>218,077</td>
</tr>
</tbody>
</table>
Impacts to Population Resiliency

Figure 17. Influence diagrams modeling how wildfire can negatively (top) or positively (bottom) impact the resiliency of white-tailed prairie dog populations. In the model, the orange box represents the stressor, and the orange and blue arrows represents the negative and positive impacts, respectively, the stressor can have on crucial habitat (blue boxes) and demographic factors (red boxes). The blue arrows represent the positive influences of the habitat and demographic factors on population resiliency (population health; yellow box).

The impacts of wildfire on white-tailed prairie dog population resiliency are complex and not well-studied (Seglund et al. 2006, p. 51). Negative impacts could include direct mortality of individuals that decreases abundance and juvenile survival and an immediate decrease in the availability of abundant vegetation. Wildland fires that are a part of altered fire regimes can also facilitate the invasion of invasive weeds like cheatgrass and woody shrubs into white-tailed prairie dog habitat. However, wildland fires may also have positive effects like stimulating the production and quality of herbaceous vegetation and opening up more suitable prairie dog habitat, which could lead to colony expansion. If the quantity and quality of vegetation and suitable habitat increase after a fire, abundance, fecundity, and juvenile survival will increase.
The effects of wildfire on white-tailed prairie dog colony connectivity are also unknown. It is possible that large swaths of burned habitat may be unsuitable dispersal corridors that prevent the movement of individuals between colonies, or wildfire may open up previously unsuitable habitat that then becomes a dispersal corridor. Whether or not the impacts of wildfire are positive or negative likely depend on the size and severity of the fire as well as the existing habitat within which a prairie dog population occurs.

Summary of Impacts to the 3Rs
A white-tailed prairie dog population exposed to a wildfire may experience a decrease or increase in resiliency, depending on the fire’s size and intensity and the habitat type within which the population occurs. Reduced vegetation, connectivity, abundance, and juvenile survival would lead to a reduction in the population’s resiliency and make it more vulnerable to other stochastic events, such as drought or a plague epizootic. If swaths of burned habitat prevent prairie dogs from dispersing between colonies, the area affected by the fire may experience reduced connectivity, further reducing resiliency. The loss of a large number of individual prairie dogs in a wildfire could decrease genetic diversity, leading to a decrease in the species’ representation.

Conversely, wildfire has the potential to improve or create new habitat on the margins of colonies, which allows them to expand and consequently increases connectivity and forage quality. This then leads to increases in abundance, fecundity, and juvenile survival, which in turn strengthen population resiliency and renders populations less vulnerable to other stochastic events. A higher number of more resilient populations across the white-tailed prairie dog’s range would lead to higher redundancy, making the species less vulnerable to catastrophic events.

Current and Suggested Conservation Measures
White-tailed prairie dogs evolved with a natural wildfire regime, and we have no specific data on the current impacts of wildfire on the species. It is reasonable to predict that wildfire may have localized positive or negative impacts on some populations, but it is unlikely that wildfire is widespread enough to impact the species as a whole. In general, the experts we consulted viewed wildfire as a positive force that can be used to maintain suitable white-tailed prairie dog habitat (A. Seglund, CPW, pers. comm., B. Holmes, CPW, pers. comm., Seglund and Schnurr 2010, pp. 156-157), but altered fire regimes may lead to the encroachment of invasive species like cheatgrass, which can reduce available forage (Whisenant 1990 in Mealor et al. 2012, p. 427; Lupis et al. 2007, p. 29). To reduce potential negative impacts of wildfire on white-tailed prairie dog populations, land managers can improve habitat by reducing invasive plants like cheatgrass through physical (hand pulling, tillage, mowing) or chemical (herbicides) means and managing grazing to prevent cheat grass encroachment (Fleischner 1994, pp. 632-633, and references within; U.S. Forest Service 2014,
Prescribed burns can also be used to manage cheatgrass invasions and restore or expand white-tailed prairie dog habitat (Seglund and Schnurr 2010, p. 164; U.S. Forest Service 2014, pp. 2-5). In Utah, the Watershed Restoration Initiative has completed projects to lessen the negative impacts of catastrophic wildfire within the white-tailed prairie dog’s range, such as reseeding after wildfire and creating firebreaks (K. Hersey, UDWR, pers. comm.).

3.2.9 Urbanization

Description

Urbanization represents a permanent loss of white-tailed prairie dog habitat and can also entail direct eradication of prairie dogs (Lupis et al. 2007, p. 26; Seglund et al. 2006, p. 45). Additionally, urbanization fragments and isolates colonies, leading to smaller colonies with higher prairie dog densities (Johnson and Collinge 2004, p. 493). Poisoning, shooting, vehicle collisions, and predation by domestic animals like dogs and cats may all increase in urban areas (Magle and Crooks 2009, p. 198; Seglund and Schnurr 2010, p. 171). Conversely, if prairie dogs are allowed to persist in developed areas, they may benefit from the high quality vegetation provided by irrigated green spaces (Seglund et al. 2006, p. 45). Fragmentation of prairie dog colonies in urban landscapes may also slow the transmission of plague across a complex (Sackett et al. 2013, p. 2450).

According to the Natural Resource Conservation Service (NRCS), development increased 59 percent from 2007 to 2012 in the United States (including territories). However, the NRCS’ definition of development is not limited to the expansion of urban areas, but includes the build-up of both large and small tracts of land as well as the construction of rural transportation corridors (NRCS 2015, pp. 2-5, 3-1). Rates of urbanization in the western United States are below the national average (White et al. 2009, pp. 41–45), but urbanization on the western slope of the Rocky Mountains in Colorado is increasing rapidly (Seglund and Schnurr 2010, p. 171). The effects of this urbanization in Colorado on white-tailed prairie dogs are expected to be mainly limited to colonies in the Montrose, Delta, and Grand Junction areas (Seglund and Schnurr 2010, p. 176).

The effects of urban fragmentation on the white-tailed prairie dog have not been studied, but some information exists for black-tailed prairie dogs. In one study, weights and sex ratios of black-tailed prairie dogs in urban environments were within normal ranges for the species (Magle 2008, p. 116). Black-tailed prairie dogs are more likely to occur on larger, contiguous habitats within urban environments rather than smaller, highly fragmented parcels (Magle and Crooks 2009, p. 197). Collapses of existing colonies have been observed within highly fragmented urban environments (Magle and Crooks 2009, pp. 197, 199). This information suggests that some prairie dogs can survive in fragmented habitat, but population loss increases with the degree of fragmentation and amount of time since fragmentation.
occurred (Magle and Crooks 2009, p. 200). While urban development is known to decrease
the magnitude of dispersal in black-tailed prairie dogs, they can still move fairly well
through areas of low intensity development (Sackett et al. 2012, pp. 415-416). Urban
colonies also exist on roadsides and at the edges of development (Johnson and Collinge

As of 2010, urban areas only accounted for 0.28 percent of the white-tailed prairie dog’s
gross range (Table 8). This value is not directly comparable to the value presented in
Seglund et al. 2006 (0.2 percent; see Table 7, p. 97) because different gross ranges were used
for these analyses. However, it is obvious that some urban areas have increased in size while
others have decreased in size (Table 8). Urbanization currently affects only a small portion
of the species’ range and is likely to have only local effects.
Table 8. Urban Areas and Clusters within the white-tailed prairie dog’s gross range. This table is an updated version of Table 7 in Seglund et al. 2006 (p. 97). Data is from the 2010 census (U.S. Census Bureau 2015). Urban Areas are characterized by populations greater than or equal to 50,000 people; Urban Clusters have populations of 2,500-49,999 people. As of 2010, Grand Junction, Colorado was the only area within the range of the white-tailed prairie dog with a population greater than 50,000 people. Fruita, Colorado was included in Seglund et al. 2006 (Table 7) as an Urban Cluster, but the U. S. Census Bureau now includes Fruita as part of the Grand Junction Metropolitan Statistical Area.

<table>
<thead>
<tr>
<th>Urban Area</th>
<th>2010 Hectares</th>
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<tbody>
<tr>
<td>Battlement Mesa, CO</td>
<td>758</td>
</tr>
<tr>
<td>Cody, WY</td>
<td>1,644</td>
</tr>
<tr>
<td>Craig, CO</td>
<td>1,472</td>
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<tr>
<td>Delta, CO</td>
<td>1,471</td>
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<tr>
<td>Eagle, CO</td>
<td>636</td>
</tr>
<tr>
<td>Evanston, WY</td>
<td>1,814</td>
</tr>
<tr>
<td>Grand Junction, CO</td>
<td>20,409</td>
</tr>
<tr>
<td>Green River, WY</td>
<td>1,221</td>
</tr>
<tr>
<td>Gypsum, CO</td>
<td>907</td>
</tr>
<tr>
<td>Kemmerer, WY</td>
<td>383</td>
</tr>
<tr>
<td>Lander, WY</td>
<td>671</td>
</tr>
<tr>
<td>Laramie, WY</td>
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<tr>
<td>Montrose, CO</td>
<td>4,697</td>
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<tr>
<td>Powell, WY</td>
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<tr>
<td>Rock Springs, WY</td>
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<tr>
<td>Roosevelt, UT</td>
<td>814</td>
</tr>
<tr>
<td>Steamboat Springs, CO</td>
<td>2,113</td>
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<tr>
<td>Thermopolis, WY</td>
<td>597</td>
</tr>
<tr>
<td>Vernal, UT</td>
<td>4,418</td>
</tr>
<tr>
<td>Worland, WY</td>
<td>575</td>
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</tbody>
</table>

Percent of Gross Range 0.28%
Impacts to Population Resiliency

Figure 18. Influence diagram modeling how urbanization impacts the resiliency of white-tailed prairie dog populations. In the model, the orange box represents the stressor, and the orange arrows represent the negative impacts the stressor can have on crucial habitat (blue boxes) and demographic factors (red boxes). The blue arrows represent the positive influences of the habitat and demographic factors on population resiliency (population health; yellow box).

White-tailed prairie dogs may be directly eradicated in areas of new development or be exposed to higher lethal control efforts, resulting in decreased abundance. Urbanization results in habitat loss, reducing the amount of abundant vegetation available for prairie dogs to eat and eliminating or compacting friable soils. In colonies surrounded by development, this can result in high competition for resources. However, if prairie dogs are tolerated in developed areas, irrigated greenspaces may provide abundant nutritious forage. Urbanization also fragments and isolates colonies, decreasing connectivity in developed areas and preventing gene flow and immigration. However, prairie dogs are capable of dispersing through areas of low intensity development.

Summary of Impacts to the 3Rs
White-tailed prairie dog colonies that are affected by urbanization may be small, isolated, and resource limited. This makes them less resilient and more vulnerable to stochastic events like a plague epizootic. Decreased connectivity between urban colonies reduces the ability of migrants to recolonize extirpated colonies following stochastic events, leading to a reduction in redundancy and making the species more vulnerable to catastrophic events.

Current and Suggested Conservation Measures
In general, fragmentation negatively affects populations by preventing dispersal and limiting gene flow. However, fragmentation may slow the transmission of a plague epizootic (but see
Stapp et al. 2004, p. 238), and surviving colonies may serve as genetic reservoirs (Sackett et al. 2013, p. 2450). The rate of urbanization in the United States is not likely to decrease. However, urbanization currently impacts only a small portion of the species’ gross range, and it is likely to have only local effects in certain areas. Management options for buffering white-tailed prairie dogs against the effects of urban development are limited, but educating the public and engaging city planners in white-tailed prairie dog conservation issues may have some localized positive impacts (Seglund and Schnurr 2010, p. 176). In some cases, managers may consider working with developers and city officials to relocate prairie dogs from areas slated for development.

3.2.10 Energy Development

Description

Oil and gas exploration and development occur throughout the range of the white-tailed prairie dog. Between 2004 and 2008, political and economic incentives increased the exploration of oil and gas resources in the intermountain west. The 2005 Energy Policy Act expedited the leasing and permitting of energy development on Federal lands (42 U.S.C. 13201 et seq.; Seglund and Schnurr 2010, p. 121). U. S. energy consumption is expected to increase only slightly in the next 35 years (U. S. Energy Information Administration (EIA) 2017, p. 10). However, domestic energy production is expected to greatly increase during that same time period with an emphasis on natural gas (EIA 2017, pp. 7-13). Significant oil and gas development within the white-tailed prairie dog’s range is expected to continue in Utah (Hersey et al. 2016, p. 2), Wyoming (BLM 2007, p. 3-11), and Montana (L. Hanauska-Brown, MFWP, pers. comm.), and alternative energy, such as solar, is developing at a rapid pace in Colorado (Seglund and Schnurr 2010, p. 117). The Dakotas/Rocky Mountain region of the U. S. is projected to lead the country’s growth of tight oil (shale oil) production in the future (EIA 2017, p. 45).

Oil and gas development includes exploration, drilling, production, and reclamation phases (Tribal Energy and Environmental Information Clearinghouse (TEEIC) 2009, entire), each of which may potentially impact the white-tailed prairie dog or its habitat. Seismic methods used for exploration include shot-hole surveys and vibroseis, which is the use of a truck-mounted vibrating plate that sends shock waves through the ground to locate oil sources. These exploration techniques have the potential to result in prairie dog mortality and to crush vegetation along the seismic route (Seglund et al. 2006, p. 45, and references within). However, a study in Wyoming found no correlations between vibroseis activity and burrow collapse or white-tailed prairie dog declines (Menkens and Anderson 1985, pp. 6, 12-13). Once an oil or gas source is discovered, permanent structures including access roads, well pads, pipelines and any other necessary infrastructure are constructed (TEEIC 2009, p. 9). Wells may be in the production phase for up to 20 to 30 years for gas wells (TEEIC 2009, p. 5) and up to 100 years for oil wells (Connelly et al. 2004, p. 7:41). When a well is taken out of production, the lessee is...
responsible for reclaiming the land back to its original condition, or as close to the original condition as possible (BLM 2007, pp. 3-11–3-13; TEEIC 2009, p. 15).

Exploration for oil and gas may increase human activity within previously undisturbed habitats (Underwood 2007, p. 10). The development of well pads and supporting infrastructure, such as roads and pipelines, reduces and fragments habitat, compacts soil, and destroys vegetation. This infrastructure also creates perches for raptors, which may increase predation pressure on colonies near these structures (Pauli et al. 2006, p. 26). New roads may increase road mortality, and prairie dog shooting may increase with increased human access (Gordon et al. 2003, p. 12).

The amount of direct habitat loss and total fragmentation associated with oil and gas development varies greatly depending on well density (number of acres per well) and spacing (distance between individual well pads). Well densities and spacing are typically designed to maximize recovery of the resource and are administered by state oil and gas agencies and the BLM on federal mineral estate. Each geologic basin has a standard spacing, but exemptions are granted (Connelly et al. 2004, pp. 7-39 to 7-40). Within the range of the white-tailed prairie dog, well spacing can vary from 5 to 160 acres (2 to 65 hectares) per well. Increasing wells per unit area decreases the amount of habitat available for wildlife. Increasing the number of wells per pad increases the size of the individual pad, but also decreases the amount of habitat fragmented. Directional, or horizontal, drilling also decreases the amount of habitat fragmentation by colo-locating multiple wells on a single pad (Copeland et al. 2009, p. 6). On BLM lands in Wyoming, single drill pads average three acres, but this estimate varies widely between projects (BLM 2007, p. 3–13). Variation in well pad size and spacing results in variation of the intensity of effects from energy development across the species’ range. The threshold levels of oil and gas development that result in reduced populations or eliminated colonies are unknown.

For our analysis of oil and gas development within the white-tailed prairie dog’s range, we applied a 3.39 acres (1.37 hectares) pad scar footprint on all known producing and non-producing wells within the species’ range, following the methods of Garman and McBeth 2014 (entire). This footprint more accurately describes the spatial impact of a well, rather than just the point of the well itself, because it attempts to account for the infrastructure and vegetation disturbance associated with well development. Although one may assume the amount of disturbance is less for a non-producing well than a producing well, we included them in our analysis because we cannot estimate the level of post-production restoration that has occurred on-site. Restoration of a closed well pad site to its natural condition may take up to 40 to 50 years (S. Garman, USGS, pers. comm.). Within the white-tailed prairie dog’s predicted range, 65,497 acres (26,206 hectares) are affected by producing well footprints and 48,653 acres (19,689 hectares) are impacted by non-producing well footprints. This accounts for 0.19 percent and 0.14 percent of the species’ predicted range, respectively. The most developed oil and gas area of the white-tailed prairie dog’s range is in northeast Utah (Figure 19).
A large portion of the white-tailed prairie dog’s predicted range in Wyoming is covered by authorized and pending oil and gas leases on BLM land (55.93 percent; Figure 20; Table 9). Authorized leases have permission to be developed, but may not yet be producing. Pending leases have submitted applications which have not yet been authorized for development. Although they are approved for development by the BLM, we do not expect all of the authorized leases will be put into oil and gas production at any one time. For example, only 46 percent and 55 percent of authorized BLM oil and gas leases in Wyoming were producing in fiscal years 2015 and 2016, respectively (C. Keefe, BLM, pers. comm.). We do not have a way of predicting how many of these authorized leases will be developed within the white-tailed prairie dog’s range in the future, but we can expect that the number of leases that go through exploration and development will be far less than the total number of authorized leases (C. Keefe, BLM, pers. comm.). Any future development in these leased areas must comply with local Resource Management Plans (RMPs), which in turn must meet requirements set forth in the National Environmental Policy Act (NEPA) (BLM 2017).
Figure 19. Map of producing and non-producing oil and gas well footprints within the predicted range of the white-tailed prairie dog. Producing and non-producing gas well footprints account for 0.19 percent and 0.14 percent of the white-tailed prairie dog’s predicted range, respectively. Since spatial data of the proper resolution were available, we used the predicted range for this analysis because it is a subset of the gross range that represents a more spatially-resolved estimate of where the white-tailed prairie dog may occur. Because of the scale of this map, the polygons representing the producing and non-producing well footprints overestimate the true area of the footprints, making it look like they cover more than 0.33 percent of the predicted range. We display the footprints this way so the reader is better able to see concentrations of oil and gas development within the species’ predicted range.
Figure 20. Map of authorized and pending oil and gas leases on BLM administered lands within the predicted range of the white-tailed prairie dog. Authorized leases have permission to be developed, but may not yet be producing. Pending leases have submitted applications which have not yet been authorized for development. Since spatial data of the proper resolution were available, we used the predicted range for this analysis because it is a subset of the gross range that represents a more spatially-resolved estimate of where the white-tailed prairie dog may occur. The predicted range encompasses 34,277,527 acres (13,871,623 hectares).

In addition to oil and gas development, other energy development including oil shale, coal, solid minerals, and renewable wind farms have authorized or pending leases within the range of the white-tailed prairie dog. Impacts associated with the development of these energy sources are similar to those for oil and gas development, such as habitat loss and fragmentation.
Table 9. Acres of authorized and pending leases for energy development on public lands administered by the BLM within the predicted range of the white-tailed prairie dog. Authorized leases have permission to be developed, but may not yet be producing. Pending leases have submitted applications which have not yet been authorized for development. Since spatial data of the proper resolution were available, we used the predicted range for this analysis because it is a subset of the gross range that represents a more spatially-resolved estimate of where the white-tailed prairie dog may occur. The predicted range encompasses 34,277,527 acres (13,871,623 hectares).

<table>
<thead>
<tr>
<th>Development Type</th>
<th>Authorized Acres</th>
<th>Percent of Predicted Range</th>
<th>Pending Acres</th>
<th>Percent of Predicted Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil and Gas</td>
<td>18,620,729</td>
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<tr>
<td>Solid Mineral</td>
<td>111,715</td>
<td>0.33%</td>
<td>174,531</td>
<td>0.51%</td>
</tr>
<tr>
<td>Renewable</td>
<td>176,577</td>
<td>0.52%</td>
<td>391,065</td>
<td>1.14%</td>
</tr>
</tbody>
</table>

In 2016, the Utah Division of Wildlife Resources and Wyoming Game and Fish Department used occupancy modeling to investigate the effects of oil and gas development on white-tailed prairie dogs. The results of Utah’s model showed conflicting effects of oil and gas development on white-tailed prairie dog occupancy; occupancy probability declined with decreasing straight-line distance to a well, but colonization probability increased with increasing well density (Hersey et al. 2016, p. 9). However, further analysis showed no relationship between predicted initial occupancy and the distance to the nearest oil or gas plot containing a well within 2000 meters of the prairie dog occupancy plot (Hersey et al. 2016, p. 19, Figure 6). Occupancy probability also increased with increasing road densities (Hersey et al. 2016, p. 7). Despite these confusing results, white-tailed prairie dog occupancy rates in Utah have remained relatively stable since 2008 (represents 4 sampling periods, Hersey et al. 2016, pp. 6-7), and populations have persisted in the state despite high levels of oil and gas development (Hersey et al. 2016, p. 9). In the analysis for Wyoming, researchers looked at the presence and count of active well pads within and at 1 and 2 kilometer buffers around sampling sites (Ceradini et al. 2017, p. 11). None of these oil and gas variables were good predictors of white-tailed prairie dog occupancy in the best-supported model (Ceradini et al. 2017, p. 13). This suggests oil and gas development does not affect the probability of prairie dogs occupying a site in Wyoming (Ceradini et al. 2017, p. 30). However, this study utilized only one year of occupancy data (2016), and it is possible occupancy is too coarse a metric to capture declines associated with oil and gas development in Wyoming (Ceradini et al. 2017, p. 30-31).
Impacts to Population Resiliency

Figure 21. Influence diagram modeling how energy development impacts the resiliency of white-tailed prairie dog populations. In the model, the orange box represents the stressor, and the orange arrows represent the negative impacts the stressor can have on crucial habitat (blue boxes) and demographic factors (red boxes). The blue arrows represent the positive influences of the habitat and demographic factors on population resiliency (population health; yellow box). The black arrow represents the unknown impacts of energy development on connectivity.

Energy development results in habitat loss, reducing the amount of abundant vegetation available to white-tailed prairie dogs and eliminating or compacting friable soils. Direct mortality from development, the increased risk of shooting associated with increased human access, and increased predation from raptors can reduce prairie dog abundance. Energy development also fragments habitat and may reduce connectivity between colonies. However, white-tailed prairie dogs are known to persist in areas of energy development (Hersey et al. 2016, p. 9), and prairie dogs are capable of dispersing through areas of low intensity development (Sackett et al. 2012, p. 416).

Summary of Impacts to the 3Rs
Reduction in habitat quality and quantity due to energy development could make prairie dog populations less resilient and more vulnerable to stochastic events. Habitat fragmentation can reduce connectivity and prevent gene flow and dispersal among colonies, leading to a reduction in population resiliency and the species’ redundancy. However, stable white-tailed prairie dog occupancy rates in areas of high energy development like northeast Utah suggest that prairie dogs are managing to disperse and maintain a metapopulation structure.

Current and Suggested Conservation Measures
In 2007, the BLM released a Statewide Programmatic White-Tailed Prairie Dog Biological Evaluation for the state of Wyoming. This document determined energy development in some
areas may contribute to declines of white-tailed prairie dogs and recommends several conservation practices that should be implemented on BLM lands to minimize impacts to the species (BLM 2007, pp. 3-14, 4-1–4-3). Suggested conservation measures include locating new access roads away from colonies, prohibiting development in occupied colonies, including conditions in drilling permits to protect prairie dogs during the reproductive season (April 1-July 15), and encouraging the use of directional drilling (BLM 2007, p. 4-1–4-3). Some, or all, of these conservation measures have been included in RMPs for BLM field offices throughout the range of the white-tailed prairie dog (Appendix A). Additional protections provided by some field offices include installing raptor anti-perching devices on structures associated with energy development, surface occupancy restrictions, and avoiding placing power poles in/near colonies (Appendix A).

Several restrictions on energy development in Greater Sage-grouse Core Areas in Wyoming may benefit white-tailed prairie dogs. Oil and gas developers are directed to minimize impacts to habitat in Core Areas by co-locating disturbances (State of Wyoming Executive Department Executive Order 2015-4, p. 4). Surface occupancy is not allowed within 0.6 miles of a greater sage-grouse lek in core areas or 0.25 miles in “non-core” sage-grouse habitat. Additional protections are afforded during the sage-grouse’s breeding season (March 15-June 30), which overlaps the white-tailed prairie dog’s reproductive period (State of Wyoming Executive Department Executive Order 2015-4, pp. B-6). While there is no regulatory restriction, wind energy development is “not recommended” in Core Areas in Wyoming (State of Wyoming Executive Department Executive Order 2015-4, pp. B-14). In Montana, the same call to minimize disturbance and surface occupancy restrictions are mandated in Core Areas (State of Montana Office of the Governor Executive Order No. 10-2014, pp. 3, 19). There are also seasonal and daily restrictions on activity to reduce impacts to sage-grouse (State of Montana Office of the Governor Executive Order No. 10-2015, p. 5). Additionally, power lines and communications towers must be erected at least 4 miles from the perimeter of a sage-grouse lek or buried to prevent raptor predation (State of Montana Office of the Governor Executive Order No.10-2015, p. 6). Wind energy development is not allowed in sage-grouse Core Areas in Montana unless it can be demonstrated that the development will not cause sage-grouse declines (State of Montana Office of the Governor Executive Order No. 10-2015, p. 8). However, none of these stipulations apply to energy development projects that existed within the Core Area prior to the release of the Executive Order (State of Montana Office of the Governor Executive Order No.10-2015, p. 5). White-tailed prairie dogs in these states may benefit from these conservation efforts where the species’ range overlaps greater sage-grouse core areas (35.2 percent of the predicted range; Figure 16).

According to our analysis, well pad scar footprints associated with energy development currently impact less than 1 percent of the white-tailed prairie dog’s historic range. Recent studies on the white-tailed prairie dog also suggest that energy development does not negatively affect the
species’ occupancy rates in Utah and Wyoming (Hersey et al. 2016, entire; Ceradini et al. 2017, entire). While energy development may have localized effects that decrease the resiliency of some white-tailed prairie dog populations, it does not appear to impact the species at a range-wide scale. Although a large portion of the white-tailed prairie dog’s predicted range in Wyoming is authorized for BLM oil and gas development, it is not likely that all of this area will be developed in the future. If these areas are developed, developers must follow the recommendations and policies set forth in the BLM field offices’ RMPs for conserving white-tailed prairie dogs (Appendix A).

3.3 Historical Condition

3.3.1 Distribution

The white-tailed prairie dog’s historical distribution does not vary greatly from its current range, and historical range maps very closely resemble the gross range we present in this SSA (Figure 6) (Hollister 1916, p. 24; Clark et al. 1971, p. 2; Seglund et al. 2006, p. 110). Because of this, the white-tailed prairie dog does not appear to have experienced a significant range contraction in the last 100 years (Antolin et al. 2002, p. 117; Knowles 2002, p. 5). Some scientists argue the reduction in white-tailed prairie dogs at the periphery of the species’ range in Montana, as well as the well-documented decrease in abundance range-wide, should be considered a range contraction (Knowles 2002, pp. 5-6; Seglund et al. 2004, p. 39; Pauli et al. 2006, p. 13). However, white-tailed prairie dogs are currently distributed throughout their historical geographic range.

3.3.2 Abundance

Estimates of historic prairie dog abundance vary widely and have been heavily debated in the scientific literature (Vermeire et al. 2004, pp. 689-691; Forrest 2005, pp. 527-528; Miller et al. 2007, p. 2801). Due to the difficulties associated with counting white-tailed prairie dogs, such as their burrowing nature, shifting colony boundaries, and uneven distribution (Seglund et al. 2004, p. 25), estimates of abundance are given as occupied acres rather than number of prairie dogs. For all prairie dog species combined, estimates of historic occupied acreage range from approximately 100 million to 250 million acres (40 to 100 million hectares) in the 19th century (Vermeire et al. 2004, p. 690, and references within). Ultimately, these historic estimates may be unreliable because they are often based on anecdotal evidence and were not assessed quantitatively (Pauli et al. 2006, p. 13).

Based on our predictive range model, as well as that of Seglund et al. 2004 (pp. 27-29), and the knowledge that the historic distribution of the white-tailed prairie dog was likely very similar to its current distribution, we can estimate that the historic range of the white-tailed prairie dog encompassed approximately 52 million acres (21 million hectares) (the species’ gross range in this SSA; see section 3.1 Range of the White-tailed Prairie Dog). Our more spatially refined
estimate of suitable prairie dog habitat (the predicted range) provides an estimate of approximately 34 million acres (13 million hectares). The extent to which either of these ranges was truly occupied by prairie dogs in the past is unknown. These models do not imply that the entire area is, or even could be, occupied by prairie dogs, and thus represent overestimations of occupied acres.

3.3.3 Stressors
The magnitudes of the stressors affecting white-tailed prairie dogs have changed over time. Sylvatic plague is a non-native disease that was introduced to the United States at the turn of the 20th century, and the first infection in a white-tailed prairie dog was not recorded until 1936 (Eskey and Haas 1940, pp. 14-15). Historic prairie dog populations were not exposed to plague, and this is not a factor that affected the historic abundance estimates provided above. Oil and gas development did occur at the time these estimates refer to (1800s), but at nowhere near the magnitude experienced today (U. S. Energy Information Administration 2013). Additionally, urbanization in the western U. S. was much lower historically than it is today (U. S. Census Bureau 2012). We do not have information on rates of historical agricultural land conversion; we can assume that agricultural land conversion increased in the 20th century as the United States population increased (USDA National Agricultural Library 2012). However, it is likely that prairie dog colonies in the 1800s were impacted at some level by agricultural land conversion. Widespread poisoning with the intent of prairie dog extermination began in the early 1900s, and the historic estimates presented above seek to quantify prairie dog numbers prior to these poisoning campaigns (Knowles 2002, pp. 1-2). It is reasonable to assume that white-tailed prairie dogs were subjected to some level of shooting historically, but we have no information on historical shooting levels. Grazing pressure by domestic livestock was at its peak in the late 1800s and early 1900s and had the potential to influence historic estimates of prairie dog abundance (Cheng and Ritchie 2006, pp. 549-550; Seglund et al. 2006, p. 49). Cheatgrass, the main invasive plant affecting prairie dog habitat, was already well established in North America in the early 1900s, but occurred at lower densities than it does now (Zouhar 2003, p. 2). Cheatgrass may have had local effects on some white-tailed prairie dog colonies in the past, but it is possible these occurred on a smaller scale than today. While historical prairie dog populations were most definitely exposed to droughts and wildfires, changing climate and wildland fire cycles most likely make these stressors more applicable to populations today (Facka et al. 2010, pp. 1759-1760; Davidson et al. 2014, p. 436; Whisenant 1990 in Mealor et al. 2012, p. 427; Balch et al. 2013, pp. 177-178).

3.4 Current Condition

3.4.1 Distribution
As described above, the extent of the white-tailed prairie dog’s current geographic distribution does not vary greatly from its historical distribution. The species continues to occupy portions of
Colorado, Montana, Utah, and Wyoming (Figure 6), but at lower densities (see discussion below).

3.4.2 Abundance

It is recognized that historical poisoning campaigns, the introduction of plague, and habitat loss have significantly reduced the abundance of white-tailed prairie dogs across the species’ range (Knowles 2002, pp. 1-2; Forrest 2005, p. 528; Miller et al. 2007, p. 2801). However, the magnitude of this decrease is difficult to assess because of a lack of quantitative historic data (Knowles 2002, p. 15; Seglund et al. 2004, p. 23; Pauli et al. 2006, p. 13; Miller et al. 2007, p. 2801). Strong efforts to determine prairie dog abundance did not begin until the 1980s after the rediscovery of black-footed ferrets in Meeteetse, Wyoming (Seglund et al. 2004, p. 24). The abundance of white-tailed prairie dogs is difficult to measure because of their burrows, less colonial nature, uneven distribution, and shifting colony boundaries (Seglund et al. 2004, p. 25; Pauli et al. 2006, p. 29). Previously, natural resource agencies throughout the range of the white-tailed prairie dog used monitoring programs with varying methods and levels of effort to determine abundance. For many states, population trends were assessed through colony mapping or transect surveys. Colony mapping is not an accurate method for assessing population trends for the white-tailed prairie dog due to the difficulty in establishing colony boundaries, the uneven distribution of white-tailed prairie dogs across the landscape, the subjective nature of determining occupied vs. unoccupied burrows, changes in activity levels within a colony, and the inaccuracy of extrapolating colony size to prairie dog abundance (Seglund et al. 2004, p. 24; Andelt et al. 2009, pp. 35, 43; Seglund 2016, p. 2). The transect survey method is a count of active prairie dog burrows (often called the “Biggins method,” Biggins et al. 1989, entire; Biggins et al. 1993, entire), and this method is still used to monitor prairie dog abundance in black-footed ferret management areas. However, several studies have not found a correlation between burrow counts and above-ground prairie dog numbers, and departures in methodology and analysis from the original Biggins technique over time make range-wide comparisons of these data unfeasible (Seglund et al. 2004, p. 25). In response to the 2002 petition to list the white-tailed prairie dog as a threatened or endangered species under the Act, the White-tailed Prairie Dog Working Group of the Western Association of Fish and Wildlife Agencies (WTPDWG) created a conservation assessment and subsequent monitoring protocol to standardize efforts for determining the status of the species across its range (Seglund et al. 2006, pp. 1-2; Seglund 2016, p. 3). In 2010, the group selected occupancy surveys as the standardized monitoring method (Seglund 2016, p. 3).

White-tailed prairie dogs can experience large annual population fluctuations (Seglund et al. 2004, p. 25; Seglund et al. 2006, p. 28). Because of this, measuring changes in occupied area through occupancy surveys is seen as a more effective way of assessing long-term population trends in white-tailed prairie dog abundance than attempting to count animals. Occupancy modeling is an objective, repeatable technique that allows for statistical measures of precision, as
well as extinction and colonization rates, unlike colony mapping (MacKenzie et al. 2002, entire). Occupancy modeling results in an occupancy probability estimate, which is the probability that a species occurs in a certain area. To determine occupancy, a subset of sites (500m x 500m plots) are chosen from the total number of plots available to white-tailed prairie dogs in a certain area (the species’ range within each state). This constitutes the occupancy modeling ‘sampling frame.’ The chosen plots are then visited in person, and the presence or absence of prairie dogs is recorded. Only one prairie dog needs to be sighted for the plot to be considered occupied. The occupancy probability is the number of occupied plots divided by the total number of available plots, adjusted by estimated detection probability. In addition to the occupancy probability, statistical models can be run using the raw data to determine if certain factors, like habitat features or stressors, are affecting the probability of an area being occupied (see example in section 3.2.10 Energy Development). Although there are still small differences in the way the states now collect and analyze this occupancy data, the transition to this standardized monitoring method has allowed us to better assess temporal trends in prairie dog abundance across the species’ range.

Occupancy surveys were performed by Colorado in 2004, 2008, 2011, and 2016; Utah in 2008, 2011, 2014, and 2016; and Wyoming in 2016 (Table 10). Full descriptions of occupancy modeling in these states are provided in annual reports (Ceradini et al. 2017, entire; Hersey et al. 2016, entire; Seglund 2016, entire). Montana does not participate in occupancy surveys because of the limited range of the white-tailed prairie dog in Montana (L. Hanauska-Brown, MFWP, pers. comm.). Based on the WTPDWG’s recommendations, the participating states agree to perform statewide occupancy surveys at least every six years (B. Van Pelt, WAFWA, pers. comm.). Utah performs occupancy surveys every three years in accordance with its Gunnison’s Prairie Dog and White-tailed Prairie Dog Conservation Plan (Lupis et al. 2007, p. 22). State management actions are triggered in Utah if surveys reveal a drastic drop in occupancy probability between samples (Lupis et al. 2007, pp. 22-23).

Because each state developed the sampling framework for its occupancy surveys differently (Ceradini et al. 2017, pp. 3-4; Hersey et al. 2016, p. 4; Seglund 2016, pp. 3-4), occupancy estimates cannot be compared between states. However, occupancy estimates can be compared between years within a state (Colorado and Utah). Based on the state average, rates of change between sampling periods in Colorado indicate an increase in occupancy from 2004 to 2008, decrease from 2008 to 2011, and slight increase from 2011 to 2016, though confidence intervals did overlap 1.0 for all sampling intervals, indicating some uncertainty (Seglund 2016, p. 8) (Table 10). This same pattern is found for the Grand Junction stratum, while the North-West stratum’s occupancy has steadily increased from 2004 to 2016, despite a plague epizootic in 2008 (Seglund 2016, p. 10). The cause of the decline in the North Park’s stratum in 2008 is unknown (Seglund 2016, p. 11).
Utah saw an increase in occupancy from 2008 to 2011, decrease from 2011 to 2014, and slight increase from 2014 to 2016. Overlapping 95 percent confidence intervals for all of these occupancy estimates indicates a fairly stable trend in Utah (see Figure 5 in Hersey et al. 2016, p.18). Management actions are triggered in Utah if a 40 percent decline is detected between survey periods (Lupis et al. 2007, pp. 22-23).

Wyoming’s 2016 occupancy estimate cannot be compared to previous estimates of prairie dog abundance in the state. Aerial mapping surveys performed in Wyoming in 2008 and 2011 were found to greatly overestimate the area of active colonies and did not produce results comparable to the 2016 occupancy surveys (Cudworth et al. 2011, p. 249; N. Bjornlie, WGFD, pers. comm.). The 2016 surveys produced occupancy rates ranging from 0.11 to 0.44, with the highest prairie dog occupancy seen on private lands and the lowest occupancy on public lands (Table 10). Wyoming has committed to performing the occupancy surveys again, likely in six years as recommended by the WTPDWG (N. Bjornlie, WGFD, pers. comm.).

Montana does not participate in occupancy surveys because of the state’s small portion of the species’ range and low number of white-tailed prairie dogs (L. Hanauska-Brown, MFWP, pers. comm.). Efforts have been made to visit colonies on a regular basis, and at times, map colony boundaries. Reviews of historic population trends in Montana are provided by Knowles (2002, p. 15) and Seglund et al. (2006, pp. 24-25) and summarized in Figure 22. In 2016, four of 23 historic colonies in Montana were occupied, and one new colony was found (L. Hanauska-Brown, MFWP, pers. comm.). Previous reviews have stated the white-tailed prairie dog population in Montana is at a high risk of extirpation (Knowles 2002, p. 15; Montana Prairie Dog Working Group 2002, p. 27; Seglund et al. 2006, p. 25). While recent colony counts have been lower than those recorded in the 1970s, an increasing trend was observed from 1997 to 2009 (Figure 22).
Table 10. Reported occupancy probabilities for white-tailed prairie dogs in Colorado, Utah, and Wyoming from 2004-2016. Surveys were not performed in all states in all years. Due to differences in methodology, occupancy probabilities are comparable within states between years, but not between states within years. Numbers in parentheses are the standard error (CO, UT) or 95 percent confidence interval (WY) of the occupancy probability estimate. Data is taken from state reports (Ceradini et al. 2017, entire; Hersey et al. 2016, entire; Seglund 2016, entire).

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<td>--</td>
<td>--</td>
<td>0.11 (0.07, 0.16)</td>
</tr>
<tr>
<td></td>
<td>Wind River</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>0.20 (0.08, 0.41)</td>
</tr>
<tr>
<td></td>
<td>Indian Reservation</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>0.28 (0.16, 0.45)</td>
</tr>
<tr>
<td></td>
<td>Checkerboard</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>0.44 (0.19, 0.74)</td>
</tr>
</tbody>
</table>

* “Strata” are used by states to stratify occupancy plots across the sampling frame within each state. Strata in Colorado are based on distinct white-tailed prairie dog population areas (Seglund 2016, p. 4). Strata in Wyoming are based on land-use type (Ceradini et al. 2017, p. 4). State Average refers to the average occupancy probability across all strata within the state.
Figure 22. Number of occupied white-tailed prairie dog colonies from 1977 to 2016 in Montana. This chart does not reflect changes in occupied acreage. This chart is created from data given in Knowles 2002 (p. 15), Seglund et al. 2006 (pp. 24-25), Montana Fish Wildlife and Parks 2009 (p. 1), and L. Hanauska-Brown (MFWP, pers. comm.). The number of colonies greatly decreased in 1997, but numbers have somewhat rebounded from that recorded low.

3.4.3 Stressors

The current conditions of stressors affecting the white-tailed prairie dog are provided in section 3.2 Stressors Affecting the Species’ Condition and Related Conservation Measures, which discussed sylvatic plague, drought, agricultural conversion, shooting, poisoning, overgrazing, invasive weeds, wildfire, urbanization, and energy development. We did not carry forward all of these stressors into our current condition analysis. A stressor was not considered in the current condition analysis if the magnitude of the stressor across the white-tailed prairie dog’s range is unknown, a negative effect of the stressor has never actually been quantified, or the stressor does not affect white-tailed prairie dogs at the species’ level (Table 11). For a stressor to have a negative effect on prairie dogs, both exposure and response must occur. In some cases, like overgrazing, we cannot estimate the level of exposure and/or response currently occurring, so we cannot generate an estimate of associated impacts to prairie dog populations. In other cases, like energy development, we can measure exposure (the cumulative footprints of oil and gas wells on the landscape), but evidence suggests white-tailed prairie dogs are relatively resilient to the stressor and do not exhibit a measureable negative response (Ceradini et al. 2017, entire; Hersey 2016, entire), so there is not likely to be an impact to prairie dog populations. We acknowledge
that some stressors likely have localized impacts within some prairie dog populations, but this SSA seeks to quantify the white-tailed prairie dog’s viability at the species’ level. While the effects of some stressors can be hypothesized, we are relying on the best available scientific data for our analysis (“Negative Response has been Quantified,” Table 11). Drought and plague were carried forward into our current condition analysis because the magnitudes of these stressors within the range of the white-tailed prairie dog are known, negative responses to these stressors have been quantified, and the stressors have species-level impacts. Impacts from the stressors that are not carried forward (agricultural conversion, shooting, poisoning, overgrazing, invasive weeds, wildfire, urbanization, and energy development) either have not been quantified or are not expected to have a measurable impact at the species-level, either individually or cumulatively.

Table 11. Consideration of stressors for inclusion in our current condition analysis for the white-tailed prairie dog. To be carried forward into our analysis, the magnitude of the stressor needs to be known, there needs to be a quantified negative response, and the negative response needs to be at the species’ level. The only stressors that meet all three of our criteria are plague and drought.

<table>
<thead>
<tr>
<th>Stressor</th>
<th>Magnitude of Stressor within WTPD range is Known</th>
<th>Negative Response has been Quantified</th>
<th>Species-Level Response</th>
<th>Stressor Carried Forward in Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plague</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Drought</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Agricultural Conversion</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Shooting</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Poisoning</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Overgrazing</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Invasive Weeds</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Wildfire</td>
<td>Yes*</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Urbanization</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Energy Development</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

*The magnitude of wildfire is not known specifically within the species’ gross or predicted ranges, but it is known within the states comprising the species’ range.

3.4.4 Analysis of Current Condition
In this section, we analyze the current conditions of individual white-tailed prairie dog populations as a way of assessing the species’ viability. For a white-tailed prairie dog population to be considered in high condition, it needs to meet the needs listed in Section 2.2 White-tailed Prairie Dog Needs. At the individual and population levels, these needs include friable soils, abundant succulent vegetation, high fecundity and juvenile survival, and connectivity between colonies (Table 1 in Section 2.2).

**Defining Populations and Analysis Units**

For the purposes of this SSA, we define a population of white-tailed prairie dogs as a complex of colonies with some barrier to dispersal or change in habitat type from adjoining complexes. Determining the spatial extent of populations for this species is difficult due to their low densities, shifting colony boundaries, and lack of empirical genetic or movement (dispersal, immigration) data. Historical and current monitoring data is not always based on biological population boundaries. For example, the strata used for occupancy surveys in Utah are based on administrative units and are not meant to denote biological populations (K. Hersey, UDWR, pers. comm.). Additionally, managers within a single state only collect monitoring data for a portion of a population that spans multiple states, such as the large complex that extends from southeast Utah to the Grand Junction area of Colorado (see Figure 6).

We used expert input and large-scale habitat information based on Level III and Level IV ecoregions (U. S. Fish and Wildlife Service 2017, pp. 10-11) to delineate three white-tailed prairie dog populations (Figure 23). Ecoregions are areas of similar ecosystems with comparable types, quality, and quantity of environmental resources, such as vegetation and soils. The Northern population is characterized by fairly dry sagebrush steppe and grassland habitats, and it encompasses all of the white-tailed prairie dog’s gross range in Wyoming and Montana as well as northeastern Utah and northwestern Colorado. The Southern population is separated from the Northern population by a line of escarpments (Level IV Ecoregion 20e; U. S. Environmental Protection Agency (EPA) 2013), which most likely represents a significant barrier to white-tailed prairie dog dispersal. This population includes colonies in southeast Utah and the Grand Junction area of Colorado and represents the driest portion of the prairie dog’s range (K. Hersey and A. Seglund, pers comm.). The North Park population in north central Colorado experiences higher precipitation than the other two populations and is characterized mostly by grassland parks and some sagebrush habitat. While the North Park population may exchange some individuals with the Northern population, there is a break in suitable habitat between the two, as evidenced by a gap in the species’ predicted range. Levels of connectivity within these populations have not been evaluated, but experts agree there is some level of dispersal/immigration at the population level.
Figure 23. The three white-tailed prairie dog populations used for analysis in this SSA. The species’ gross range is divided into the Northern, Southern, and North Park populations based on expert input and large-scale habitat information from Level III and Level IV ecoregions.

Because each state that participates in routine white-tailed prairie dog occupancy surveys uses a different sampling frame, occupancy data is not comparable across state lines. However, our populations do cross state lines. To allow for the utilization of this occupancy data to determine population trends, we subdivided each of the three biological populations based on state borders, resulting in nine analysis units (Figure 24). To maintain continuity within our analysis of current condition, we evaluated all of the factors pertaining to population condition (not just occupancy data) at this analysis unit level.
Acknowledgement of Uncertainty

The SSA framework requires us to assess a species’ biological status such that the analyses and information provided in this report could be used for a multitude of decisions and activities carried out under the authority of the Act (USFWS 2016, p. 7). In the case of the white-tailed prairie dog, we are called to evaluate the species’ status to inform the Service’s decision on whether to list the species as threatened or endangered. Describing the white-tailed prairie dog’s biological status, and ultimately its viability, is difficult because of the complex, and sometimes unknown, interactions among the stressors that may impact population resiliency. For example, the impacts of the relationship between plague and connectivity, or plague and precipitation, are intricate and still under study (see discussion in section 3.2.1 Sylvatic Plague). However, we must complete our analysis using the best available information, while acknowledging any key uncertainties or assumptions along the way.

Measuring Conditions of Analysis Units

For a white-tailed prairie dog population to be considered in high condition, it needs to meet the needs listed in Chapter 2 of this SSA. At the individual and population levels, we identified these needs as friable soils, abundant succulent vegetation, high fecundity and juvenile survival, and connectivity between colonies (Table 1 in Chapter 2). We originally sought to include all of
these variables in our analysis of current condition. However, after consulting with experts and taking into account data availability, we made some modifications to our analysis. While experts agreed that friable soils are an important need for prairie dogs, they stressed that no empirical studies have been completed analyzing specific types or amounts of soils that separate “good” and “bad” white-tailed prairie dog habitat. While connectivity is essential to maintaining prairie dog metapopulation dynamics, we do not have range-wide data that allows us to measure this factor. Because of the unreliable nature of colony mapping data (discussed in Section 3.4.2 Abundance), measuring distances between colonies within a complex is not a scientifically rigorous method for analyzing connectivity. Finally, no current, range-wide, demographic data measuring fecundity and/or juvenile survival rates have been collected for the white-tailed prairie dog.

Based on expert input and available data, we modified our analysis to more accurately reflect conditions that affect the white-tailed prairie dog and that are easily measurable for our current condition analysis (Table 12). We measured two factors that influence habitat (Precipitation Amount and Precipitation Variability) and one factor based on demographics (Population Trend). We classified each of our nine analysis units as being in “high,” “moderate,” or “low” condition for each of the three factors (Table 12). Populations that are in high condition are healthier and have higher resilience than lower condition populations, meaning they are less vulnerable to stochastic events.

The scientific literature and the experts we consulted with agree that precipitation is one of the main drivers of prairie dog population dynamics, influencing the availability and quality of vegetation as well as the incidence of plague (Facka et al. 2010, entire; Davidson et al. 2014, entire). Vegetation levels fluctuate with precipitation levels; in dry years there is less vegetation, and in wet years there is more vegetation. Habitats with more vegetation likely have higher prairie dog abundances or densities (Crocker-Bedford 1976, pp. 68-69; Hoogland 1981, p. 923; Facka et al. 2010, p. 1759; Davidson et al. 2014, p. 435). The overall impact of precipitation on plague is not well understood, which complicates our analysis. Increased precipitation can increase (Eads and Hoogland 2016, pp. 7-8; Eads et al. 2016, p. 1050) or decrease (Parmenter et al. 1999, pp. 816-817; Stapp et al. 2004, pp. 237-238; Snäll et al. 2008, pp. 244-245; Snäll et al. 2009, p. 501) the incidence of plague epizootics. Additionally, other colony characteristics like size and spacing also regulate plague dynamics (Stapp et al. 2004, pp. 237-238).

Because range-wide vegetation data is not available, we measured precipitation levels across the range in our current condition analysis as a surrogate for vegetation. Experts indicated that both the amount and variation of precipitation is important for prairie dog population health (Figures 25 and 26). Populations in drier environments will have less forage available than colonies in wetter environments, and prairie dogs likely occur in lower densities in these dry areas (Crocker-Bedford 1976, pp. 68-69). Additionally, populations subjected to large swings in annual precipitation, and thus vegetation, may be more stressed than those adapted to an environment
with a fairly stable forage base (even if that forage base is low). By quantifying precipitation amount and variability, we can assess the effects of drought, one of the stressors we identified that impacts white-tailed prairie dog viability, on population condition. Although the interactions of plague and precipitation complicate our analysis of the white-tailed prairie dog’s current condition based on our two habitat factors (Precipitation Amount and Variability), our overall goal is to measure these factors as a proxy for vegetation and thus, habitat health. We made a few key assumptions for this analysis: 1) precipitation data is a good proxy for vegetation data, 2) prairie dog populations that experience higher precipitation during the active season are in higher condition than those exposed to low precipitation, and 3) prairie dog populations that experience high variability in precipitation from year to year are in lower condition than those that experience more stable annual precipitation levels. The validity of our assumptions is strengthened by the results from recent research on black-tailed prairie dogs and Gunnison’s prairie dogs in highly variable environments (Facka et al. 2010, entire; Davidson et al. 2014, entire). In both of these studies, population dynamics were greatly affected by annual precipitation levels, and populations crashed in years of low precipitation (Facka et al. 2010, pp. 1755-1758; Davidson et al. 2014, pp. 434-435).

To measure precipitation amount, we calculated monthly average precipitation values for March to October (the white-tailed prairie dog’s active season) from 2000 to 2015 for each analysis unit using DayMet data (Oak Ridge National Laboratory Distributed Active Archive Center, https://daymet.ornl.gov/). For comparison, we looked at long-term (1895 to 2016) precipitation averages from March to October for each of the four states within the gross range of the white-tailed prairie dog (National Oceanic and Atmospheric Administration National Centers for Environmental Information, https://www.ncdc.noaa.gov/cag/). Both of the precipitation datasets we used are synthesized from observed weather station data; Daymet data has a one kilometer resolution, and the NOAA data has a five kilometer resolution (Oak Ridge National Laboratory Distributed Active Archive Center, https://daymet.ornl.gov/overview.html; National Oceanic and Atmospheric Administration National Centers for Environmental Information, https://www.ncdc.noaa.gov/monitoring-references/maps/us-climate-divisions.php). Average monthly precipitation values for the long-term, 122 year period ranged from 13.8 millimeters (mm) per month (Utah) to 68.8 mm per month (Colorado), with an overall average of 38.2 mm per month. We classified analysis units with average monthly precipitation values within two standard deviations of the overall long-term mean across all states (between 27.2 mm and 49.2 mm per month) as “moderate” condition. Analysis units with values above and below two standard deviations of the mean were classified as “high” or “low” condition, respectively. In other words, we sought to tease out “outlier” areas where analysis units may have more or less forage available than an average population. Using two standard deviations from the long-term precipitation mean also represents a conservative analysis because the data used for our long-term precipitation average are at a state-wide scale. This may have caused our long-term precipitation average to be biased high since the data include areas outside the prairie dog’s gross range that may experience more
precipitation, such as eastern Wyoming. Using two standard deviations from the mean as the metric for our categories helped alleviate this problem by preventing the artificial classification of analysis units as low when they represent normal precipitation levels for white-tailed prairie dog habitat in biological reality.

Figure 25. Average precipitation levels across the gross range of the white-tailed prairie dog, calculated from March to October (the white-tailed prairie dog’s active season), 2000 to 2015. Precipitation averages ranged from 13.7 to 95.5 mm per eight month period. Based on a histogram of the values, we truncated the data at 65 mm because outlying high values were driving the stretch function used to create the color range (low to high precipitation) for the map. This was done for display purposes only, and high values were not truncated from our analysis of current condition.

We assessed precipitation variability by assessing how often an analysis unit’s average monthly precipitation values deviated from that analysis unit’s rating for Precipitation Amount condition (low, moderate, or high), known as the “home category.” The more times that average monthly precipitation deviated from the home category, the lower the precipitation variability condition (see Figure 27 for an example). In other words, higher precipitation variability leads to lower prairie dog population resilience and thus, a lower Precipitation Variability condition for the population. In this analysis, we are assuming that more variability in precipitation has a negative effect on vegetation availability, and thus a negative effect on the resiliency of our analysis units (see reasoning above). Populations of white-tailed prairie dogs subjected to large swings in
annual precipitation, and thus vegetation, may be more stressed than those adapted to an environment with a fairly stable forage base (even if that forage base is low).

Figure 26. Variation in precipitation levels (standard deviation from the mean) across the range of the white-tailed prairie dog, calculated from March to October (the white-tailed prairie dog’s active season), 2000 to 2015. Variation in precipitation ranged from 4.1 to 38.7 mm around the mean. Based on a histogram of the values, we truncated the data at 16 mm because outlying high values were driving the stretch function used to create the color range (low to high variation) for the map. This was done for display purposes only, and high values were not truncated from our analysis of current condition.

The effects of plague, one of the main stressors driving white-tailed prairie dog population resiliency, are captured in our assessment of population trends. White-tailed prairie dog populations can exhibit dramatic fluctuations in abundance from year to year, a phenomenon that is likely a result of plague epizootics (Cully and Williams 2001, p. 895; Seglund et al. 2006, pp. 7-8). Plague has also resulted in the white-tailed prairie dog exhibiting a metapopulation structure with colonies “winking in and out” as they are extirpated by plague and subsequently recolonized (Cully and Williams 2001, p. 902; Knowles 2002, p. 18, 20; George et al. 2013, p. 1573). Populations that have high variability in abundance, such as those with colonies continually affected by plague epizootics, are less resilient and more vulnerable to stochastic events than those with more stable population trends.
Figure 27. Average monthly precipitation values from March to October (the white-tailed prairie dog’s active season), 2000 to 2015 in the Montana analysis unit. Horizontal red lines represent two standard deviations from the overall long-term mean across all states (27.2 mm, 49.2 mm). Montana has one value in high condition, one value in low condition, and 14 values in moderate condition for the Precipitation Amount category, suggesting precipitation in this area does not fluctuate much. The Montana analysis unit is in “moderate” condition for Precipitation Amount, so the analysis unit’s “home category” for our assessment of Precipitation Variability is moderate (Table 12). Only two values fall outside of this category. Therefore, Montana is in “high” Precipitation Variability condition based on our criteria in Table 12.

We assessed Population Trend condition, or the increase or decrease of abundance within an analysis unit through time, using recent occupancy data (Table 10) and expert opinion. Populations with stable or increasing abundance trends have higher resilience to stochastic events than those with declining trends. Therefore, analysis units that exhibit stable or increasing population trends are in high condition. Some populations have shown declines in the past due to plague or other stressors, but they have also demonstrated resiliency and shown evidence of recovery. Analysis units with these trends are not as resilient as those with stable or increasing population trends, but they are not at high risk of extirpation like a population with steadily declining abundance estimates. When using occupancy data, we defined a stable population trend as overlapping confidence intervals for all occupancy estimates through time. When data of this type was not available for a certain analysis unit, we asked local experts to categorize the Population Trend condition of the analysis unit based on our criteria in Table 12.
Table 12. Conditions category table outlining the criteria for ranking populations as low, medium or high condition for specific habitat and demographic factors important for the resiliency of white-tailed prairie dog populations. For our analysis, average monthly precipitation is from March to October (the white-tailed prairie dog’s active season), 2000 to 2015.

<table>
<thead>
<tr>
<th>Analysis Unit Condition</th>
<th>Precipitation Amount</th>
<th>Precipitation Variability</th>
<th>Population Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Average monthly precipitation is greater than or equal to 49.2 millimeters</td>
<td>Precipitation levels exhibit low variability; 2 or fewer average annual precipitation values fall outside of the home category for Precipitation Amount</td>
<td>Population exhibits a stable or increasing trend</td>
</tr>
<tr>
<td>Moderate</td>
<td>Average monthly precipitation is between 27.2 and 49.2 millimeters</td>
<td>Precipitation levels exhibit moderate variability; 3 to 6 average annual precipitation values fall outside of the home category for Precipitation Amount</td>
<td>Population exhibits a slight decline; At least one sampling period shows a significant decline, but also evidence of recovery</td>
</tr>
<tr>
<td>Low</td>
<td>Average monthly precipitation is below 27.2 millimeters</td>
<td>Precipitation levels exhibit high variability; More than 6 average annual precipitation values fall outside of the home category for Precipitation Amount</td>
<td>Population exhibits a consistent, substantial decline</td>
</tr>
</tbody>
</table>
Calculating Final Condition Scores for Analysis Units

The criteria presented in our conditions category table (Table 12) were used to determine the overall current condition of each white-tailed prairie dog analysis unit (Table 13). The habitat and demographic factors (Precipitation Amount, Precipitation Variability, and Population Trend) included in Table 13 were not weighted equally in this analysis. In our opinion, as well as those of our species experts, an analysis unit’s population trend is the most important piece of information for determining its resiliency. Population trend information synthesizes multiple factors affecting the species’ condition, including precipitation and other things that we cannot directly measure, or those we may not have even identified. Nonetheless, we feel that it is still important to specifically include habitat factors like precipitation if the information is available to do so because there is a strong link between such factors and population dynamics for other prairie dog species (Facka et al. 2010, entire; Davidson et al. 2014, entire). Moreover, habitat factors like precipitation may change in predictable ways and can therefore be used to estimate future conditions in ways that population trends cannot (see Chapter 4. Future Condition).

For our determination of overall condition for each analysis unit, we decided population trend is twice as important as the combined effects of our two precipitation categories. Additionally, there is a more direct link between average precipitation and prairie dog population dynamics than precipitation variability, so we decided to give it more weight in our analyses. Relative weights were assigned to each factor to maintain these relationships: 3x for Population Trend, 1x for Precipitation Amount, and 0.5x for Precipitation Variability. This means population trend carries twice the weight of precipitation: a ratio of 3 to 1.5. Each analysis unit was given a numeric score relative to Precipitation Amount, Precipitation Variability, and Population Trend: 1 for low condition, 2 for moderate condition, and 3 for high condition. An analysis unit’s overall condition score was then calculated as the sum of all the factor scores multiplied by their relative weights (Figure 28).

This overall condition score must then be translated into an overall current condition category of low, moderate, or high. An analysis unit with all low, all moderate, or all high ratings for the three factors would have overall conditions scores of 4.5, 9.0, or 13.5 respectively. We took the difference between the lowest and highest possible overall condition scores (13.5 – 4.5 = 9) and divided this into three equal intervals representing the breadth of possible scores. A score of 4.5 to 7.5 means the analysis unit is in overall low condition, 7.5 to 10.5 is in overall moderate condition, and 10.5 to 13.5 is in overall high condition. In the case where an analysis unit’s overall score fell on the cusp of two overall condition categories, such as having an overall score of 7.5, we acted conservatively and rated the analysis unit as being in the lower overall condition category.
Figure 28. Example of calculating the overall current condition score for the Montana analysis unit. Montana is in moderate condition for Precipitation Amount, high condition for Precipitation Variability, and moderate condition for Population Trend. This results in an overall condition score of 9.5, which is moderate. This can be interpreted to mean the Montana analysis unit is more vulnerable to stochastic events than some other analysis units, but its population trends and precipitation characteristics impart some resilience to this analysis unit. If an analysis unit’s overall current condition score falls on the cusp of two overall condition categories, such as a score of 7.5, the analysis unit will be in the lower overall condition category.
Table 13. Current condition table rating analysis units as low, moderate, or high condition based on three habitat and demographic factors: Precipitation Amount, Precipitation Variability, and Population Trend. Condition ratings are based on the categories given in Table 12 (conditions category table). The three habitat and demographic factors were not weighted equally in our determination of overall current condition, as explained in Section 3.4.4 Analysis of Current Condition by Population, Calculating Final Conditions Scores for Analysis Units and are represented by the numbers in parentheses in the title of each factor.

<table>
<thead>
<tr>
<th>Population</th>
<th>Analysis Unit</th>
<th>Precipitation Amount Condition (1x)</th>
<th>Precipitation Variability Condition (0.5x)</th>
<th>Population Trend Condition (3x)</th>
<th>Overall Current Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Montana</td>
<td>Moderate</td>
<td>High</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Wyoming</td>
<td>Moderate</td>
<td>Moderate</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Northern Utah</td>
<td>Moderate</td>
<td>Moderate</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>North Central Colorado</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Northeast Utah</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Northwest Colorado</td>
<td>Moderate</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>North Park</td>
<td>North Park</td>
<td>Moderate</td>
<td>Low</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Southern</td>
<td>Southeast Utah</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Grand Junction</td>
<td>Moderate</td>
<td>Moderate</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>
3.5 Synopsis of Historical and Current Conditions

According to our basic analysis of relevant factors, the white-tailed prairie dog currently has six analysis units in overall high condition and three analysis units in overall moderate condition across its range (Figure 29). If we extrapolate these results to the population level, the Northern and Southern populations are in moderate to high condition, and the North Park population is in moderate condition (Table 13). While habitat factors (Precipitation Amount and Variability) vary from low to high condition among analysis units, population trends are stable or exhibit some declines and recovery from stochastic events (Table 13). Despite the potential for multiple stressors to act on specific populations (listed in Table 11 and described in 3.2 Stressors Affecting the Species’ Condition and Related Conservation Measures), the overall moderate to high current conditions of populations, taking into account both habitat and demographic factors, indicate that these stressors are not cumulatively impacting the white-tailed prairie dog at the species’ level. Our analysis suggests the white-tailed prairie dog subsists within an array of habitat conditions across its range including drier areas, wetter areas, and somewhat...
unpredictable environments, but populations currently exhibit resiliency to this variation and do not suffer from protracted declines.

Populations of white-tailed prairie dogs continue to be distributed throughout the species’ historical geographic range, thus exhibiting redundancy. There are no known genetic or morphological differences between the animals in these analysis units, but white-tailed prairie dogs do appear to be adapted to a range of environmental conditions. For example, the Northeast Utah analysis unit experiences low amounts of annual precipitation which may lead to lower quality vegetation, but the population trend is stable and the analysis unit is in overall high condition. White-tailed prairie dogs in the North Central Colorado analysis unit may experience more plague exposure due to their wetter habitat that favors fleas, but population trends are stable despite stochastic events like plague epizootics. This infers that white-tailed prairie dog populations currently exhibit representation and may have the ability to adapt to changing environmental and biological conditions.

It is important for us to note that we do not believe the white-tailed prairie dog’s current condition as a species is a direct result of any ongoing conservation measures. While measures to combat plague, such as dusting and SPV, certainly have effects at the colony level, the limited spatial scope of these measures likely does not increase resilience at the species, or even population, level. However, if a larger portion of the prairie dog’s range did receive these conservation measures, it is possible this could positively impact the viability of the species. For example, a Population Viability Analysis found that a moderate reduction in plague epizootics, such as what could potentially be provided by dusting or SPV, dramatically reduced the extinction risk of white-tailed prairie dog populations in Colorado (Seglund and Schnurr 2010, pp. 111-112).

Chapter 4. Future Condition

In this chapter, we predict the future conditions of the nine white-tailed prairie dog analysis units under five potential scenarios of changes in stressors, in part due to climate change, and conservation efforts. This analysis will help us predict how viability of the white-tailed prairie dog may change in the future.

4.1 Climate Change

Greenhouse gas (GHG) emissions increased at an unprecedented rate during the 20th century, resulting in global climate change characterized by warming atmospheric and ocean temperatures, diminishing snow and ice, and rising sea levels (Intergovernmental Panel on Climate Change (IPCC) 2014, pp. 2-3). Scientists use a variety of climate models, which include consideration of natural processes and variability, as well as various scenarios of potential levels and timing of GHG emissions, to evaluate the causes of changes already observed and to project
future changes in temperature and other climate conditions (e.g., Meehl et al. 2007, entire; Ganguly et al. 2009, pp. 11555, 15558; Prinn et al. 2011, pp. 527, 529). Combinations of models and emissions scenarios yield very similar projections of increases in the most common measure of climate change, average global surface temperature (commonly known as global warming), until about 2030. Although projections of the magnitude and rate of warming differ after about 2030, the overall trajectory of all the projections is one of increased global warming through the end of this century, even for the projections based on scenarios that assume that GHG emissions will stabilize or decline. There is strong scientific support from projections that warming will continue through the 21st century, and that the magnitude and rate of this change will be influenced substantially by the extent of GHG emissions (IPCC 2014, p. 8; Meehl et al. 2007, pp. 760–764 and 797-811; Ganguly et al. 2009, pp. 15555–15558; Prinn et al. 2011, pp. 527, 529).

It is important for us to acknowledge any potential effects of climate change in our analysis of the future condition of the white-tailed prairie dog. To do this, we used climate change data from the USGS’ National Climate Change Viewer (NCCV), which averages the results of 33 global climate change (GCM) models and provides predictions for two GHG emissions scenarios (RCP4.5, RCP8.5) at three future time periods (2025 to 2049, 2050 to 2074, 2075 to 2099) (USGS 2017, p. 3). It is well accepted that using an ensemble of GCMs (like the NCCV) for predictions is a better approach than relying on results from a single GCM (Bradley 2009, pp. 204-205; Snäll et al. 2009, p. 501, and references within). In the NCCV, GCM projections can be down-scaled to the U. S. county level for more refined analyses. The two GHG emissions scenarios used in the NCCV come from the latest IPCC report. RCP4.5 is an intermediate emissions scenario where atmospheric CO₂ concentrations are expected to equal approximately 650 ppm after the year 2100. In RCP8.5, emissions aggressively increase to approximately 1370 ppm CO₂ after the year 2100 (IPCC 2014, p. 57; USGS 2017, p. 3). For comparison, current atmospheric CO₂ concentrations are around 400 ppm (USGS 2017, p. 3). The NCCV provides estimates of error and precision for its projections, such as standard deviations and the level of agreement between GCMs (USGS 2017, pp. 3-8). The reference period for changes in climate variables is 1981-2010 (USGS 2017, p. 4). NCCV predictions of future climate in the four states forming the white-tailed prairie dog’s range are summarized in USGS 2016b (entire), USGS 2016c (entire), USGS 2016d (entire), and USGS 2016e (entire).

We amassed NCCV model predictions down-scaled to the county level within the white-tailed prairie dog’s predicted range. Since the uncertainty of future climate response to global warming increases with time from the present (see Figure 2.1 in IPCC 2014, p. 59), we did not include the longest time frame provided by the NCCV models in our analysis and conservatively capped our predictions at approximately 60 years into the future. This still allows us to evaluate changes during two of the time periods provided by the NCVV models, approximately 30 years (2025 to 2049) and 60 years (2050 to 2074) into the future. We used different emissions scenarios depending on the parameters set forth in each of our future scenarios (see Section 4.2.3 Descriptions of Future Scenarios). This represents a more refined evaluation than the state-
wide summaries provided by USGS (USGS 2016b-e). Across all of our future climate scenarios, mean annual maximum temperature is expected to increase through time, with the magnitude of the increase amplified under the RCP8.5 emissions scenario (range: 2 to 6 degrees Fahrenheit or approximately 1 to 3 degrees Celsius). In general, precipitation in March and April is expected to increase across the prairie dog’s range under both emissions scenarios. This effect is magnified through time, with increased precipitation also predicted in January and February after 2050. The exception is Colorado, with different counties showing expected increases or decreases in April precipitation. A large portion of the prairie dog’s range is expected to experience decreased summer precipitation. The exception is Utah, which sees increased July and August precipitation under both RCP4.5 and RCP8.5 emissions scenarios after 2050. Differences in precipitation range from 0 to 0.7 in (0 to 18 mm) per month for these different projections. According to these models, the increase in spring precipitation is expected to override the decrease in summer precipitation, resulting in a slight increase in mean annual precipitation for all emissions scenarios across the white-tailed prairie dog’s range. Across the species’ range, snow water equivalent and soil water storage are expected to decrease, and evaporative deficit is expected to increase. Evaporative deficit is the difference between water available in the soil and water lost to evapotranspiration. As evaporative deficit increases, the landscape becomes drier, and drought conditions increase.

Many climate change experts warn that relying on precipitation values alone does not give a complete picture of the future effects of climate change. The effects of increased temperature and precipitation can confound each other, and the effects of increased temperature dominate increased precipitation in some climate models (Stewart et al. 2004, p. 224). As temperatures warm, so does evaporation, sometimes negating the effects of increased precipitation. This, along with decreased winter snowpack, explains the expected decrease in soil moisture and increase in evaporative deficit within the white-tailed prairie dog’s range in the future. All of these effects lead us to conclude that, at a range-wide scale, white-tailed prairie dog habitat may be drier in the future due to climate change (Stewart et al. 2004, p. 230; Dai 2011, p. 59). This effect would likely be amplified under higher levels of GHG emissions (USGS 2016). We relied on measures of evaporative deficit instead of annual precipitation for our predictions of drought conditions that may affect viability of the white-tailed prairie dog in the future.

4.2 Analysis of Future Condition

4.2.1 Acknowledgement of Uncertainty

Climate models have great utility because they allow us to make predictions of how climate may change in the future, but their results should be interpreted cautiously. Models are mathematical representations of what can happen, but they do not always accurately predict future events. Climate models have greatly improved in recent years, but projections for precipitation remain less reliable than those for surface temperature (O’Gorman and Schneider 2009, p. 14744;
Trenberth 2011, p. 133; IPCC 2014, p. 56). For our analysis of the white-tailed prairie dog’s future condition, we acknowledge the innate uncertainty associated with climate modeling. We also recognize these models represent some of the best available scientific data we can utilize for predicting the species’ future condition.

Several studies have predicted an increase in precipitation variability in the future due to the effects of climate change, in the form of more frequent extreme precipitation events (O’Gorman and Schneider 2009, p. 14744; Trenberth 2011, p. 123; IPCC 2014, p. 60). Models more accurately predict this change in the mid latitudes outside of the tropics, including North America (O’Gorman and Schneider 2009, p. 14776). An increase in extreme precipitation events does not equate to a wetter environment, as this escalation is countered by increased temperatures and evapotranspiration (Trenberth 2011, p. 129). Rather, this represents a redistribution of annual precipitation that actually leads to a drier landscape (Trenberth 2011, pp. 123, 129, 130, 133). While we have good evidence of increased precipitation variability in the future, we do not have a metric for estimating the magnitude of this increase. Because of this, we used conservative judgment and required a relatively large increase in precipitation variability to shift an analysis unit into a lower condition in the future.

There are also uncertainties associated with the efficacy of conservation efforts in the future. Because of the relatively small area of the white-tailed prairie dog’s predicted range that is currently being dusted or treated with SPV to combat plague, we do not believe the species’ current condition is contingent upon current conservation measures. Recent research shows that SPV can protect colonies from plague, but this protection is likely dependent on vaccination timing and uptake rates as well as the vaccination status of neighboring colonies (Rocke et al. 2017, pp. 9-11). This means a large-scale, coordinated vaccination or vaccination and dusting effort would be necessary to protect the species as a whole. In one of our future scenarios, we assumed that a large, targeted increase in these efforts could have effects at the population level, which is supported by the positive results from studies at smaller scales (Biggins et al. 2010, p. 21; Seglund and Schnurr 2010, pp. 111-112; Rocke et al. 2017, p. 7; Tripp et al. 2017, pp. 14-16). If this assumption is correct, greater implementation of these conservation efforts across the range of the white-tailed prairie dog would have the potential to make populations, and ultimately the species as a whole, more resilient, thereby safeguarding the species’ current redundancy and representation.

4.2.2 Stressors

Climate change, among other factors, has the potential to change the magnitude of some stressors that may impact white-tailed prairie dog population resilience in the future (Table 14). Rather than including climate change as a separate stressor in our scenarios for evaluating the white-tailed prairie dog’s future condition, we incorporated it throughout our analysis by assessing the potential influence of climate change scenarios on plague and drought, which were selected as
the principal components of our analysis using the same reasoning as in our current condition analysis (see Section 3.4.3 Stressors). While some stressors may increase in magnitude in the future (Table 14), similar to current condition (see Section 3.5 Synopsis of Historical and Current Conditions), we have no reason to believe any stressors other than drought or plague would singularly or cumulatively affect the species-level status of the white-tailed prairie dog in the future. Having good, current information on the impacts of drought and plague on the resiliency of white-tailed prairie dog populations means we are better able to predict, with less uncertainty, how these stressors may impact the viability of the white-tailed prairie dog in the future.

For our future condition analysis, we looked at how future climate change may affect levels of drought and plague through changes in precipitation. Changes in these stressors could then impact Precipitation Amount, Precipitation Variability, and Population Trend, the three categories measured in our current condition analysis. Climate change effects in the western United States are expected to include increased temperatures, decreased snowpack, earlier snowmelt, higher wildfire risk, decreased soil moisture, and increasingly severe droughts (Semtner 2004, pp. 6-7; Stewart et al. 2004, pp. 223-224; Abatzoglou and Kolden 2011, p. 474; Dai 2011, p. 57; IPCC 2014, p. 52). Reduced and/or more variable precipitation may reduce the quality or quantity of vegetation available on prairie dog colonies, leading to population declines (Facka et al. 2010, p. 1759; Davidson et al. 2014, pp. 434-435). Climate change also has the potential to increase invasions of invasive weeds like cheatgrass, with some scenarios predicting relatively large increases within the states comprising the white-tailed prairie dog’s gross range (Bradley 2009, p. 202; Abatzoglou and Kolden 2011, p. 475). Increased drought due to climate change could affect the quality and quantity of vegetation available to prairie dogs, thus impacting population resiliency.

Future changes in precipitation due to climate change may impact plague dynamics (Parmenter et al. 1999, pp. 816-817; Collinge et al. 2005, p. 7; Stapp et al. 2004, p. 237; Snäll et al. 2008, p. 245; Eads and Hoogland 2016, pp. 7-8; Eads et al. 2016, pp. 1050-1051), which would manifest in our Population Trend category. Unfortunately, the direction of this impact (positive or negative) is difficult to predict. Increased precipitation in April through July of the preceding year and a decrease in the number of hot days (>29.4 degrees Celsius) during the focal year have been found to increase plague transmission between colonies of black-tailed prairie dogs, meaning plague risk may be higher in wet years (Collinge et al. 2005, p. 7; Snäll et al. 2008, p. 245; Snäll et al. 2009, p. 501). One biological model, operating under the assumption that decreased precipitation will decrease plague transmission, predicted lower levels of plague in black-tailed prairie dog colonies in Montana in the future (Snäll et al. 2009, pp. 504-505). High levels of predicted global warming, similar to the current standard emissions scenario of RCP8.5, led to the largest decrease in plague transmission in the model (Snäll et al. 2009, pp. 504-505; IPCC 2014, p. 57). In contrast, other researchers have hypothesized that dry periods and higher temperatures may actually increase plague risk by increasing flea loads on prairie dogs in poor
body condition (Eads et al. 2016, pp. 1046-1047). Spring precipitation and summertime
temperatures are both expected to increase throughout the white-tailed prairie dog’s range under
various climate change scenarios (U. S. Geological Survey (USGS) 2016). The possible
interaction and unknown relative contributions of temperature and precipitation make predicting
future plague risk very difficult. Ultimately, a better understanding of the complex interplay of
annual precipitation variability over multiple years, primary productivity, and prairie dog
densities may be needed to predict future vulnerability of populations to plague epizootics (Eads
and Biggins 2017, pp. 12-13).
Table 14. Possible future changes in the magnitudes of stressors that may impact white-tailed prairie dog population resiliency. Entries with an asterisk (*) in the Possible Future Changes column represent stressors that are predicted to change in response to climate change. Like in our current condition analysis, we only assessed changes in drought and plague in our future condition scenarios.

<table>
<thead>
<tr>
<th>Stressor</th>
<th>Possible Future Changes</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plague</td>
<td>May increase or decrease*</td>
<td>Eads et al. 2016, pp. 1050-1051; Snäll et al. pp. 504-505</td>
</tr>
<tr>
<td>Drought</td>
<td>May increase*</td>
<td>Semtner 2004, p. 6; Stewart et al. 2004, p. 230; Dai 2011, pp. 57-59; USGS 2016</td>
</tr>
<tr>
<td>Agricultural Conversion</td>
<td>May increase or decrease*</td>
<td>Lawler et al. 2014, p. 7493</td>
</tr>
<tr>
<td>Shooting</td>
<td>Unknown</td>
<td></td>
</tr>
<tr>
<td>Poisoning</td>
<td>Unknown</td>
<td></td>
</tr>
<tr>
<td>Overgrazing</td>
<td>Unknown</td>
<td></td>
</tr>
<tr>
<td>Wildfire</td>
<td>May increase*</td>
<td>Semtner 2004, p. 7; Abatzoglou and Kolden 2011, p. 474</td>
</tr>
<tr>
<td>Energy Development</td>
<td>May increase</td>
<td>U. S. Energy Information Administration 2017, pp. 11-14</td>
</tr>
</tbody>
</table>

*a Models predict losses of rangeland and pasturelands, but cropland may increase in response to growing global food demands.
4.2.3 Descriptions of Future Scenarios

For our analysis of the white-tailed prairie dog’s future condition, we constructed five future scenarios focused on changes in stressors and levels of conservation efforts (Table 15). These scenarios are meant to cover a large breadth of future conditions that could occur in the white-tailed prairie dog’s range, and all scenarios may not be equally plausible. To analyze future condition, we projected each scenario to two time periods in our analysis of future condition, 30 years and 60 years from now, corresponding to our climate models.

**Scenario 1**

In Scenario 1, plague outbreaks decrease in magnitude and frequency in response to more frequent, prolonged droughts. A key assumption of this scenario is that the plague dynamics of white-tailed prairie dog populations will respond to climate change in the same way predicted for black-tailed prairie dogs in Snäll 2009 (entire): plague decreases with increased global warming (emissions scenario RCP8.5) because of decreased primary productivity and fewer flea vectors (Snäll et al. 2009, pp. 504-505; IPCC 2014, p. 57). For continuity, we used projected changes in evaporative deficit under RCP8.5 to estimate the effects of increased drought on the habitat factors evaluated for each of our analysis units. We assumed decreased plague would have large positive effects on population trends, but that increased drought would negatively affect prairie dog abundance in the long term because of decreased forage. We believe this assumption is reasonable because even though release from plague would impact populations in a very positive way, severe drought has been implicated in prairie dog population crashes independent of plague (Facka et al. 2010, entire; Davidson et al. 2014, entire). In this scenario, conservation efforts like monitoring, dusting, and SPV distribution continue at their current levels.

**Scenario 2**

Scenario 2 can be considered a continuation of current conditions. Droughts and plague outbreaks continue at their current frequency and intensity, and the level of annual GHG emissions does not change considerably from the current level. Conservation efforts continue at their current levels.

**Scenario 3**

In Scenario 3, drought increases in duration and frequency under GHG emissions scenario RCP4.5, but plague outbreaks continue at their current magnitude and frequency. We created this scenario to capture some of the uncertainty in the predicted interaction between climate change and plague, as discussed in Section 4.2.2 Stressors. In other words, this scenario represents a future where increased drought does not influence plague dynamics. Conservation efforts continue at their current levels.
**Scenario 4**

Scenario 4 represents a pessimistic future scenario in which both drought and plague conditions worsen. Drought increases in duration and frequency range-wide under emissions scenario RCP4.5, and plague outbreaks increase in magnitude and frequency (Eads and Hoogland 2016, pp. 7-8; Eads et al. 2016, pp. 1050-1051). Because we have no reason to believe conservation efforts would ever be completely suspended (which would create the most pessimistic outlook possible), they continue at current levels. This scenario allows us to evaluate how the conditions of the analysis units may change in response to severely degraded conditions.

**Scenario 5**

Scenario 5 details a future where additional conservation efforts are implemented to counteract increasing stressors. As in Scenario 4, droughts and plague increase in severity. However, managers respond by increasing conservation efforts like dusting, monitoring, and SPV distribution. Management actions are targeted to where they are most needed using the most effective timing and methods, such as dusting burrows in the fall, using SPV in conjunction with dusting, and vigilantly monitoring populations for epizootics (Antolin et al. 2002, p. 122; Tripp et al. 2016 pp. 556, 559-560). A key assumption of this scenario is that an increase in targeted conservation efforts will have significant, positive effects on population trends that counteract the effects of increased plague and drought. This assumption is supported by the results of small-scale studies that found plague control efforts can greatly improve prairie dog survival and colony persistence (Biggins et al. 2010, p. 21; Seglund and Schnurr 2010, pp. 111-112; Rocke et al. 2017, p. 7; Tripp et al. 2017, pp. 14-16). This scenario allows us to evaluate the extent to which intense conservation efforts could change the conditions of analysis units affected by the circumstances presented in Scenario 4.
Table 15. Five scenarios used for predicting the future condition of the white-tailed prairie dog in this SSA. The IPCC emissions scenario used for evaluating each future scenario are included in parentheses below the scenario titles.

<table>
<thead>
<tr>
<th>Scenario 1  (RCP8.5)</th>
<th>Scenario 2  (no drastic change from current emissions rates)</th>
<th>Scenario 3  (RCP4.5)</th>
<th>Scenario 4  (RCP4.5)</th>
<th>Scenario 5  (RCP4.5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drought increases in duration and frequency range-wide</td>
<td>Drought is relatively stable compared to current levels</td>
<td>Drought increases in duration and frequency range-wide</td>
<td>Drought increases in duration and frequency range-wide</td>
<td>Drought increases in duration and frequency range-wide</td>
</tr>
<tr>
<td>Plague outbreaks decrease in magnitude and frequency</td>
<td>Plague outbreaks continue at their current magnitude and frequency</td>
<td>Plague outbreaks continue at their current magnitude and frequency</td>
<td>Plague outbreaks increase in magnitude and frequency</td>
<td>Plague outbreaks increase in magnitude and frequency</td>
</tr>
<tr>
<td>Conservation efforts continue at current levels</td>
<td>Conservation efforts continue at current levels</td>
<td>Conservation efforts continue at current levels</td>
<td>Conservation efforts continue at current levels</td>
<td>Conservation efforts increase from current levels in response to increased plague and drought; management actions are targeted to where they are most needed using the most effective timing and methods</td>
</tr>
</tbody>
</table>
4.2.4 Predicting Future Condition

We predicted the future conditions of each analysis unit based on the variations of drought, plague, and conservation efforts specified in our future scenarios. Specifically, we predicted changes in the three habitat and demographic factors measured in our current condition analysis. We assessed changes in drought by looking at future predictions of evaporative deficit in each of the analysis units using the scaled-down climate models described in Section 4.1 Climate Change. Evaporative deficit data was only analyzed for the months of March through October to ensure correspondence with our precipitation data. As described earlier, evaporative deficit is a better predictor of future drought conditions than precipitation levels alone. Evaporative deficit is not directly comparable to our current condition precipitation data, and we cannot simply predict future Precipitation Amount condition by subtracting evaporative deficit from our current precipitation data. Because of this, we had to make qualitative assessments of how Precipitation Amount may change in the future based on our expert judgement. In our assessment of future condition, analysis units with large evaporative deficits (compared to other values in the dataset) that are on the cusp of two Precipitation Amount categories were moved into lower Precipitation Amount condition under some of the future scenarios. This method has the potential to overestimate or underestimate the effects of future drought on our habitat and demographic factors, but it represents our use of the best available scientific information. Even though this represents a rather qualitative assessment, it still highlights relative differences between analysis units that may help managers target conservation efforts in the future.

Although it is widely accepted that precipitation will become more variable in the future under climate change, we have no quantitative information on changes in precipitation variability. In light of this uncertainty, and the lower weight given to Precipitation Variability condition in our quantification of overall condition, we acted conservatively and only decreased Precipitation Variability condition under high emissions scenarios for analysis units that are on the cusp of two Precipitation Variability categories under some of our future scenarios. This means we may be underestimating the effects of increased precipitation variability on the resiliency of white-tailed prairie dog populations in the future.

We assessed future changes in Population Trend condition mainly by evaluating changes in the level of plague outlined in each scenario. Because plague is the major driver of white-tailed prairie dog population dynamics, we liberally projected changes in Population Trend condition due to increases or decreases in plague. In extreme scenarios, such as a high emissions scenario at the longer time point, we also projected that abundance could suffer due to increased drought and decreased forage. Again, this represents a qualitative assessment based on our expert judgement, and we may be overestimating or underestimating the true effects these changes may have on white-tailed prairie dog population resiliency in the future.
We weighted each of the habitat and demographic factors in our future condition analysis the same way as in our current condition analysis (see explanation in Section 3.4.4 Analysis of Current Condition, Calculating Final Condition Scores for Analysis Units and Figure 28). Population Trend condition is twice as important as Precipitation Amount and Precipitation Variability for determining future population condition (resiliency).

4.2.5 Results of Future Condition Analysis

In this section, we present the results of our future condition analysis under five scenarios, 30 and 60 years into the future. Full tables with results for each habitat and demographic factor, under each scenario, at each time point, are included in Appendix B.

Results: Scenario 1

The largest drops in Precipitation Amount condition are seen in Scenario 1 as high levels of GHG emissions under RCP8.5 lead to an increasing evaporative deficit across the white-tailed prairie dog’s range that increases over time. We predict this trend could cause three analysis units to be in low condition for Precipitation Amount in 30 years, and five analysis units to be in low condition in 60 years. The Precipitation Variability conditions for Montana and Northwest Colorado, the only analysis units currently in high condition for Precipitation Variability, decrease to moderate in the longer time frame. We made this conservative prediction, i.e., only analysis units currently in high condition are affected at the longest time frame, because we do not have a good method of predicting precipitation variability into the future. We predict plague outbreaks will be much decreased under Scenario 1 due to global warming, as explained in Section 4.2.2 Stressors. This leads us to predict that eight out of nine analysis units will be in high condition for Population Trend 30 years from now. We predict Montana will remain in moderate condition despite release from plague because other documented stressors, like poisoning on private lands, are likely to continue acting on those colonies (L. Hanauska-Brown, MFWP, pers. comm.). In 60 years, we predict Population Trend conditions in most of the analysis units will begin to suffer despite release from widespread plague due to decreased forage resulting from drought (as discussed in Section 4.2.2 Stressors). Because of this, we predict six out of nine analysis units will be in moderate condition for Population Trend in 60 years, two will remain in high condition, and one will be in low condition. Since Northwest Colorado and North Park are predicted to have lower increases in evaporative deficit than the other analysis units under our climate models, we do not predict they will experience large decreases in Population Trend condition due to increased drought and decreased forage. Thus, we predict they will be in high condition for Population Trend condition in 60 years. Because of the large decrease in plague and relatively low increase in evaporative deficit, North Park is actually predicted to see an increase in Population Trend condition from its current condition. Under Scenario 1, we predict seven analysis units will be in overall high condition and two will be in overall moderate condition in 30 years. At 60 years, we predict this will drop to two analysis units in overall high condition, six analysis units in moderate condition, and one analysis
unit in low condition (Figure 30). Although this scenario results in a slight increase in resiliency in the short term (one additional analysis unit in high condition), we predict there will be a net decrease in resiliency range-wide 60 years from now. Under this scenario, colonies will experience less widespread plague because of global warming, but they become more stressed over time because of increasingly intense droughts that reduce available forage. This decreased resilience could make colonies more vulnerable to stochastic stressors, such as a localized shooting episode or wildfire. However, we predict that only one analysis units will be in overall low condition, and thus at a higher risk of extirpation. Therefore, the species’ redundancy is likely to be preserved. Although the species’ current level of redundancy is maintained in this scenario because populations will continue to be distributed across the range, they may exist at lower densities because of a decrease in available forage. We also predict current levels of representation will be maintained under Scenario 1 because populations will still be spread across the breadth of ecological conditions present in the white-tailed prairie dog’s range.
Figure 30. Predicted changes in the conditions of white-tailed prairie dog analysis units over time, from current condition to 30 (2025 to 2049) and 60 (2050 to 2074) years into the future, under Scenario 1. In Scenario 1, drought increases in duration and frequency, plague outbreaks decrease in magnitude and frequency, and conservation efforts continue at current levels.
Synopsis: Scenario 2
In Scenario 2, colonies continue to experience plague and drought conditions similar to those of the present. Because of this, we do not predict any changes in overall condition for any of the analysis units at either of our time points. We predict six analysis units will be in overall high condition, and three will be in overall moderate condition at 30 and 60 years in the future (Figure 31). Under this scenario, we predict populations will continue to subsist within an array of habitat conditions across the species’ range including drier areas, wetter areas, and somewhat unpredictable environments, but populations will exhibit resiliency to this variation and will not suffer from protracted declines. We predict the nine analysis units will continue to be distributed across the species’ historic range within a breadth of ecological settings, thus maintaining the species’ current redundancy and representation.
Figure 31. Predicted changes in the conditions of white-tailed prairie dog analysis units over time, from current condition to 30 (2025 to 2049) and 60 (2050 to 2074) years into the future, under Scenario 2. Under Scenario 2, the conditions of the analysis units do not change because plague, drought, and conservation efforts all remain at current levels.
**Synopsis: Scenario 3**

Under Scenario 3, colonies experience more intense and frequent droughts due to ongoing climate change (RCP4.5), but plague outbreaks do not decrease as predicted in Scenario 1. Instead, plague outbreaks continue at their current magnitude and frequency. We predict these conditions would result in decreased Precipitation Amount condition scores in 30 years for four analysis units that are on the edge of their current Precipitation Amount category and are predicted to have a relatively large increase in evaporative deficit under RCP4.5. However, we predict Population Trend conditions will be maintained in these analysis units because there is no predicted increase in plague under this scenario. In 60 years, we predict five analysis units will be in low Precipitation Amount condition and four will be in moderate Precipitation Amount condition because of further increases in evaporative deficit. Although droughts are predicted to increase under RCP4.5, they are not predicted to reach the magnitude described in Scenario 1 under RCP8.5, and we do not predict significant, analysis unit-wide declines in Population Trend condition due to decreased forage. Conservatively, we only predicted a decline in Precipitation Variability condition for Montana in 60 years because it is currently on the cusp of being in the moderate category for Precipitation Variability. We predict Northwest Colorado, which currently has the most stable precipitation conditions of all the analysis units, will remain in high Precipitation Variability condition 30 and 60 years from now.

At both time scales, we predict six analysis units will be in high overall condition and three analysis units will be in moderate overall condition (Figure 32). This represents no net change in overall condition from our current condition analysis. We predict populations will continue to subsist across the species’ range despite overall drying of the landscape and will not suffer from protracted declines, thus demonstrating no decrease in resiliency from current levels. Under this scenario, we expect all of the analysis units will continue to be distributed across the species’ historic range within a breadth of ecological settings, maintaining current levels of redundancy and representation.
Figure 32. Predicted changes in the conditions of white-tailed prairie dog analysis units over time, from current condition to 30 (2025 to 2049) and 60 (2050 to2074) years into the future, under Scenario 3. In Scenario 3, drought increases in duration and frequency, plague outbreaks continue at their current magnitude and frequency, and conservation efforts continue at current levels.
Synopsis: Scenario 4

Under Scenario 4, colonies experience an increase in the magnitude of both droughts and plague. Forage decreases as the evaporative deficit increases, and colonies are decimated by more frequent plague epizootics. This leads us to predict future decreases in the three condition categories for all of the analysis units, leading to a range-wide decline in population resiliency. At both time points, we predict that seven analysis units will be in overall moderate condition, and two will be in overall low condition (Figure 33). North Park is the only analysis unit not expected to drop in overall condition because of its relatively small increase in evaporative deficit predicted by our climate models under RCP4.5, which means this analysis unit may be less affected than others by drought. These predicted decreases in condition may make populations more vulnerable to stochastic events, and the Montana analysis unit is predicted to experience substantial declines because of the multitude of stressors acting on those colonies (L. Hanauska-Brown, MFWP, pers. comm.). Although we predict that all nine analysis units will remain extant and distributed across the species’ range under Scenario 4, colonies in Montana and Southeast Utah may be at a higher risk of extirpation due to the analysis units’ low overall conditions. If the Montana or Southeast Utah analysis units were to become extirpated, the species’ redundancy would be decreased. However, the Montana analysis unit is at the periphery of the species’ range and is a part of the larger Northern population. Five other analysis units with similar ecological settings are predicted to persist within the Northern population, so the extirpation of colonies in Montana would not likely result in a significant decrease in the species’ representation. The extirpation of the Southeast Utah analysis unit would represent a range contraction at the southern border of the white-tailed prairie dog’s range, but the Grand Junction analysis unit, which has a similar ecological setting, is predicted to persist. The loss of the Southeast Utah analysis unit would represent a decrease in the species’ redundancy, but representation may still be maintained.
Figure 33. Predicted changes in the conditions of white-tailed prairie dog analysis units over time, from current condition to 30 (2025 to 2049) and 60 (2050 to 2074) years into the future, under Scenario 4. In Scenario 4, drought and plague both increase in magnitude and frequency while conservation efforts continue at current levels.
Synopsis: Scenario 5
In Scenario 5, populations experience an increase in the magnitude of droughts and plague as they do in Scenario 4, which leads us to predict they will experience declines. However, this scenario predicts that managers will respond to an increase in stressors by increasing and targeting their conservation efforts, such as dusting, SPV, and monitoring, to buffer colonies from the negative effects of drought and plague. We predict that Precipitation Amount and Variability conditions will decrease in the same manner as they did in Scenarios 3 and 4 under GHG emissions scenario RCP4.5, resulting in lower habitat conditions. However, we predict that increased conservation efforts will be effective and will maintain Population Trend conditions relative to current levels, which prevents large decreases in overall condition due to plague.

In 60 years, we predict that six analysis units will be in overall high condition, and three analysis units will be in overall moderate condition, representing no net change from the current condition (Figure 34). While habitat conditions are expected to deteriorate, management actions for fighting plague are predicted to have large positive effects that will prevent population trend conditions from deteriorating. Under this scenario, we predict the analysis units will continue to exhibit resiliency to stochastic events, in contrast to Scenario 4. While colonies within the analysis units may experience localized declines due to lower habitat conditions, we predict that all nine analysis units will remain extant and distributed across the range of ecological settings within the species’ distribution, maintaining current redundancy and representation.
Figure 34. Predicted changes in the conditions of white-tailed prairie dog analysis units over time, from current condition to 30 (2025 to 2049) and 60 (2050 to 2074) years into the future, under Scenario 5. In Scenario 5, drought and plague both increase in magnitude and frequency, but conservation efforts increase and are targeted to where they are most needed using the most effective timing and methods.
Chapter 5. Species Viability

We have considered what the white-tailed prairie dog needs for viability (Chapter 2) and have evaluated the species’ current condition in relation to those needs (Chapter 3). We also forecast how the species’ condition may change in the future under five different scenarios (Chapter 4). In this chapter, we synthesize the results from our historical, current, and future analyses and discuss the potential consequences for the future viability of the white-tailed prairie dog. We assess the viability of the species by evaluating the ability of the species to maintain a sufficient number and distribution of healthy populations to withstand environmental stochasticity (resiliency), catastrophes (redundancy), and changes in its environment (representation) into the future.

5.1 Resiliency

*Resiliency is the ability of populations to tolerate natural, annual variation (stochasticity) in their environment and to recover from periodic disturbance.*

Plague and widespread poisoning were introduced in the 20th century as novel stressors affecting white-tailed prairie dog populations. While we do not have empirical data on habitat condition or specific population trends within our analysis units to assess the species’ historical condition, evidence suggests historical populations had high resiliency due to the species’ high abundance and the absence of some current stressors. Although there is consensus among experts that prairie dog abundance has significantly declined since 1900 (Knowles 2002, pp. 1-2; Forrest 2005, p. 528; Miller et al. 2007, p. 2801), the species is still distributed across its historical range (Antolin et al. 2002, p. 117; Knowles 2002, p. 5).

Since there is no accurate historical baseline to which we can compare, our analysis of the white-tailed prairie dog’s current condition and resiliency is “limited to studying artifacts of what once existed” (Miller et al. 2000, p. 319). Historical populations were not subjected to plague, which is now one of the main drivers of white-tailed prairie dog population resiliency. Currently, the white-tailed prairie dog is characterized by three populations with nine analysis units distributed across the species’ range. Based on the relevant factors evaluated in our analysis, six of the analysis units are currently in overall high condition, and three are in moderate condition (Table 13). This means that two thirds of our white-tailed prairie dog analysis units exhibit high resiliency and are well-equipped to withstand stochastic variation, such as a plague epizootic or drought. Across the species’ range, populations display stable or increasing abundance or have managed to recover after declines, despite variation in habitat conditions. The persistence of populations across the species’ range, despite continued plague outbreaks and widespread drought, is a testament to the species’ inherent resiliency (Pauli et al. 2006, p. 28).

Our predictions of future condition varied under our five future condition scenarios, but, in general, we predict the species will maintain moderate to high resiliency in the future (Table 16).
The exceptions are Scenario 1 in 60 years and Scenario 4 at both time points. In Scenario 1, we predict the Southeast Utah analysis will be in overall low condition in 60 years because of poor habitat conditions. However, the other eight analysis units remain in overall moderate or high condition. In Scenario 4, which represents our most pessimistic scenario, population resiliency is expected to decline range-wide as both plague and droughts are predicted to increase in frequency and intensity. Still, in the majority of our future scenarios, we predict white-tailed prairie dog populations will maintain moderate to high levels of resiliency across the species’ range.

5.2 Redundancy

Redundancy is the ability of a species to withstand catastrophic events. Redundancy is measured by the duplication and distribution of populations across the range of the species. Historically, white-tailed prairie dog populations ranged from southern Montana, through central and southern Wyoming, into northeastern Utah and northwestern Colorado. The number of colonies that were distributed across this historic range is unknown. Current populations of white-tailed prairie dogs occupy the same spatial distribution, but colonies within those populations may have decreased in number due to the significant decline in the white-tailed prairie dog’s abundance after 1900 ((Knowles 2002, pp. 1-2; Forrest 2005, p. 528; Miller et al. 2007, p. 2801). This represents a potential decrease in the species’ redundancy, but we have no way of measuring the degree of this loss.

The white-tailed prairie dog remains distributed across the spatial extent and ecological settings of its historic range, but colonies are likely more fragmented and isolated than they were before the introduction of plague (Clark 1977, p. 63; Cully and Williams 2001, p. 903; Miller et al. 1994, p. 678; Knowles 2002, p. 24). The species currently exhibits a metapopulation structure, with colonies in a constant flux of expansion, contraction, extirpation, and recolonization (Knowles 2002, pp. 18, 20; Johnson and Collinge 2004, p. 496). Stable occupancy rates across the range, and recovery from declines in the only two analysis units not in high condition for Population Trend, leads us to conclude the three larger white-tailed prairie dog populations have intact metapopulation structures. While the species’ redundancy is likely lower than in the past, white-tailed prairie dog colonies still have high duplication and distribution of populations across the species’ range. This redundancy makes it unlikely that a catastrophic event could extirpate all of the analysis units at once.

Under the majority of our future scenarios, we predict the white-tailed prairie dog will retain all nine analysis units across its range in moderate to high condition. While localized declines may be realized in the populations that decreased in condition under Scenario 1, only the Southeast Utah analysis unit is predicted to be in overall low condition in 60 years, and thus, at a higher risk of extirpation at that time. In Scenario 4, the Montana and Southeast Utah analysis units are in overall low conditions at both 30 and 60 years, making them more vulnerable to extirpation.
from a severe stochastic event under this scenario. However, the Montana analysis unit is at the periphery of the species’ range and represents a small fraction of the colonies making up the white-tailed prairie dog’s distribution. While the extirpation of the Montana and Southeast Utah analysis units would indicate a decrease in the species’ redundancy, the three larger populations would remain extant. In the face of a catastrophic event under Scenario 4, it is possible that some, but likely not all, of the analysis units could be extirpated.

5.3 Representation

*Representation is the ability of a species to adapt to changing physical (climate, habitat) and biological (diseases, predators) conditions. It can be thought of as the ‘adaptability’ of the species.*

A species’ representation is measured by looking at the genetic, morphological, behavioral, and ecological diversity within and among populations across its range. The more representation, or diversity, a species has, the more likely it is to persist in changing environments. Historically, the white-tailed prairie dog was distributed throughout a large range covering parts of four western states. Within this range, the prairie dog occupied a variety of habitats, including sagebrush steppe, short grass prairie, and semiarid canyonlands (EPA 2013) spanning elevations from 1,150-3,200 m (Tileston and Lechleitner 1966, p. 295; Flath 1979, p. 63). Precipitation levels vary greatly among these habitats, from high levels of annual precipitation in north central Colorado to the arid deserts of southern Utah. We know of no morphological, behavioral, or genetic differences between these historical populations.

White-tailed prairie dog populations still occupy their historic range and all of the varied habitats within it. The Northern population (Montana, Wyoming, Northern Utah, North Central Colorado, Northeast Utah, and Northwest Colorado analysis units) is characterized by sagebrush steppe habitat. There is some variability in precipitation for this population from west to east; the Northeastern Utah analysis unit on the western edge of the species’ distribution is in low precipitation amount condition, and North Central Colorado in the east is in high condition. Other than Montana, all of the analysis units in the Northern population are in high overall condition, representing adaptation to local environmental conditions. The North Park population is separated from the Northern population by a strip of unsuitable habitat not included in the predicted range and is smaller than the other populations. It is characterized by a single sagebrush parks ecosystem and is moderate for all of our current condition categories. The North Park population has experienced some population declines, but has also showed recovery (Table 10). It is unknown if these declines are associated with environmental factors or plague because plague monitoring does not occur in the area (Seglund 2016, p. 11). The Southern population (Southeast Utah and Grand Junction analysis units) is characterized by much drier, desert-like conditions. Southeast Utah is in low precipitation amount condition, and Grand Junction is moderate. While white-tailed prairie dogs likely persist in lower densities in this area.
due to less abundant vegetation, population trends show stable occupancy. Southeast Utah is in overall moderate condition, and Grand Junction is in overall high condition. The diversity of habitats currently occupied by the white-tailed prairie dog is a good measure of the species’ current level of representation.

Genetic diversity or gene flow between the three larger populations has not been characterized. However, there is evidence that some white-tailed prairie dogs may have genes that afford them immunity against plague, evidenced by antibody titers in survivors in Utah (Knowles 2002, p. 20). In black-tailed prairie dogs, survival of plague-challenged individuals varied by collection site (South Dakota, Colorado, Texas), suggesting a genetic component to resistance that varies by region (Rocke et al. 2012, pp. 113-114). Since this has not been tested in the white-tailed prairie dog, we do not know if levels of immunity vary between analysis units or populations, which could increase the species’ representation.

Climate models predict the white-tailed prairie dog will likely experience drier conditions across its range in the future (see Section 4.1 Climate Change). White-tailed prairie dogs currently occupy many semi-arid sites and are often associated with drier areas (Clark 1977, p. 2; Knowles 2002, p. 7). In three out of five of our future scenarios, two of which forecast increased drought, we predict that analysis units will remain in moderate to high condition. For instance, we predict that eight out of nine analysis units will be in moderate to high overall condition in 60 years despite the highest increases in evaporative deficit predicted in Scenario 1. The exception is Scenario 4, where we predict large decreases in overall condition that are driven by widespread increases in plague, which devastates populations. However, in the majority of our future scenarios, we predict the white-tailed prairie dog will continue to occupy the full extent of its range and ecological settings and will maintain its current level of representation.
Table 16. Summary of the overall condition scores predicted for the white-tailed prairie dog analysis units under five future scenarios, 30 and 60 years into the future. Analysis units can be in overall low (L), moderate (M), or high (H) condition. We give full descriptions of these results in Section 4.2.3 Results of Future Condition Analysis.

<table>
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<tr>
<th>Analysis Units</th>
<th>Scenario 1 30 Years</th>
<th>Scenario 1 60 Years</th>
<th>Scenario 2 30 Years</th>
<th>Scenario 2 60 Years</th>
<th>Scenario 3 30 Years</th>
<th>Scenario 3 60 Years</th>
<th>Scenario 4 30 Years</th>
<th>Scenario 4 60 Years</th>
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<td>H</td>
<td>M</td>
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<td>H</td>
<td>M</td>
<td>M</td>
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<td>H</td>
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<tr>
<td>North Central Colorado</td>
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<td>M</td>
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<tr>
<td>Northwest Colorado</td>
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<td>Grand Junction</td>
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</table>
5.4 Synopsis of Viability

*Viability is the ability of a species to sustain populations over time. Species which exhibit high resiliency, redundancy, and representation are more viable than those that do not.*

The white-tailed prairie dog currently exhibits levels of resiliency, redundancy, and representation that allow populations to persist throughout the species’ entire historic range, but at lower abundances than historically. Currently, six analysis units are in overall high condition, and three analysis units are in overall moderate condition. Populations are still distributed across the species’ historic range and all of the varied habitats within it, demonstrating redundancy and representation. The white-tailed prairie dog has managed to persist despite a widespread poisoning campaign in the early 20th century, the introduction of a devastating non-native pathogen (plague), and an extensive drought in the western U. S. for the last 17 years.

We forecast the future viability of the species by predicting the responses of our analysis units to conditions under five future scenarios 30 and 60 years into the future. Based on the factors evaluated in our analysis, we do not predict that any of the analysis units will become extirpated in any of the scenarios, and we predict that all of the analysis units will remain in moderate to high condition in three out of five future scenarios. The exceptions are Scenario 1 at 60 years and Scenario 4 at both time points. In Scenario 1, we predict the Southeast Utah analysis unit will be in overall low condition in 60 years because of poor habitat conditions. However, the other eight analysis units remain in overall moderate or high condition. Under Scenario 4, conditions worsen to the point that all of the analysis units are expected to decrease in resiliency, and the Montana and Southeast Utah analysis units are predicted to be in low overall condition and thus, at a higher risk of extirpation. However, the Montana analysis unit is at the periphery of the species’ range and is a part of the larger Northern population. Five other analysis units with similar ecological settings are predicted to persist within the Northern population under Scenario 4, so the extirpation of Montana would not represent a significant decrease in the species’ redundancy or representation. The extirpation of the Southeast Utah analysis unit would represent a range contraction at the southern border of the white-tailed prairie dog’s range, but the Grand Junction analysis unit, which has a similar ecological setting and is part of the same larger population, is predicted to persist under Scenario 4.

The current persistence of the white-tailed prairie dog across a variety of habitat types, despite the devastating effects of plague, is a testament to the species’ resiliency. Investment in targeted conservation efforts that combat plague epizootics, like those described in future Scenario 5, could further increase the species’ viability and make it less vulnerable to other stochastic or catastrophic events. Habitat restoration in areas affected by cheatgrass invasion could help buffer colonies from some of the harmful effects of increased droughts. Most importantly, regular monitoring should continue to evaluate population conditions into the future.
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Personal Communications


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Appendix A. Conservation Measures on Public Lands Administered by the BLM

This table includes conservation measures detailed in field office Resource Management Plans (RMPs) that specifically benefit white-tailed prairie dogs on BLM lands. Sources are included in parentheses below each field office name (second column).

<table>
<thead>
<tr>
<th>State</th>
<th>Field Office</th>
<th>No Special Recreation Permits issued for prairie dog hunting</th>
<th>Poisoning prohibited, unless colonies pose a threat to human health and safety</th>
<th>No surface occupancy in prairie dog colonies</th>
<th>Surface disturbance avoided in colonies, when practicable</th>
<th>Vehicle use limited to existing roads and trails</th>
<th>Raptor anti-perching devices encouraged/required</th>
<th>New power lines buried, or new power poles avoided, in colonies</th>
<th>Monitoring/surveys in project areas</th>
<th>Allows/encourages colony expansion</th>
<th>Other conservation measures</th>
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<td>WY</td>
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*blm 2000, pp. 2-38, A-9, T-51, T-83

**blm 2008b, pp. 2-26, 2-50, 2-51, A1k-9

***blm 2008c, pp.2-25, 2-55

**blm 2014, pp. 66, 69

**blm 2015d, pp. 3-21 – 3-23, L-21, L-26

**blm 2008a, pp. 39,40,131

**blm 2008d, pp. 46, 86

**blm 2008e pp. 31, 122

**blm 2015a, pp. 33, A-13
BLM staff in Wyoming are instructed not to provide the locations of prairie dog colonies to recreational shooters, and the BLM in Wyoming employs the philosophy of not encouraging prairie dog shooting on public lands (BLM 2007, p. 3-17).

The Uncompahgre field office is in the process of updating its 1989 RMP. In 2016, a Draft RMP was available for public comment which included some prairie dog conservation measures within its discussion of alternatives (BLM 2016). Until the Draft RMP is finalized, the field office operates under the 1989 RMP. There are no specific conservation measures relating to prairie dogs in the 1989 RMP. However, the 1989 RMP does include some No Surface Occupancy restrictions for oil and gas development in certain parts of the resource area (Areas of Critical Environmental Concern).

<table>
<thead>
<tr>
<th>Location</th>
<th>X^</th>
<th>X</th>
<th>X^l</th>
<th>X^m</th>
<th>X</th>
<th>X^n</th>
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<td>Little Snake (BLM 2001, p. 22)</td>
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<tr>
<td>White River (BLM 2015c, pp. 2-22, 1-51)</td>
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<td>Grand Junction (BLM 2015b, pp. 18, 44, 45, 56, 57, B-26, B-54)</td>
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<td>X</td>
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<td>Uncompahgre** (BLM 2010b, p. 2)</td>
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a BLM staff in Wyoming are instructed not to provide the locations of prairie dog colonies to recreational shooters, and the BLM in Wyoming employs the philosophy of not encouraging prairie dog shooting on public lands (BLM 2007, p. 3-17).

** The Uncompahgre field office is in the process of updating its 1989 RMP. In 2016, a Draft RMP was available for public comment which included some prairie dog conservation measures within its discussion of alternatives (BLM 2016). Until the Draft RMP is finalized, the field office operates under the 1989 RMP. There are no specific conservation measures relating to prairie dogs in the 1989 RMP. However, the 1989 RMP does include some No Surface Occupancy restrictions for oil and gas development in certain parts of the resource area (Areas of Critical Environmental Concern).

a No printed maps of prairie dog colonies will be provided to recreational shooters (see also BLM 2007, p. 3-17)
b Avoid activities that could collapse burrows in colonies >200 acres; Colonies will be inventoried at least every 10 years
c Colonies >12.5 acres in size
d No control allowed if mountain plover or burrowing owl is present on colony
e Includes any colony active in the last 10 years
f Controlled surface use April 1 – July 31 if mountain plover is present on colony
g Considered a priority for management due to declining populations
h Statewide shooting closure on public lands from April 1 – June 15 (Utah Division of Wildlife Resources 2016, Regulation R657-19-6)
i Controlled surface use in Coyote Basin; No surface disturbance within 660 feet of colony??
j Commitment to maintain and enhance white-tailed prairie dog habitat
k Restrictions on development from March 1 – June 15; Maintain at least 90 percent of currently occupied prairie dog habitat as undisturbed in the Management Focus Area; Allows for the control of plague vectors; Provide in-kind compensation for habitat loss and displacement when appropriate
l Disturbance >1 acre in colonies <10 acres; No surface disturbance permitted in prairie dog colonies April 1 – June 15
m Surface disturbance avoided March 1 – May 1
n Goal to maintain 15,500 acres of occupied prairie dog habitat on BLM-administered lands in the Wolf Creek Ferret Management Area
o Seismic activity avoided March 1 – July; Provide in-kind compensation for habitat loss and displacement when appropriate
Within certain wildlife emphasis areas; surface use prohibited April 1 – July 15

Manage habitat in the salt shrub desert community and wildlife emphasis areas to maintain viable populations of WTPD and obligate species

Allows prairie dog relocation

Statewide shooting closure on public lands from March 1 – June 14 (Colorado Parks and Wildlife 2016, p. 3).

BLM 2007, p. 4-2

No surface disturbing activities within 660 feet of active colonies. Additionally, no permanent above-ground structures are allowed within the 660 foot buffer.

Grazing is managed to allow adequate vegetation production in prairie dog habitat

“The BLM will manage land uses within occupied and historic white-tailed prairie dog colonies to preserve the habitat.”
### Appendix B. Future Condition Tables

Tables B-1 – B-10 are our future condition tables rating analysis units as low, moderate, or high condition based on three habitat and demographic factors: Precipitation Amount, Precipitation Variability, and Population Trend. Condition ratings are based on the categories given in Table 11 (conditions category table), and our methods for determining future condition are explained in Section 4.2.4 Predicting Future Condition. The three habitat and demographic factors were not weighted equally in our determination of overall current condition, as explained in Section 3.4.4 Analysis of Current Condition by Population, Calculating Final Conditions Scores for Analysis Units and represented by the numbers in parentheses in the title of each factor.

Table B-1. Projected future conditions of white-tailed prairie dog analysis units under Scenario 1, 30 years into the future.

<table>
<thead>
<tr>
<th>Population</th>
<th>Analysis Unit</th>
<th>Precipitation Amount Condition (1x)</th>
<th>Precipitation Variability Condition (0.5x)</th>
<th>Population Trend Condition (3x)</th>
<th>Overall Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Montana</td>
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<td>High</td>
<td>Moderate</td>
<td>Moderate</td>
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<tr>
<td></td>
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Table B-2. Projected future conditions of white-tailed prairie dog analysis units under Scenario 1, 60 years into the future.

### Scenario 1: 60 Years (2050-2074)

<table>
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<tr>
<th>Population</th>
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<th>Habitat Factors</th>
<th>Demographic Factors</th>
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Table B-3. Projected future conditions of white-tailed prairie dog analysis units under Scenario 2, 30 years into the future.

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<th>Overall Condition</th>
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Table B-4. Projected future conditions of white-tailed prairie dog analysis units under Scenario 2, 60 years into the future.

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<th>Analysis Unit</th>
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<th>Precipitation Variability Condition (0.5x)</th>
<th>Population Trend Condition (3x)</th>
<th>Overall Condition</th>
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Table B-5. Projected future conditions of white-tailed prairie dog analysis units under Scenario 3, 30 years into the future.

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Table B-6. Projected future conditions of white-tailed prairie dog analysis units under Scenario 3, 60 years into the future.

### Scenario 3: 60 Years (2050-2074)

<table>
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<th>Population</th>
<th>Analysis Unit</th>
<th>Precipitation Amount Condition</th>
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<table>
<thead>
<tr>
<th>Overall Condition</th>
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<tbody>
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</table>
Table B-7. Projected future conditions of white-tailed prairie dog analysis units under Scenario 4, 30 years into the future.

<table>
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<th>Population</th>
<th>Analysis Unit</th>
<th>Precipitation Amount Condition (1x)</th>
<th>Precipitation Variability Condition (0.5x)</th>
<th>Population Trend Condition (3x)</th>
<th>Overall Condition</th>
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</thead>
<tbody>
<tr>
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Table B-8. Projected future conditions of white-tailed prairie dog analysis units under Scenario 4, 60 years into the future.

**Scenario 4: 60 Years (2050-2074)**

<table>
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<th>Population</th>
<th>Analysis Unit</th>
<th>Precipitation Amount Condition (1x)</th>
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<th>Population Trend Condition (3x)</th>
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<tbody>
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<tr>
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Table B-9. Projected future conditions of white-tailed prairie dog analysis units under Scenario 5, 30 years into the future.

<table>
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<th>Analysis Unit</th>
<th>Precipitation Amount Condition (1x)</th>
<th>Precipitation Variability Condition (0.5x)</th>
<th>Population Trend Condition (3x)</th>
<th>Overall Condition</th>
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</thead>
<tbody>
<tr>
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Table B-10. Projected future conditions of white-tailed prairie dog analysis units under Scenario 5, 60 years into the future.

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<th>Precipitation Variability Condition (0.5x)</th>
<th>Population Trend Condition (3x)</th>
<th>Overall Condition</th>
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