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## Threats and Stressors to Species at Risk and Ecological Systems, Practical Implications, and Management Strategies for Installations in Colorado and the Western U.S.

Colorado State University

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# Executive Summary

This document describes work funded by the Department of Defense Legacy Resource Management Program, Project Number 14-770 (Purchase Request Number W81EWF-4125-0556) by Colorado State University, by and through its Colorado Natural Heritage Program and Center for Ecological Management of Military Lands.

## Background and Approach

Species and ecological systems face continued pressure from a variety of inter-related threats, including expanding urbanization, habitat degradation, climate change, and others. As threats to biodiversity continue, the Department of Defense (DoD) could find its installations shouldering more conservation responsibility in the future. To better understand evolving natural resource management challenges, we conducted an analysis of current and potential future threats to three ecological systems and five species-at-risk (SAR) on Fort Carson, Piñon Canyon Maneuver Site (PCMS), and the U.S. Air Force Academy (USAFA or the Academy).

The objectives of this study were to:

1. Analyze vulnerability of species and ecosystems to stressors at local and regional scales;
2. Identify potential species declines that could adversely affect future training operations;
3. Incorporate spatial data to evaluate possible distribution shifts and other species/ecosystems responses in relation to destabilizing events;
4. Develop recommendations to scale down the ecosystem management concept and help halt species declines both on and off installations; and
5. Document our process and lessons learned to facilitate similar analyses by other installations for their species and ecological systems.

In consultation with installation personnel, we identified the following ecological systems and species as the focus of the study:

- Pinyon-juniper woodlands
    - pinyon jay (*Gymnorhinus cyanocephalus*)
    - gray vireo (*Vireo vicinor*)
- Shortgrass prairie
    - burrowing owl (*Athene cunicularia*)
- Cliffs and canyons (including outcrops and pine barrens)
    - golden eagle (*Aquila chrysaetos*)
- Preble's meadow jumping mouse (*Zapus hudsonius preblei*)

For each of these target species and ecosystems, we synthesized the most current information on distribution, status, ecological processes and life history. For ecological systems, we calculated potential impact from incompatible land uses, using existing GIS layers. We also evaluated existing models of potential distribution shift in response to climate change for both ecological systems and species, as well as potential impacts from military training.

## Overview of Results

All three ecological systems evaluated have significant potential for adverse impacts from incompatible land uses, based on geographic proximity to mappable infrastructure. Across the distribution of pinyon-juniper, only 11% of this system is further than one mile from at least one mappable incompatible land use. That number is 7% for shortgrass prairie, and 8% for cliffs and canyons. Not surprisingly, the land use with the greatest acreage of potential impact is roads. This is an indication of potential for impact only. Not all vulnerable acres of these systems will be impacted equally, and some will not be impacted at all. However, at least two significant influences over the health of these systems were not included in our analysis due to lack of spatial data: invasive species and livestock grazing.

Future vulnerability to climate change can only be projected at this point. Available information suggests that future climate conditions are likely to be very challenging for pinyon pine, but potentially beneficial for juniper species. If extent and health of pinyon pine deteriorate, impacts to pinyon jays could be significant. A variety of vulnerability assessment methods have been applied to shortgrass prairie, all with the same result: highly vulnerable. Cliffs and canyons are expected to experience climate effects similar to shortgrass prairie, though potentially with fewer impacts where they are sparsely vegetated. However, altered hydrology could affect rare canyon ferns. Assessments of vulnerability to climate change produced variable results for all of the species included in this report, with the exception of Preble's meadow jumping mouse, which was ranked as extremely vulnerable.

## Pinyon-Juniper

We focused on the distribution of two-needle pinyon (*Pinus edulis*) and used the term "pinyon-juniper" to refer to both pinyon-juniper woodlands and pinyon-juniper savannas. The primary processes that influence the formation and persistence of pinyon-juniper include climate, grazing, fires, tree harvest, and insect-pathogen outbreaks (West 1999a; Eager 1999). The manifestations of this ecological system are highly variable across its range. Romme et al. (2009) distinguish three types of pinyon-juniper vegetation: *persistent woodlands* (trees with sparse understory), *pinyon-juniper savannas* (on gentle topography with well-developed grass/forb cover, trees in low to moderate densities, minor shrub component), and *wooded shrublands* (well-developed shrub component, variable grass/forb and tree density). All types are found at Fort Carson and PCMS.

In Colorado, pinyon-juniper supports 41 Species of Greatest Conservation Need (SGCN) (CPW 2015). Of Colorado SGCN inhabiting pinyon-juniper, this habitat type is *the* primary, or *a* primary habitat for 28 species. Of these, five have been named by DoD Partners in Flight (PIF) as Mission-Sensitive Priority Bird Species: pinyon jay, gray vireo, Lewis's woodpecker, northern goshawk, and olive-sided flycatcher.

Land uses that may be incompatible with this system and the wildlife who rely on it are pervasive across the landscape, though many of these uses are comparatively low-density and dispersed. Only 11% of the land cover mapped as pinyon-juniper forests and woodlands occur further than one mile away from at least one mappable threat. That number is a conservative (worst-case) scenario since it represents land uses within a mile of pinyon-juniper, and not all impacts may extend over that distance. However, it does not reflect stresses from other activities for which we did not have spatial data, including invasive species, livestock grazing, recreation, and solar energy development.

With regard to climate change, future precipitation and temperature patterns are projected to be less favorable for pinyon, enabling juniper to become more dominant. Pinyon-juniper woodlands are projected to experience summer temperatures warmer than the current temperature range in more than one third of its current distribution in Colorado. Projected winter precipitation levels are generally within the current range, but spring and summer precipitation for 9-16% of the current distribution are projected to be lower than the driest end of the current range. The pinyon-juniper system has large ecological amplitude so warmer conditions may allow expansion, as long as there are periodic cooler, wetter years for recruitment. The availability of canopy microsites to promote establishment and survival of seedlings may become increasingly important as conditions become drier (Redmond and Barger 2013). Increased drought may drive increased fires and insect outbreaks, from which these woodlands would be slow to recover.

Under hotter and drier conditions, the ability of landscapes at Fort Carson and PCMS to support pinyon pine is predicted to decrease. Much of Fort Carson is predicted to become more suitable for one-seed juniper, while to the southeast, much of the area that currently supports juniper would no longer be suitable for that species. This agrees with other regional projections that suggest that some areas of southeast Colorado may eventually convert to a semi-desert grassland (Rehfeldt et al. 2012).

In regard to identified system-level threats, we recommend the following:

- Expedite the development of updated/revised forest management plans. Within the context of multiple stressors such as insects, drought and climate change, a clean and well-prioritized management plan is critical.
- Continue to implement a combination of thinning and burning prescriptions to reach desired conservation, safety and mission support objectives. However, great care must be taken in managing these types. Fuels reduction treatments in pinyon-juniper forest types have potential to degrade ecological conditions by creating novel stand structures and altering natural disturbance regimes. Consider the needs of pinyon-juniper obligate bird species when planning treatments.
- Initiate or continue to implement monitoring for adaptive management of pinyon-juniper systems. Linking monitoring attributes with management prescriptions will help improve the effectiveness and fine-tune best management practices over time.
- Develop and use a state and transition framework to facilitate management decisions, monitoring, and adaptive management with respect to prescriptions. A new management

objective becomes development and maintenance of a given percentage of the pinyon-juniper acreage in each of the different pinyon-juniper community types.

- Examine and incorporate considerations related to climate change scenarios into forest management planning. Considerations might include stand replacement considerations, site-specific considerations for forest treatments or planting, anticipated fire behavior under climate change, and identification of refugia (e.g., cooler, moister sites) where species might persist or experience less ecological stress.

## Pinyon Jay

According to the 2016 Partners in Flight Landbird Conservation Plan, Breeding Bird Survey (BBS) data show that the continental population of the pinyon jay has suffered an 84% loss from 1970 – 2014. The plan further estimates that an additional 50% of the remaining population could be lost within 19 years if trends experienced over the past 10 years continue (Rosenberg et al. 2016).

The pinyon jay is often considered a mutualist with pinyon pines, where the pines provide jays with the seeds that are their primary food source, nesting sites, and protection from predators, while jays act as dispersal agents for the pinyon seeds (Wiggins 2005). The pinyon jay's primary habitat has been impacted throughout the interior western U.S. by a complex web of potential threats, including weakened condition of trees due to drought, resulting in increased mortality from insect outbreaks and increased risk of wildfire (which is further exacerbated by fuel buildup related to fire suppression, especially in the wildland-urban interface). Loss, degradation, and fragmentation of habitat have resulted from these disturbances, as well as from energy production, urban development, forest management, and incompatible grazing.

The cumulative effects of these impacts are likely to be exacerbated by climate change in at least some components of the pinyon jay's habitat. Observed and projected climate trends for Colorado generally point to decreased suitability for the pinyon-juniper woodlands that provide the primary habitat for pinyon jays. Audubon's modeled projections for future pinyon jay habitat suitability suggest that in the nearer term (2020), suitability could increase somewhat in the southern Front Range and southeastern Colorado regions around Fort Carson, PCMS, and the Air Force Academy compared to present. Longer time frames show decreasing habitat suitability overall, with the best habitat shifting from the current core range of Nevada, Arizona, and New Mexico northward into Colorado and Wyoming. Modeled projections by van Riper et al. (Figure 37) generally support this prediction.

At Fort Carson and PCMS, potential threats to pinyon jays include: 1) fragmentation and degradation of habitat from training activities, 2) drought and climate change, 3) noise and disturbance from human activities, and 4) tree damage from insects.

Recommendations for habitat management to benefit pinyon jays include:

1. Maintain extensive stands of pinyon-juniper or pinyon woodlands at the landscape scale, with emphasis on retaining mature, cone-producing trees.

2. Identify and maintain occupied home ranges.
3. Maintain structural diversity in pinyon-juniper woodlands.
4. Manage human use and disturbance to protect nesting colonies and cone-producing trees.
5. Fire is *not* recommended as a management tool in pinyon-juniper habitat.

Information needs include:

1. Specific information on pinyon jay occurrence and habitat use at Fort Carson, PCMS, and potentially other Colorado installations.
2. Investigations of pinyon jay habitat use during and after high cone crop years to test apparent preferences for young classes and invasion zones that have been documented in Nevada (Nevada Wildlife Action Plan Team 2012).
3. Research into the ability of pinyon jay flocks to breed in shifted home ranges (e.g., in response to habitat loss from fire, insect, other disturbance) (Wiggins 2005).
4. Pinyon jay response to thinning and other forest management treatments in Colorado (Wiggins 2005).

## Gray Vireo

Breeding Bird Survey data show a significantly increasing trend for gray vireo across their range, though some authors consider BBS efforts inadequate to monitor the species because of its patchy distribution, cryptic nature, and occurrence in remote areas (Barlow et al. 1999, Shuford and Gardali 2008, Butler et al. 2013). Reported increases may be attributable in part to increased survey effort. However, despite reports of increasing population numbers, the gray vireo population is still very small.

Some authors consider the gray vireo an obligate of mature, relatively weed-free and open pinyon-juniper, juniper, or oak woodlands with a shrubby under story (Balda 1980; Parrish et al. 2002). There have only been a few sightings of gray vireo on Fort Carson and PCMS, so habitat use there is not well known.

The gray vireo has not been well-studied with specific regard to threats. Available life history information is insufficient to support clear determination of human and land-use related impacts to this species (Parrish et al. 2002). Some authors suggest that the greatest threats to gray vireos are clearing, thinning, and/or other degradation of habitat to improve forage or reduce expansion into grasslands and shrublands, exurban development, and energy development, as well as large-scale loss of from drought and insect outbreaks (Gilliahn 2006, Walker and Doster 2009, Barlow et al. 1999, Butler et al. 2013, Johnson et al. 2014, 2015). At Fort Carson and PCMS, habitat loss and degradation has occurred due to development and training activities. Wildfires and prescribed fires are also somewhat common on Fort Carson and PCMS. These events have changed the composition and structure of woodland habitats at these installations, but how these changes may have affected the gray vireo is unknown. Gray vireos have been observed at the edge of pinyon juniper woodlands at Fort Carson using open grasslands, and it is possible that more open habitats from fires could create improved habitat conditions for gray vireo. However, open and disturbed landscapes such as burned areas used for training could lead to increased numbers of brown-headed cowbirds, which are known to parasitize gray vireo nests. The potential effects of fire and training activities on habitat quality and brown-headed cowbird parasitism are unexplored, and warrant further investigation.

The potential vulnerability of the gray vireo to climate change is uncertain. Gardali et al. (2012) found the gray vireo to be a lower priority compared to some other species, but still of concern for potential climate impacts in California. Molinari et al. (2016) determined that the gray vireo is vulnerable to climate change (also in California). Pierce (2007) considers climate change a potential threat to gray vireo habitat in New Mexico, where increasing temperatures may lead to effectively drier conditions, reducing the health of pinyon-juniper woodlands and subjecting them to increased pressure from drought, fire, and pests. Spatial models projecting future distribution also present conflicting information. The National Audubon Society considers the gray vireo "Climate Threatened." Though their climate model projects greatly increased overall "climate space," they predict an almost complete shift in the location of suitable breeding areas for the gray vireo (Figure 43), with only 3% of the current breeding range remaining suitable by 2080 (National Audubon Society 2013). In contrast, Van Riper et al. (2014) projects an overall range increase from 58 –71% between 2010 and 2099 across the southwestern U.S., but with much of the current breeding range remaining persistent in its present location (Figure 44). Hatten et al.'s 2016 analysis, which built on the van Riper et al. study, projected a range contraction for gray vireo at mid-century, but an overall 58% increase by end century, with predicted current range persistence comparable to van Riper's.

Recommendations for management of populations and habitat include:

1. Maintain extensive stands of pinyon-juniper and pinyon woodlands at the landscape scale.
2. Identify and maintain occupied home ranges.
3. Maintain structural diversity in pinyon-juniper woodlands.
4. Manage human use and disturbance.
5. Fire is *not* recommended as a management tool in pinyon-juniper habitat.

Information needs include:

1. Research on basic life history information, including breeding phenology, population dynamics (e.g., clutch size, fledging success, effects of brood parasitism, survivorship and recruitment, population trends) (Latta et al. 1999, Parrish et al. 2002, GBBO 2010).
2. Research on gray vireo habitat selection, especially with regard to percent canopy closure, preferred density and species composition of the shrub layer (Latta et al. 1999, GBBO 2010).
3. Improved understanding of population trends and habitat threats (GBBO 2010).
4. Potential effects of fire and training activities on habitat quality and brown-headed cowbird parasitism.

## Shortgrass Prairie

The shortgrass prairie region covers about 34 million hectares in the western central and southern Great Plains (Lauenroth et al. 2008). The largest remaining intact tracts of shortgrass prairie are in southeastern Colorado and northeastern New Mexico. DoD installations within the range of the shortgrass prairie primarily lie within the western portion of the biome. Of these, PCMS and Fort

Carson have the most significant extent of shortgrass prairie. The primary ecological processes that maintain shortgrass prairie are drought and grazing.

According to Colorado's state wildlife action plan (CPW 2015), shortgrass prairie supports 48 Species of Greatest Conservation Need (SGCN), including one federally listed species (black-footed ferret). Of Colorado SGCN inhabiting shortgrass prairie, this habitat type is *the* primary, or *a* primary habitat for almost all of them. Eight shortgrass prairie species have been named by DoD PIF as Mission-Sensitive Priority Bird Species: bald eagle, burrowing owl, golden eagle, grasshopper sparrow, loggerhead shrike, long-billed curlew, mountain plover, and prairie falcon.

Rangewide, approximately half of the historic distribution of shortgrass prairie has been converted to other uses (Neely et al. 2006). Across its remaining distribution, only about seven percent of the shortgrass prairie is unaffected by at least one incompatible land use. The primary threats to the shortgrass prairie system near Fort Carson and PCMS are residential and commercial development, energy production, disturbance due to training, and climate change. Non-native species are also significant issues in some areas.

Climate change vulnerability assessments have been conducted for shortgrass prairie in Colorado under three greenhouse gas emissions scenarios (Decker and Fink 2014, Colorado Natural Heritage Program 2015). Though technical analysis methods differed, shortgrass prairie ranked as highly vulnerable to climate change within a mid-cetury timeframe under all three scenarios. Key effects include warmer summer nighttime low temperatures and extended periods of drought. About 78% of shortgrass prairie in Colorado is likely to be exposed to effectively drier conditions, even with unchanged or slightly increased precipitation. For shortgrass prairie in Colorado's eastern plains, more than half of the current range is projected to experience annual *mean* temperatures above the current statewide *maximum* temperature. Although the dominant shortgrass species are adapted to warm, dry conditions, stabilizing vegetation (especially blue grama), can be slow to recover after even a relatively short-term drought (Rondeau et al. 2013), and buffalograss is less drought tolerant than blue grama (Aguiar and Lauenroth 2001).

Recommendations for management include:

1. Locate and use seed source that contains native variants resistant to drought, fire, and military disturbance.
2. Expand the "hardening" of heavy use areas (bivouac, helipads, wet area crossings, etc.) that are too difficult or costly for restoration using gravel, road base, and rock to reduce fugitive dust and other erosion.
3. Use erosion control blanket on critical areas if plausible, where high erosion rates and steep slopes are a concern.
4. Limit high disturbance maneuvers (neutral-steer turns for tracked vehicles, high-speed turns in muddy areas by wheeled vehicles, bivouac training on non-hardened sites) in areas that are already partially degraded due to erosion, invasive plant species, poor soils, etc.
5. Expand prescribed burn program in shortgrass prairie to landscape scales outside of SDZs and installation perimeter areas where burns are currently conducted. We recommend the

installation target a historic fire return interval estimated at 5-30 years (mean 15-20 year fire return) to achieve multiple ecological benefits and manage fuel loads to avoid high-severity, large scale burns that cannot be managed. This effort would need to incorporate site-specific considerations with respect to fuels, weather/drought, weeds, and watershed condition.

6. Increase the use of two-track over completely cleared roads/trails especially those that are used solely for transit/convoy and not maneuvers.
7. Pursue a change in procedure to allow LRAM funding for all sites that negatively impact training, regardless of the site's environmental compliance status, or whether or not the issue was caused by training.
8. Use prescribed fires for noxious weed management instead of mechanical or chemical control.

### Burrowing Owl

Various sources report differing information on the status of burrowing owl. The most recent analysis of Breeding Bird Survey data show a mixed trend for burrowing owl across the U.S. and Canada (1966-2013 data), with decreases in Canada, portions of the Great Basin, and the eastern and southern portions of its range, but increases in other areas including southeastern Colorado (Figure 64, Sauer et al. 2016). Conway et al. (2010) theorized that inconsistent trends across the owl's range may be due to owls becoming less migratory, with birds becoming resident in southern locations rather than continuing to migrate to northern locations.

The burrowing owl typically nests in relatively flat, open, sparsely vegetated areas (e.g., deserts, grasslands, shrubsteppe), as well as highly altered habitats such as golf courses, airports, vacant lots in urban settings, and cemeteries (Haug et al. 1993, Jones 1998, Dechant et al. 1999). In Colorado, burrowing owls are predominately found in shortgrass prairie habitats and are strongly associated with prairie dog colonies (Martin 1983, Jones 1998, Wickersham 2016).

Buildings, air fields, storage tanks and other infrastructure have been built within burrowing owl habitat on Fort Carson and PCMS. Reports from recent sampling years at Fort Carson indicate that shortgrass prairie condition may be in decline (e.g., drought, increased erosion, altered composition of native perennials, decreased forage available for prairie dogs) (Clawges 2014). The distribution of prairie dogs at Fort Carson and PCMS has been highly variable since 2001.

The primary factors implicated in burrowing owl population declines are habitat alteration and fragmentation, prairie dog eradication, predation, and prey limitation. Training activities at Fort Carson and PCMS can damage shortgrass prairie, resulting in the loss or degradation of nesting and foraging habitat for burrowing owl. Burrowing owls are more likely to be resilient to the direct effects of military training than other species due to spending much of their time underground as well as being more likely to nest in sites with shorter grass and more bare ground, as previously discussed. Human intrusion and disturbance is an ongoing issue. Although not a primary threat, burrowing owls are sometimes struck and killed by aircraft at Fort Carson and PCMS.

Some authors consider climate change to be a major threat to burrowing owl populations (Audubon Society 2015; Cruz-McDonnell and Wolf 2016). The National Audubon Society considers the burrowing owl to be "Climate Endangered." According to their modeling, up to 77% of burrowing owl breeding habitat could be lost by 2080, and only 33% of its current winter range remaining intact (with the other 67% shifting to new locations but an overall increase in winter range of 29%, Audubon Society 2015). We used NatureServe's Climate Change Vulnerability Index to estimate vulnerability within the burrowing owl's distribution across the western U.S. as well as its distribution in Colorado, and found that the species ranked "Moderately Vulnerable" in Colorado but "Highly Vulnerable" in the western U.S. The primary factors driving vulnerability in our assessment were dependence on a few species for generation of habitat, and those species are expected to be adversely impacted by climate change, low levels of genetic diversity, and predicted loss of current breeding range (National Audubon Society 2015).

Management recommendations include:

1. Collaborate with partners to manage for landscape scale heterogeneity (e.g., work with local and regional partners to support extensive connectivity among burrowing owl populations, Conway et al. 2010).
2. Maintain populations of prairie dogs and other fossorial mammals to provide habitat and prey.
3. Conduct regular monitoring to document status of breeding populations.

Additional recommendations for DoD installations provided by Conway et al. (2010) are generally consistent with the management approach currently in place at Fort Carson and PCMS, including:

1. Adopt and implement standardized monitoring protocols to identify conflicts between burrowing owl populations and the military mission early (recommended monitoring intensity is greater than that currently employed at Fort Carson).
2. Maintain low grasses adjacent to burrowing owl breeding sites.
3. Maintain burrowing mammals to provide nesting and roosting burrows and prey.
4. Develop site-specific plans that support maintenance of owl and rodent populations consistent with Wildlife Aircraft Strike Hazard (WASH) safety needs.

## Cliffs and Canyons

The cliff, canyon, and outcrop system is widespread across the western and southern portions of the Great Plains. In many places it occurs in small patches, but larger concentrations are found along the Rocky Mountain Front, particularly in the vicinity of Fort Carson and PCMS. Cliff and outcrop vegetation is typically sparse, and often restricted to shelves, cracks and crevices in the rock. Canyon slopes are often characterized by open to moderately dense pinyon and juniper woodlands. Occasional seeps and springs of the canyon walls provide habitat for regionally rare ferns. Shale or "chalk" barrens support populations of narrowly endemic species, such as the Colorado endemics roundleaf four o'clock (*Mirabilis rotundifolius*), Pueblo goldenweed (*Oonopsis puebloensis*), and golden blazingstar (*Mentzelia chrysantha*).

Cliffs, outcrops, breaks and barrens are all the result of erosional processes. The breakdown of substrate rocks (weathering) into soil is influenced by climate, vegetation and other biota, topography, parent material, and the passage of time. Erosion of weathered particles by wind, water, and the force of gravity is the primary natural disturbance process in these environments.

In Colorado, cliffs and canyons support 18 Species of Greatest Conservation Need (SGCN) (CPW 2015), including one federally listed species (Mexican spotted owl). Of Colorado SGCN inhabiting cliffs and canyons, this habitat type is *the* primary, or *a* primary habitat for almost all. Two species have been named by DoD PIF as Mission-Sensitive Priority Bird Species: golden eagle and prairie falcon.

With the exception of some low-relief outcrops and barrens, this system does not readily lend itself to permanent human development or infrastructure. In terms of the mappable land uses that we analyzed, the greatest source of potential stress on cliffs, canyons, and outcrops is, not surprisingly, roads. However, cliff, canyon, and outcrop habitats are somewhat impacted by energy production (especially wind turbine farms) and, in some areas, military maneuvers. Continued gradual habitat fragmentation and degradation is likely to have the greatest impact on rare or endemic species and plant communities. Warmer future conditions, coupled with a potential for increased frequency of severe storm events, may change the structure and distribution of these habitats considerably. If changing climate conditions result in an increased frequency of extreme storm events, patterns of runoff and erosion may change, with the potential to impact cliff, canyon and outcrop habitats. Drought conditions may also contribute to increased erosion in some instances if soil-holding vegetation is depleted.

## Golden Eagle

Debate is ongoing regarding the current status of the golden eagle's continental population. USFWS (2009) tentatively concluded that the golden eagle was declining. Other recent estimates of population trends for golden eagles are mixed. Millsap (2013) determined that the population in the western U.S. was stable overall from 2006-2010. Nielsen et al. (2014) found declines in numbers of juveniles in the Northern Rockies and Southern Rockies/Colorado Plateau BCRs, but no decline in total abundance across the western U.S. Breeding Bird Survey data from 1966 – 2013 also present a mixed picture of trend for golden eagle, with increases in some places and decreases in others. PIF's 2016 Landbird Conservation Plan shows an overall 6% increase from 1970-2014 for the U.S. and Canada (Rosenberg et al. 2016). A 2016 status update for Bald and Golden Eagle Protection Act determined that status is still somewhat equivocal, with count data suggesting a stable population, but demographic data forecasting a slight decline (Millsap et al. 2016).

Golden eagles occupy a wide range of habitats, most commonly where cliffs occur near open spaces that support abundant prey populations (Kochert et al. 2002). In Colorado, golden eagles are documented most frequently in cliff habitats, but also use pinyon-juniper, ponderosa pine and other coniferous woodlands, grasslands from alpine to prairies, shrublands (especially sagebrush), riparian, and rural agricultural areas (Wickersham 2016).

With no natural predators, impacts from interactions with humans is the most severe direct threat golden eagles face and the main cause of their mortality. These include collisions (e.g., cars, utility lines, wind turbines), electrocution (electrical lines), and toxins (e.g., lead from ammunition, secondary poisoning from rodent control).

The Audubon Society considers the golden eagle "Climate Endangered." Their models project a loss of 41% of current breeding range and 16% of winter range by 2080. Paprocki et al. (2014) found a significant poleward range shift for golden eagle at a rate of 7.74 km. per year. Van Buskirk (2012) found an increase of approximately 30 days in the time between golden eagle spring and autumn migrations since 1970. Chamberlain and Pearce-Higgins (2013) suggested that impacts from climate change may manifest more through effects on prey availability rather than through direct effects on birds per se. They noted that the issue appeared to be less a problem of mismatched phenology so much as alterations in prey populations and prey availability.

Much of the cliff habitat on Fort Carson and PCMS is relatively inaccessible or off limits for training purposes. However, there is some potential for disturbance to nesting eagles, collision with aircraft and utility lines, and impacts to important prey species (particularly prairie dogs). Installation plans include measures for avoidance and mitigation of disturbances and appropriate management of prairie dogs. In addition to these, we would recommend:

1. Implementation of a long-term monitoring strategy to detect impacts from climate change, including both eagle phenology and prey availability components.
2. Increased emphasis on inter-agency and cross-jurisdictional information sharing, the better to advance all parties' understanding of the status of local and regional golden eagle populations and early detection of evolving management needs (particularly with regard to climate change).

### Preble's Meadow Jumping Mouse at the U.S. Air Force Academy

The distribution of Preble's meadow jumping mouse (PMJM) is restricted to the Rocky Mountain front from southeastern Wyoming southward along the Front Range of Colorado to Colorado Springs. The PMJM is listed as threatened by the U.S. Fish and Wildlife Service (USFWS 1998). The PMJM is found in two major river drainages in Colorado: the South Platte River and the Arkansas River drainages. The Monument Creek population of PMJM, which includes the associated tributaries, is the largest PMJM population in the Arkansas River drainage. With much of Monument Creek and the viable PMJM habitat being found on the U.S. Air Force Academy, the Academy's PMJM population is the most valuable conservation priority for PMJM recovery in the Arkansas River drainage. Because there are only a handful of medium and large PMJM populations targeted for conservation in the PMJM Recovery Plan (USFWS 2015), the Academy PMJM population is invaluable for rangewide recovery of the subspecies.

The primary reason for PMJM decline is associated with habitat loss along and near riparian corridors throughout its range (USFWS 2015). Loss and fragmentation of habitat is attributed to urban development, construction of highways and bridges, water development, increased runoff and flood control, mining (sand, gravel), and overgrazing.

The most significant issue for PMJM management on the Academy is increased riparian habitat erosion caused by elevated storm water runoff from urban development. This impacts the population of PMJM at the Academy and jeopardizes the conservation of PMJM in the southern part of its range. Since the federal listing of PMJM in 1998, the lands east of the Academy have experienced a dramatic increase in urban development (Kuby et al. 2007). The associated increase in impervious surface has increased the frequency, rate, and volume of storm water runoff and the degree of flooding that occurs on the Academy.

Because projected warmer and drier conditions are expected to decrease the quality and quantity of riparian habitats, PMJM is especially vulnerable (USFWS 2015). Although many models project a slight increase in precipitation (averaging 5% increase or less annually) for the PMJM range by mid-century, a simultaneous temperature increase of 4°F or more means that no areas in the current PMJM range will receive sufficient compensatory precipitation to maintain current runoff patterns. Reduced summer flows are predicted to result in more frequent drought stress for riparian habitats, with a resulting loss or contraction of the habitat (Rood et al. 2008), especially at lower elevations (Lukas et al. 2014), potentially including the lower elevational limit of PMJM occurrence. These conditions are not limited to transition streams on the Front Range. A statewide climate change vulnerability assessment for Colorado shows that predicted temperature and precipitation are outside of historic means for wetland and riparian habitats across all elevational gradients (Decker and Fink 2014). This means that – if projections hold true – water providers and users could be competing with ecosystem instream flow needs across the state, and depending on how regional precipitation patterns play out, they could be doing so simultaneously. Future climate projections for downstream water compact states are similarly problematic (Palmer et al. 2009).

High management priorities for PMJM at the Academy include:

1. Maintain riparian habitat that is being lost along the eastern boundary and along Monument Creek due to increased runoff and erosion caused by land use changes east of the Academy that are jeopardizing the PMJM population.
2. Collaborate with the City of Colorado Springs and El Paso County on effective mitigation and correction of PMJM habitat loss on the Academy from upstream storm water management. Such conversations may identify where the installation of flood-mitigation features can reduce flows that reach the Academy. Monument Branch, Middle Tributary, Black Squirrel Creek, and Kettle Creek have the longest stream miles of any of the tributaries, and thus, are likely to have the most value for PMJM habitat conservation because of their potential for more habitat and PMJM.
3. Consider a monitoring program specifically targeting health of riparian vegetation to provide early warning of decline and reduced resiliency in the habitat component most critical for PMJM.
4. Expand collaboration across multiple sectors (agricultural producers, forest managers, developers, and water providers, as well as a multitude of governmental agencies) to develop adaptive capacity in the highly connected aquatic and riparian systems that support PMJM habitat.

# Contents

# Introduction, Military Context, and Study Approach

# 1 Introduction

Species and ecological systems face continued pressure from a variety of inter-related threats, including expanding urbanization, invasive species, habitat degradation, climate change, and others. As threats to biodiversity continue, the Department of Defense (DoD) could find its installations shouldering more conservation responsibility in the future. To better understand evolving natural resource management challenges, we conducted an analysis of current and potential future threats to three ecological systems (hereafter "ecosystems") and five species-at-risk (SAR) on Fort Carson, Piñon Canyon Maneuver Site (PCMS), and the U.S. Air Force Academy (USAFA or the Academy).

## 1.1 Study Objectives

The natural resource programs at Fort Carson, PCMS, and the Academy manage their ecosystem resources within a regional context that may influence, or be influenced by, factors that cross installation boundaries. Among the benefits of ecosystem management is a landscape perspective toward reducing and abating threats to SAR. In this way, species status can maintained or improved in a regional context, species declines can be prevented or ameliorated, and managers can gain improved guidance for designing monitoring programs and measuring success. From a military perspective, mission complications related to SAR can be lessened.

The objectives is this study were to:

1. Analyze vulnerability of species and ecosystems to environmental and training-related stressors at local and regional scales;
2. Identify potential species declines that could adversely affect future training operations;
3. Incorporate spatial data to evaluate possible distribution shifts and other species/ecosystems responses in relation to destabilizing events;
4. Develop installation-specific and strategic recommendations to scale down the ecosystem management concept and help halt species declines both on and off installations; and
5. Document our process and lessons learned to facilitate similar analyses by other installations for their species and ecological systems.

## 1.2 Ecosystems and Species Targets

### 1.2.1 Fort Carson and PCMS

In collaboration with natural resource managers at Fort Carson and PCMS, we determined that the most appropriate way to focus the study would be on the major ecological systems that make up the physical environment within which the majority of training and other components of the military mission on Fort Carson and PCMS occurs. These ecological systems are:

- Shortgrass prairie

- Pinyon pine and juniper woodlands and savannas (referred to hereafter as pinyon-juniper)
- Cliffs, canyons, and outcrops (including pine barrens).

As part of the Legacy-funded Central Shortgrass Prairie Species at Risk Conservation Innovation and Implementation project (project number 08-214), 25 species were identified as Species at Risk (SAR) for Colorado Front Range DoD installations. Of these species, natural resource managers at Fort Carson and PCMS identified three as priorities for analysis: **burrowing owl** (*Athene cunicularia*), **gray vireo** (*Vireo vicinor*), and **pinyon jay** (*Gymnorhinus cyanocephalus*). These species inhabit the two most significant habitat types for military training in the region – shortgrass prairie and pinyon-juniper. All three species are DoD Partners in Flight (PIF) monitoring priorities, Species of Greatest Conservation Need in Colorado, and U.S. Fish and Wildlife Service Birds of Conservation Concern. In addition, in consultation with DoD PIF, we determined that there was added value in building on to the body of knowledge gained via previous Legacy investments in these species (project numbers 08-243, 09-243, 09-425, 10-425).

Since the 2009 development of the SAR list, Fort Carson and PCMS identified additional species that are currently impacting the training mission. Concerns about how emerging stressors may influence management prompted the addition of a fourth species: **golden eagle** (*Aquila chrysaetos*). This species breeds primarily in cliff and canyon habitats, but forages widely, especially over the grasslands used intensively for military training at Fort Carson and PCMS. Like the other bird species listed above, the golden eagle is a DoD PIF monitoring priority, Colorado Species of Greatest Conservation Need, and USFWS Bird of Conservation Concern.

### 1.2.2 U.S. Air Force Academy

The most significant management issues on the USAFA have been focused on the federally listed **Preble's meadow jumping mouse**. The USAFA represents a significant proportion of the remaining distribution for this jumping mouse. Given this species' restriction to riparian habitats, there is potential for increasing drought to have a strong influence on future natural resource management and expenditures for the Academy as changes in precipitation patterns and stream hydrology impact riparian habitats. Thus, potential future issues related to water management and climate change are of particular concern to USAFA's natural resource manager.

## 1.3 Study Area

We assessed threats and vulnerability at regional and local scales. We defined the primary study area as the western Great Plains, represented by the Central Shortgrass Prairie (CSP) and Southern Shortgrass Prairie (SSP) ecoregions (Figure 1). Fort Carson, PCMS, and the U.S. Air Force Academy are located along the western edge of the Central Shortgrass Prairie ecoregion, where it abuts the Southern Rockies ecoregion along the Rocky Mountain front. The Southern Shortgrass Prairie ecoregion was included because it contains a significant portion of the shortgrass prairie and western burrowing owl distributions. For the pinyon-juniper ecosystem, pinyon jay, and gray vireo, we defined a secondary area of interest that includes species distributions that extend west into the Colorado Plateau region (Figure 2).

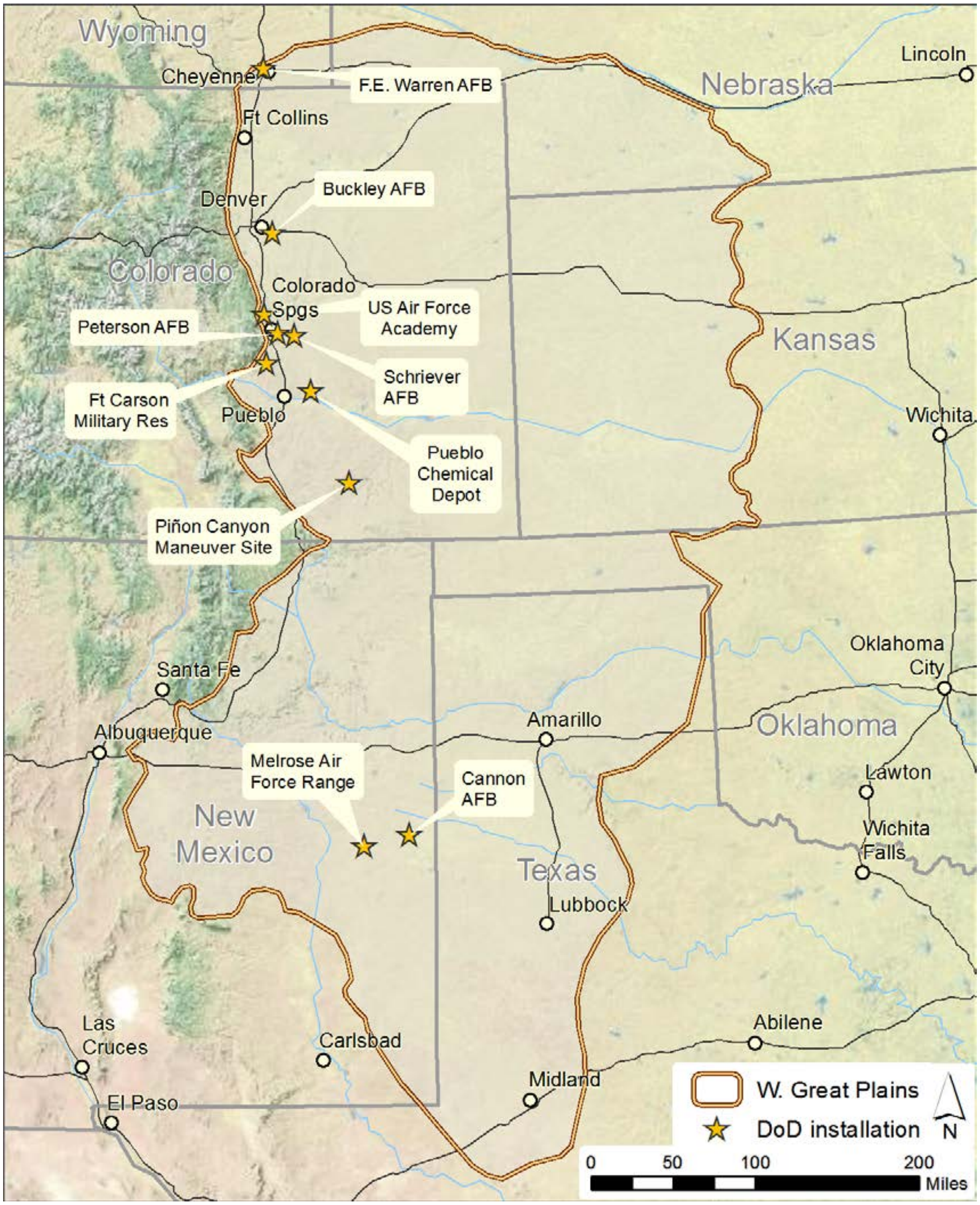



**Figure 1. Primary study area and location of DoD installations within the western Great Plains.**

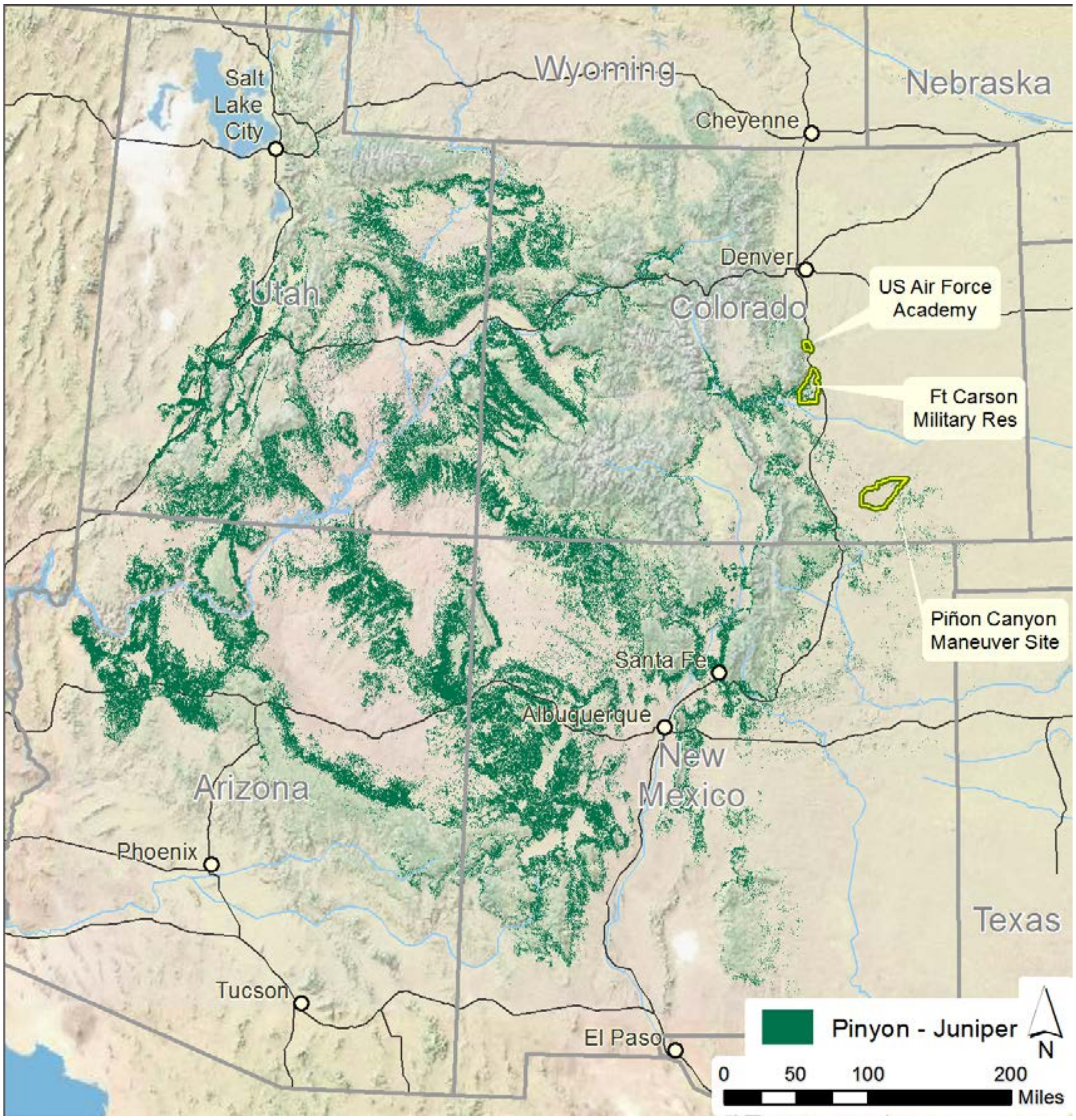



**Figure 2. Secondary area of interest for two-needle pinyon pine with juniper species and associated birds (pinyon jay and gray vireo).**

### 1.3.1 Regional Overview

Fort Carson and the U.S. Air Force Academy occur along the ecotone between the Rocky Mountains to the west and the Great Plains to the east. There is considerable high-density urban development along the mountain front, with a typical suburban – exurban – rural gradient and associated infrastructure into the foothills as well as onto the prairie. PCMS occurs in a more rural setting, and is primarily surrounded by rangeland used for cattle grazing.

### 1.3.2 Current Climate

The western Great Plains, where Fort Carson, PCMS, and the USAFA are located, has a continental climate with both east-west and north-south gradients. Over the central plains, precipitation decreases from east to west, while temperatures and day-lengths increase from north to south. The climate is characterized by large seasonal contrasts, as well as inter-annual and longer term variability (Pielke and Doesken 2008). The relatively high elevation, continental interior position, and proximity to mountain ranges on the west produce a dry environment with large diurnal temperature variation (Pielke and Doesken 2008). The region is classified as a semi-arid, with a moderate deficit of precipitation in relation to potential evapotranspiration (Meigs 1952, Safriel et al. 2005). Drought is a characteristic climatic extreme in the region. Periodic high winds (chinooks) result from the flow of high westerly winds over the mountains, but average wind movement is less in foothills and piedmont than on the plains to the east (WRCC 2004)

***Precipitation***

Precipitation trends in the western Great Plains are similar to those of the larger Great Plains area, in that western areas are driest. Annual precipitation is generally less than 20 inches, and soils are periodically moist only in a shallow top layer, typically less than 1-2 feet deep (Schantz 1923). Along the western edge of the plains, the Rocky Mountains create a rain shadow and a zone of increasing precipitation in the foothill and piedmont areas. Precipitation rapidly increases with increasing elevation. Mean annual precipitation varies from 20+ inches in the eastern prairie to 12 inches in the western prairie (Pielke and Doesken 2008). Precipitation increases to 16-18 inches in foothills and piedmont areas.

Precipitation on the western Great Plains generally originates from the Gulf of Mexico. In spring and summer months, warm moist air from the Gulf extends further north, while in fall and winter, cold Arctic air from the polar region dominates (WRCC 2004). When these contrasting air masses meet, severe weather and precipitation often result. Spring warming brings thermal instability and atmospheric mixing producing windy conditions, and thunderstorms become common. Precipitation may be the most important ecological driver, particularly in the shortgrass prairie. Lauenroth and Sala (1992) found that shortgrass productivity was primarily influenced by precipitation rather than temperature in northeastern Colorado. A large proportion (70-80%) of annual precipitation falls during the growing season (WRCC 2004), and most of this is received during a limited number of large rainfall events (Pielke and Doesken 2008). Daily precipitation amounts are usually small (5mm or less), and do not contribute much to soil water recharge, which instead is primarily dependent on large but infrequent rainfall events (Parton et al. 1981, Heisler-White et al. 2008). Snowfall amounts are highest in the north, but generally snow is a small component of annual precipitation. Most of the annual precipitation is quickly evaporated and transpired into the atmosphere rather than soaking into the soil (Pielke and Doesken 2008). Larger rainfall events allow moisture to penetrate deeper into the soil profile, and enable an increase in above-ground net primary production (Heisler-White et al. 2008).

***Temperature***

Temperatures show significant variation both daily and seasonally. Average daily temperature spans are 25-30°F, with diurnal variation generally greatest in summer. Winter temperatures are cold, with nights below freezing and chilly daytime temperatures. Seasonal extreme lows below -20°F have been recorded (WRCC 2014). In general, the number of frost free days is greater in more southern latitudes, although freezing temperatures have been recorded in all months except July and August. Summer maximum temperatures are frequently in the 90's, especially in southern locations; temperatures of 100°F or above have been recorded even in the northern portion of the region (WRCC 2014). Temperature variation in the foothill and piedmont is less than on the plains, with lower summer temperatures and higher winter temperatures producing a climate that is more moderate than that for the plains to the east (WRCC 2004).

***Seasonal Variation and Severe Weather***

Winters can be mild and dry when Pacific air masses are blocked by the Rocky Mountains under zonal flow conditions, or cold and snowy under meridional flow patterns that bring arctic air or upslope snow. Spring is transitional with warming conditions and lingering arctic air and possible heavy snow. In summer, a “dry line” separating humid Gulf air from dry desert southwest air forms in the western plains, and thunderstorms often form along this boundary. Summer thunderstorms can produce locally heavy precipitation that can that can cause localized flooding in areas of topographic relief. In late summer, the North American monsoon can bring moisture from the southwest. Typical autumn weather is relatively fair and dry, with periodic cool, wet weather and the possibility of early snow (Pielke and Doesken 2008).

Severe weather, especially in the shortgrass prairie, includes thunderstorms, hail, tornados, and high winds. Thunderstorms produce dangerous cloud-to-ground lightening, as well as damaging hail. Tornados can occur throughout the plains, but are most intense in the eastern and southern reaches of the shortgrass prairie (Pielke and Doesken 2008). Strong winds are frequent in winter and spring (WRCC 2004), and act to dry out soils that are already low in moisture. High winds make dust storms common during these seasons.

### 1.3.3 Current and Past Land Use

The western Great Plains region has been sparsely populated both prehistorically and since European settlement. With the exception of major urban centers along the Front Range, this trend has continued into the present. Cropped agriculture, both irrigated and dryland, is the primary land use in the shortgrass prairie. Livestock production (almost entirely cattle) remains the predominant land use on non-cropped prairie, and in the pinyon-juniper ecosystem. Many grazing operations also involve feedlots dependent on irrigated feed crops (Hart 2008).

***Prehistoric Human Presence***

The earliest human inhabitants of the region are thought to have been hunter-gatherers of the Clovis culture some 13,000 years ago, but evidence of Paleo-Indian presence at the time of Folsom culture (11,000-10,000 years before the present) is much more common. During the Altithermal period (7,000 to 4,000 years before present) the area would have been even hotter and drier than current conditons, suggesting that human populations shifted to the margins of the area, or to locations with predictable water supply. Archaic period sites are typically rock shelters associated with cliffs or canyons, and concentrated on the margins of the plains. Fort Carson includes two such sites in Turkey Creek Canyon: Gooseberry shelter site, first occupied between 5,722 and 5,653 years ago (Cassells 1997), which would have been before the arrival of pinyon pine in the region, and the Recon John shelter. Flint quarries and bison kill sites are also documented from the Archaic period, especially in canyons and breaks of the eastern margins of the Llano Estacado (Gunnerson 1987). Cliff, canyon and outcrop areas have received sporadic use as quarry sources of particular substrate material for building and other needs, as shelter sites, or as game drive and butchering sites. Clovis and Folsom hunters both used weapon points made of flint from quarries in canyons of the Canadian River region (Gunnerson 1987). Quarrying for building material in the cliffs and canyons ecosystem has continued throughout the period of settlement, up to the present.

Beginning in about 2,000 years ago, there is evidence of agriculture and pottery use on the eastern margins of the region, and plains village cultures are established by the 8th or 9th century CE (Hart 2008). Even before the arrival of the horse, hunter-gatherer camp sites were in use throughout the shortgrass plains (Wedel 1953).

Some ancestral Puebloan communities were present along the southwestern edges of the Great Plains. Plains Woodland cultures subsisting on bison, elk, deer and small game, as well as foraged plant food, and perhaps rudimentary horticulture are more typical of the region; both Fort Carson and PCMS include Plains Woodland sites dated from about 400-1,000 years ago (Cassells 1997). Sites from the later Apishapa Phase of the post-Archaic plains cultures are also found on both installations, and represent the last of the permanent habitations outside the pueblo communities before the advent of horse-driven Plains Indian culture (Gunnerson 1987).

#### ***Native American Inhabitants***

By the time of the Spanish arrival in the 1500s, pueblo communities were found in northern and central New Mexico, to the west of the southern Great Plains, while the majority of the southwestern Great Plains region was the domain of the plains Apache. Around the early 1700s, as plains tribes acquired horses, Comanche and Ute bands replaced the Apache; eventually Arapaho and Cheyenne occupied most of the region north of the Arkansas River (Cassells 1997). As some tribal groups began to accumulate large horse herds, bison herds declined in size by the 1830s due to hunting for fur and provisioning as well as competition for forage. Bison were essentially gone from the region by the early 1880s (Hart 2008).

#### ***Land Use Since European Settlement***

Early Spanish and American explorers, fur trappers, and migrants generally bypassed or traversed the shortgrass region without settling. With the acquisition of the Louisiana territory by the United States, more people of European descent entered the region. European settlement of the shortgrass prairie region began in the early 19th century with the establishment of forts and trading posts, but crop agriculture and livestock production did not become widely established until the passage of the Homestead Act in 1862 (Hart 2008).

#### Cropland

Crop growing was initially confined to areas where irrigation was easily available, near larger perennial rivers or streams. Irrigated crops include alfalfa, corn, sugar beet, and cotton; dryland wheat is the primary non-irrigated crop (Lauenroth et al. 2008). Even the severe drought of the Dust Bowl years (1934-1937) did not reverse the ongoing development of cropland. The recurrence of drought, in combination with the spread of rural electrification and the development of new pumping technologies led to the widespread use of groundwater for irrigation (Hart 2008). By now, the distribution of cropland is closely tied to the extent of the Ogalalla aquifer. Depletion of the aquifer and urban demand for water are likely to have a significant impact on agricultural production in the future.

### Ranching

With the advent of homesteading in the area, sheep and cattle ranching became the primary economic activity. Although many of the early settlers raised both sheep and cattle on small tracts, this gradually evolved into large-scale cattle ranching on consolidated ranches (Friedman 1985). The introduction of railway transport facilitated the movement of range cattle to markets further east. Charles Goodnight and Oliver Loving's cattle drive of 1866 initiated the large-scale movement of range livestock through the western margins of the region. For a few decades, mild winters allowed the rapid expansion of the trade, until changing climatic conditions and a decline in prices ended the era of long distance cattle drives in the region.

Since the late 1800s, distribution and density of pinyon and juniper and the accompanying native understory has been significantly altered by anthropogenically induced changes in fire frequency and grazing patterns. Livestock production remains the primary economic land use in the pinyon-juniper ecosystem, along with a minimal amount of crop or forage production in areas that can be irrigated. Approximately 65-70% of shortgrass prairie remaining in natural vegetation is still mostly used for livestock grazing (Hart 2008). Cliffs and canyons also receive occasional use by domestic livestock.

# 2 Military Context: Missions, Requirements and Preferences for Fort Carson and PCMS

## 2.1 Training Landscape[1]

As one of the Army's Power Projection Platforms, Fort Carson has a high priority role in the deployment and mobilization of battle ready units for major geopolitical conflicts. The units that are housed and trained at Fort Carson must be prepared to deploy at any time while additional units move to the installation for training. Fort Carson is currently home to the 4th Infantry Division (Mechanized), 43rd Sustainment Brigade, 10th Special Forces Group (Airborne), 71st Ordnance Group, and numerous smaller support units. Fort Carson and the PCMS also support the Colorado National Guard, Army Reserve Units, and other military units. The mission of Fort Carson is to train, house, mobilize, deploy, and sustain combat-ready, multi-component integrated forces. Fort Carson and the PCMS provide facilities and service to the U.S. Armed Forces that require land and airspace to practice combat skills and operations on a year-round basis. To accomplish this mission, realistic and quality training opportunities are necessary. The mosaic of natural communities, and the varied topography found on these installations, as well as climate extremes ranging from hot summers to cold winters provide a variety of training scenerios. The majority of land at both Fort Carson and the PCMS is used for military training (Table 1).

**Table 1. Land use and acreages by land use type at Fort Carson and PCMS (Directorate of Environmental Compliance and Management [DECAM] 2007).**

| Land Use | Fort Carson Acres (138,303 total) | PCMS Acres (235,368 total) |
|---|---|---|
| **Developed** | | |
| Cantonment | 5,177 (4%) | 1,659 (1%) |
| Camp Red Devil | 233 (<1%) | - |
| Butts Airfield | 644 (<1%) | - |
| Ammo Reclaim and Ammunition Supply Point | 592 (<1%) | - |
| Tent City | 544 (<1%) | - |
| ***Developed Total*** | ***7,190 (5%)*** | ***1,659 (1%)*** |
| **Special Use** | | |
| Turkey Creek Recreation Area | 1,235 (1%) | - |
| Bird Farm Recreation Area (Wildlife Complex) | 634 (<1%) | - |
| Golf Course | 365 (<1%) | - |
| Archery Range | 29 (<1%) | - |
| Haymes Reservoir | 72 (<1%) | - |
| Northside Reservoir | 51 (<1%) | - |
| Townsend Reservoir | 37 (<1%) | - |
| Scout Camp | 73 (<1%) | - |
| Wildlife Demonstration Area | 246 (<1%) | - |

[1] Adapted from DECAM 2015

| Land Use | Fort Carson Acres (138,303 total) | PCMS Acres (235,368 total) |
|---|---|---|
| Turkey Creek Protected Species Area | 70 (<1%) | - |
| Gary Walker Buffer Zone | 718 (<1%) | - |
| Off-limits Wildlife/Buffer Zone | | 10,731 (5%) |
| ***Special Use Total*** | ***3,710 (2%)*** | ***10,731 (5%)*** |
| **Military Field Training** | | |
| Maneuver and Training Areas | 92,479 (67%) | 184,557 (79%) |
| Impact Buffer Zone | 5,287 (4%) | - |
| Small Arms Impact Area | 6,075 (4%) | - |
| Large Impact Area | 15,602 (11%) | - |
| Tank Table VIII, Range 145* | 2,066 (1%) | - |
| Multipurpose Range Complex* | 4,472 (3%) | - |
| Range 123* | 1,422 (1%) | - |
| Canyonlands+ | - | 29,452 (13%) |
| Soil Protection Sites+ | - | 4,191 (2%) |
| Hogback+ | - | 3,778 (2%) |
| ***Military Field Training Total*** | ***127,403 (92%)*** | ***222,978 (95%)*** |

### 2.1.1 Training Areas and Ranges

***Fort Carson***

Fort Carson is divided into 56 Training Areas (Figure 3). These Training Areas are assigned to any unit for field training and include all land except impact areas, tank tables, the Multipurpose Range Complex, various recreation sites, and the Cantonment Area (Figure 4). For the primary military use for each training area at Fort Carson, see Table 3.4.2.3a of DECAM 2007.

Fort Carson has the following range facilities: 30 basic marksmanship ranges, 13 collective live-fire ranges, 9 direct fire gunnery ranges, 62 indirect fire facilities, 4 special live-fire facilities, and 45 other, nonlive-fire facilities (Figure 3)(DECAM 2007).

***PCMS***

Training Area designations have changed on the PCMS as the Army gains experience training on these lands. In 1985 the PCMS was divided into five large Training Areas as detailed in the PCMS Acquisition Environmental Impact Statement (EIS) (U.S. Army 1980). This system allowed for approximately three-fifths of trainable lands on the PCMS to be rested for two entire growing seasons. Lands were rested for two years and then rotated into use as other lands that had been in use were rotated back into rest. This system conserved training lands, but its limitations on military training options were too severe to allow the Army to meet its training needs.

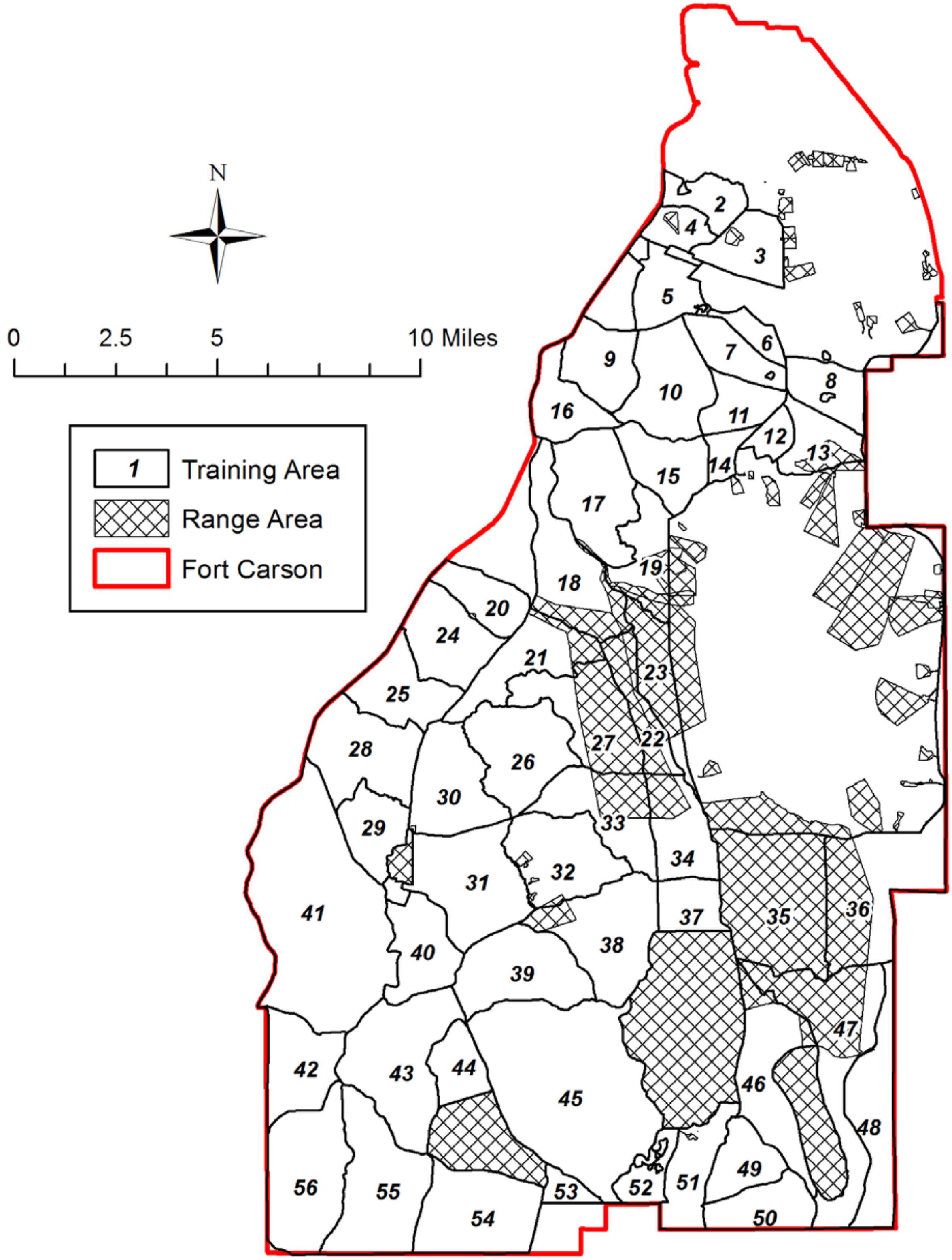



**Figure 3. Fort Carson Training Areas and Ranges.** Source: DECAM 2007.

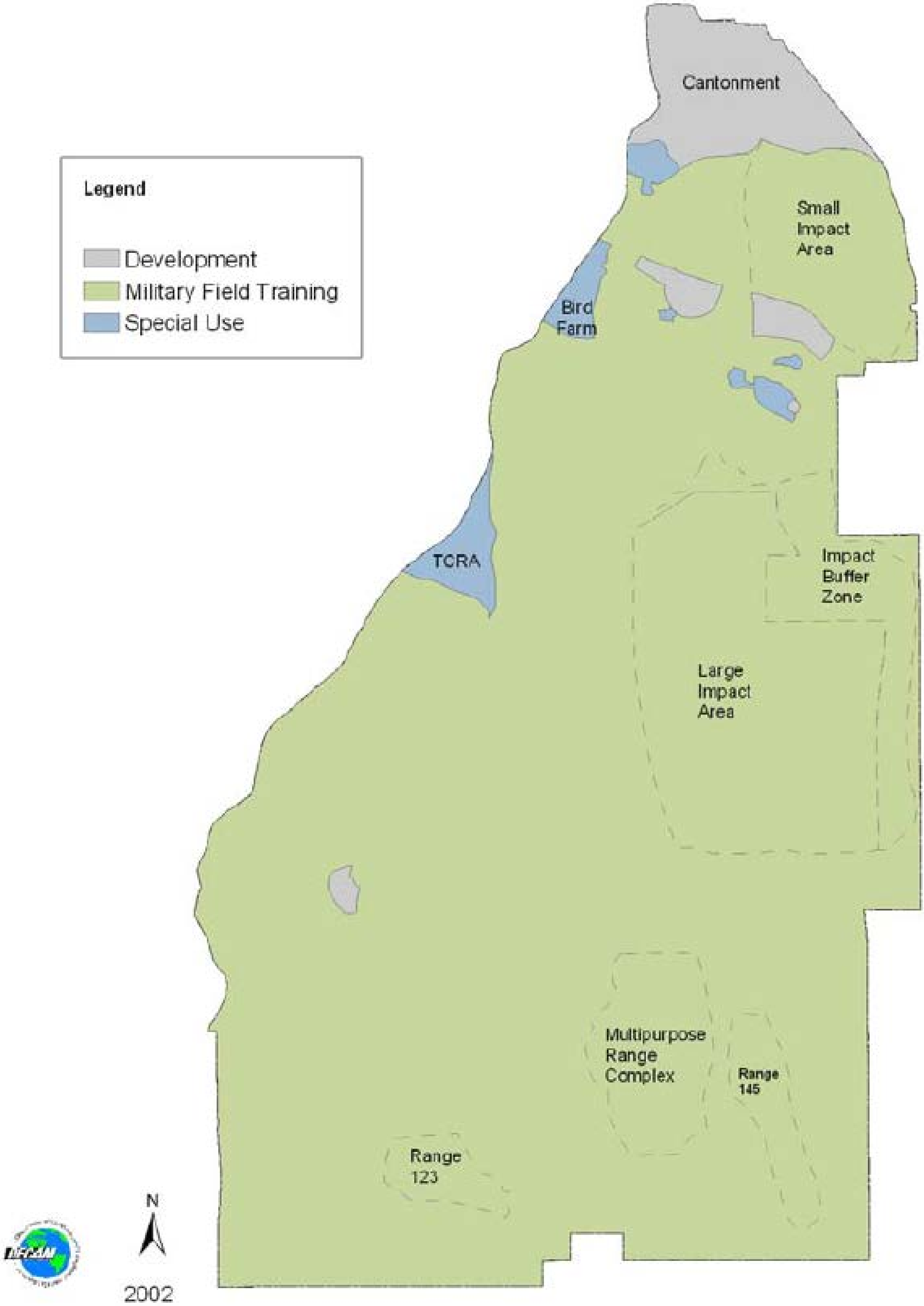



**Figure 4. Fort Carson General Land Use.** Source: DECAM 2007.

In 1990 the system was changed. The PCMS was divided into 24 Training Areas (Figure 5) to allow for greater flexibility and deferment of approximately 50% of the available Training Area at any given time. For the primary military use for each training area at the PCMS, see Table 3.4.2.3b of DECAM 2007. Dismounted training is allowed in areas deferred from mechanized training.

A new rotation was implemented beginning in fall 1992 (DECAM 2007). Approximately 92,000 acres of available maneuver lands were being rested for a period of two years. In 1997 the system was again adjusted to provide more site-specific rehabilitation options and increase military training options. The 24 designated training areas were unchanged; however, units could use a combination of training areas to form a maneuver box, such as is often used in Training Areas 7 and 10, to accommodate certain larger area training requirements. Certain training areas are available only for dismounted training (those designated with letters). Lettered areas are always available for dismounted training. Smaller, numbered Training Areas (1, 2, 3, 4, 5, 6, 8, and 9) are rested as needed. There is also a provision to use deferment designations to protect site-specific rehabilitation sites in damaged portions of maneuver boxes. The end result of the rest/rotation/deferment program at the PCMS is that virtually all areas of the PCMS (except the Cantonment Area and the Wildlife Area/Safety Buffer along the canyon rim) are open to some types of training virtually all of the time. Damaged areas are identified and referred to ITAM for repair, and sensitive areas are protected from potentially damaging training. Restricted Training Areas B and C were formerly the Soil Protection Area (Figure 6). The Soil Protection Area was off-limits to all training from 1983 until 1990 when it was open to dismounted-only training through 2004. However, since the area has recovered over the past 20 years, most of it was opened to mechanized military maneuver in 2005. Remaining protection areas (dismounted training only) consists of Soil Protection Sites.

The PCMS constructed live-fire ranges just south of the Cantonment Area in 2004-2005 for small arms qualification and a Live Fire Maneuver Range for convoy type training in the north-central portion of the installation (Figure 5). None of these ranges use ammunition that can generate unexploded ordnance.

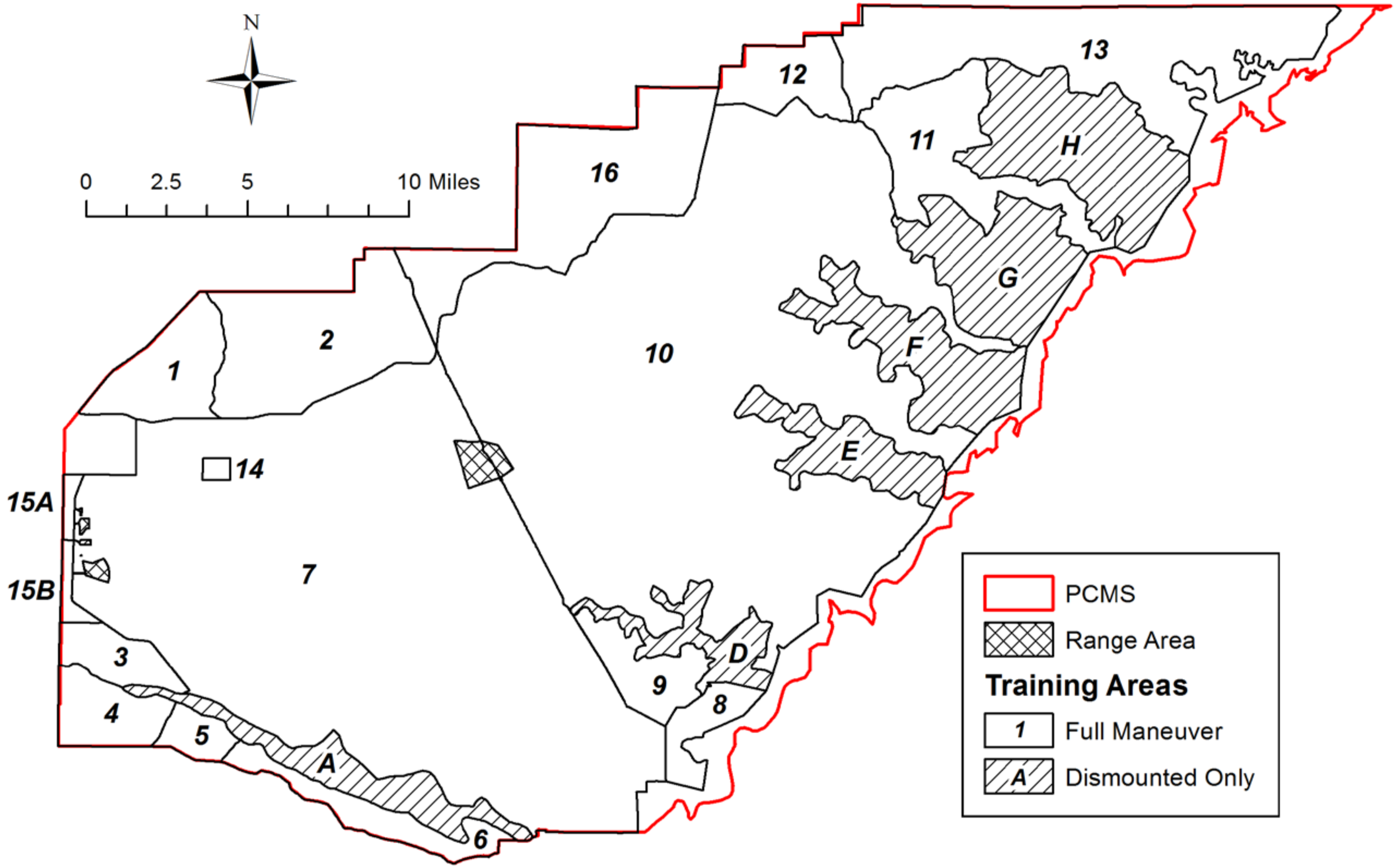



**Figure 5. PCMS Training Areas and Ranges.** Source: DECAM 2007.

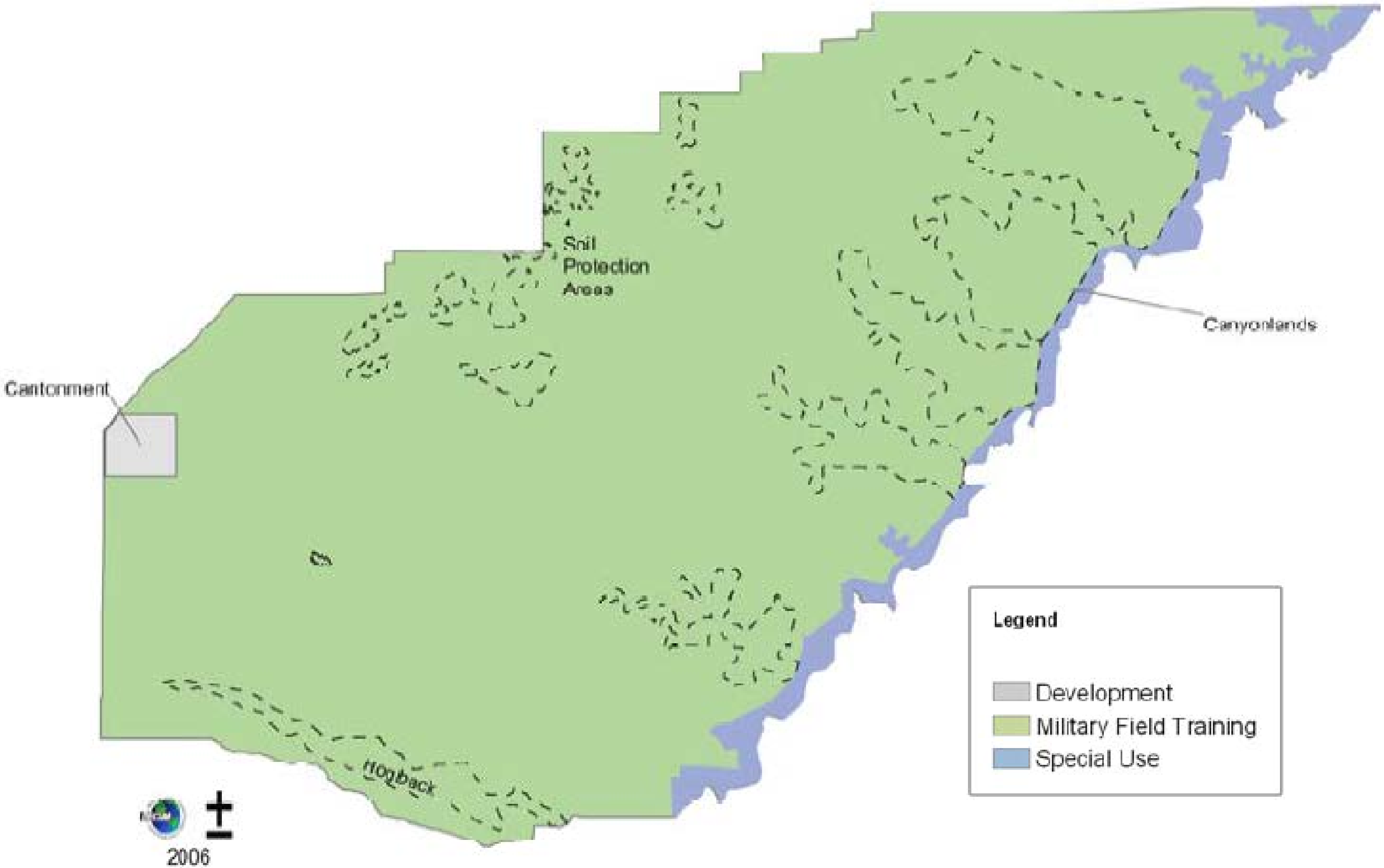



**Figure 6. General Land Use on the PCMS.** Source: DECAM 2007.

## 2.2 Historical Use and Missions[2]

### 2.2.1 Fort Carson

On January 6, 1942, one month after Pearl Harbor was attacked, the site for Camp Carson was selected. By November 4, 1942 construction was completed. Military training began in midsummer 1942, and 104,165 soldiers trained at Camp Carson during World War II. A Training Center for basic and advanced training was briefly activated in 1961, and in 1962 the Army's first mechanized infantry division (the 5th) was activated. Air operations, which began in 1949 on a dirt strip on the edge of the current installation, became a modern airfield in 1966 when Butts Field was completed. Between 1965 and 1966, 78,741 acres were added to accommodate requirements for mechanized training.

The most recent 15-20 years' changes in troop units at Fort Carson reflect the installation's evolving role in the defense of the nation. During this period, several units both were both added to and removed from Fort Carson leading to the current unit makeup (see Section 2.3.3). The most significant development in the structure of the units training at Fort Carson and PCMS in terms of environmental impact was the addition of the 1st Stryker Brigade Combat Team (1SBCT) in mid-2104.

### 2.2.2 PCMS

In the mid-1970s the Army began searching for additional land on which to conduct military maneuvers. The additional land was necessary for brigade-sized units of the 4th Infantry Division (Mechanized) and associated reserve units. An Environmental Impact Statement (EIS) was prepared in 1980 to evaluate potential environmental impacts from the proposed acquisition of training land. After the EIS process was completed, 245,000 acres were purchased by September 17, 1983. Subsequently, several thousand acres, not suitable for military training due to terrain or to being landlocked (no access), were turned over to the US Forest Service, Comanche National Grasslands. That transfer left the PCMS with approximately 236,000 acres. Military training began in August 1985. No troop units are permanently stationed at the PCMS. Training areas at Fort Carson and the PCMS have been viewed holistically in recent years, with a view to accommodating the needs of increased numbers of soldiers and units assigned to Fort Carson. There are a limited number of small arms ranges and specialty ranges such as the live-fire convoy range, but the PCMS's primary purpose is still mechanized maneuver training. There is a small permanent group of civilian employees at the PCMS, which is augmented during training exercises.

### 2.2.3 Past Training[3]

#### *Fort Carson*

Past training largely resembles current training patterns. See section 2.3 for current training types and patterns. The primary departure from past training at Fort Carson is the addition of units due

[2] Adapted from DPW 2015.
[3] Adapted from Doe et al. 2008

to 2005 Base Realignment and Closure, as well as a reduction in deployments due to the end of large scale military operations in Iraq and Afghanistan. These factors will likely lead to an increase in heavy maneuver training at Fort Carson and PCMS, but are not expected to increase beyond previously analyzed levels (DPW 2015).

***PCMS***

Full-scale maneuver training activities at PCMS were initiated in 1986 approximately three years after the Army completed the land acquisition purchase. The frequencies, durations and intensities of military training exercises at PCMS have varied significantly over the 1985-2008 period due to the type and quantity of units stationed at Fort Carson, their mission and training requirements, and deployment-rotation schedules to overseas theaters. Table 2 provides a summary of the training usage of PCMS during the period 1985-2008, specifically indicating number of "training weeks" during which major training events occurred (Note: this information extracted from internal data provided by Fort Carson). This training summary does not provide specific information on exact training locations used within PCMS. However, it can be presumed that the major Brigade-sized training events utilized the majority of the PCMS maneuver space to some degree, with higher use occurring in the core of the maneuver corridor (TA 7 and 10) and other preferred areas.

Typically, during these designated training periods, brigade-sized units (3,000-5,000 Soldiers and 300-400 vehicles), occupied PCMS for a 4-5 week period, using the major training areas/maneuver corridors associated with current Training Areas 7 and 10 (formerly Training Areas A, D and E), and comprising approximately 130,000 acres, or approximately 55% of the total PCMS acreage. Each Brigade-level training rotation/iteration at PCMS generally consisted of a continuous period of training, beginning with small unit training in preparation for the capstone force-on-force maneuver event. During the initial two weeks, smaller-units (platoon, company and battalion) within the brigade would establish training sites and conduct unit-level competency activities within designated training areas/complexes. The remaining three weeks would be used to conduct force-on-force scenarios across broad expanses of the PCMS landscape. These fictional scenarios would be driven by an operational concept and associated maneuver graphics overlays, indicating unit boundaries for maneuver within the prescribed training areas. Individual units and vehicles would thus maneuver according to these general scenarios using prescribed tactics and procedures. Therefore, while it is impossible to document the exact locations and paths used by each vehicle it is generally understood from these scenarios where the most vehicle traffic would occur. Similarly, the locations of large assembly areas and resupply points during the exercise are not specifically known, but generally follow the same patterns of use due to terrain operational restrictions.

The data shown in Table 2 indicates that the decade from 1990-1999 represents the major use period of PCMS in terms of the frequency and magnitude of training events, with an average of approximately 12 weeks of usage per year. During this 10-year period, Brigade-sized rotations/maneuvers of Mechanized Infantry and Armored Cavalry units occurred throughout all four seasons of the year, with several years (1991, 1992, 1993, 1995, and 1997) experiencing three out of four seasons of use. This period of use is also significant because it parallels the re-stationing

**Table 2. PCMS training cycles from 1985 to 2008.** Distinct periods of training intensity are represented by four horizontal bands. Source: Doe et al. 2008.

**PCMS Training Cycles, 1985 - 2008**
**Maneuver Brigade-sized Rotations (Weeks of Use)**

| YEAR | WINTER | SPRING | SUMMER | FALL | SUM | | KEY EVENTS | TRAINING NOTES/ Units Training | Tng Land Mgmt Policies |
|---|---|---|---|---|---|---|---|---|---|
| 1985 | | | 4 | 3 | 7 | 48 | | 2/4 INF | Rest-Rotation Cycle: 5 large tng areas (A-E), with 60% of lands rested for 2-yr period; Soil Protection Areas in place |
| 1986 | 3 | | 5 | 4 | 12 | | | 3/4 INF, 1/4 INF | |
| 1987 | | 3 | | 3 | 6 | | | 2/4 INF, 3/4 INF | |
| 1988 | 4 | | 5 | | 9 | | | 3/4 INF | |
| 1989 | 7 | | 3 | 4 | 14 | | | 1/4 INF, 2/4 INF, 3/4 INF, 35 ID (ARNG) | |
| 1990 | | | 5 | 7 | 12 | 105 | | 3/4 INF, " STRIKER CHALLENGE" | Revised training areas - 24 TAs with 50% of land rested at any given time; Maneuer Damage/wet soils restrictions in place; Soil Protection Areas in place |
| 1991 | 4 | 4 | | 4 | 12 | | Operation Desert Storm: Aug 1990- Feb 1991 | 1/4 INF, 2/4 INF, 3/4 INF, 35 ID (ARNG) | |
| 1992 | 4 | 4 | | 7 | 15 | | Somalia Conflict: Aug 1992 - Mar 1994 | 1/4 INF, 3/4 INF, 7/158 AVN | |
| 1993 | 2 | 10 | | 7 | 19 | | | 1/4 INF, 3/4 INF, 3/3 CAV, 4/3 CAV | |
| 1994 | | | 4 | 7 | 11 | | Bosnian Conflict:March 1992 - Nov 1995 | 1/4 INF, 3/4 INF | |
| 1995 | 8 | 4 | 3 | | 15 | | | 3/4 INF, 137/69 BDE (35 ID) | |
| 1996 | 4 | | 4 | | 8 | | | 3/4 INF, 1/3 CAV | |
| 1997 | | 2 | 3 | 8 | 13 | | | 3/4 INF, 1/3 CAV, "STRIKER CHALLENGE" | |
| 1998 | | | 6 | | 6 | 31 | | 3/4 INF | Revised rest-rotation land use - no formal removal of land for rest. Numbered Tng Areas rested as need with site-specific rehabiliation; Spring deferment eliminated ; Wet soils policy & Soil Protection Areas in place |
| 1999 | | 1 | 4 | | 5 | | | 3/4 INF, 1/3 CAV | |
| 2000 | | 5 | | | 5 | | | 3/4 INF | |
| 2001 | 6 | | | | 6 | | | 2/3 CAV | |
| 2002 | | 5 | | | 5 | | | 1/3 CAV | |
| 2003 | | | | | 0 | | | Company and below-sized events only | |
| 2004 | | | 4 | | 4 | | GWOT | 2/2 INF | |
| 2005 | | | | | 0 | 4 | GWOT | Exercise Bayonet Strike (2/2 INF); Company and below-sized events only | Soil protective areas opened to mechanized maneuver use; revised to Soil Protection Sites only |
| 2006 | | | 1 | | 1 | | | | |
| 2007 | | | | | 0 | | | | |
| 2008 | 3 | | | | 3 | | | 2/4 INF | |
| SUM | 45 | 38 | 51 | 54 | 188 | 188 | | | |

| LEGEND: Unit | Full Unit Title | Home Station |
|---|---|---|
| 1/4 INF | 1st Brigade, 4th Infantry Division (Mech) | Fort Carson, Colorado |
| 2/4 INF | 2nd Brigade, 4th Infantry Division (Mech) | Fort Carson, Colorado |
| 3/4 INF | 3rd Brigade, 4th Infantry Division (Mech) | Fort Carson, Colorado |
| 1/3 CAV | 1st Squadron, 3rd Armored Cavalry Regiment | Fort Carson, Colorado |
| 2/3 CAV | 2nd Squadron, 3rd Armored Cavalry Regiment | Fort Carson, Colorado |
| 3/3 CAV | 3rd Squadron, 3rd Armored Cavalry Regiment | Fort Carson, Colorado |
| 4/3 CAV | 4th Squadron, 3rd Armored Cavarly Regiment (Avn) | Fort Carson, Colorado |
| 2/2 INF | 2nd Brigade, 2nd Infantry Division | Fort Carson, Colorado |
| 35 ID | 35th Infantry Division, Army National Guard | Fort Leavenworth, Kansas |

of the Third Armored Cavalry (3ACR) Regiment from Fort Bliss, TX to Fort Carson, CO in the 1995-96 period. The use of PCMS by the 3ACR was significant for several reasons: 1) it is one of the largest mechanized units in the Army force, 2) its reconnaissance and security missions dictate large geographic areas of responsibility requiring more training space than available at Fort Carson, and 3) the 3ACR places a high value on maneuver/reconnaissance training in the field. Thus, the ACR was predisposed to fully utilize the land resources available to them at PCMS. These factors ultimately led to considerations and revisions of the land use criteria and controls at PCMS, as documented in the *Environmental Assessment for Training Area Management and Modifications for PCMS* (U.S. Army 1997), in accordance with the National Environmental Policy Act (NEPA). The EA was intended to provide more flexibility to the 3ACR for its training mission and included 1) elimination of the spring and winter deferment periods and modified restrictions to off-road vehicular maneuver, and 2) temporary realignment of some of the Training Areas to allow use of a larger portion of the combined maneuver area. The EA was approved with a Finding of No Significant Impact (FONSI).

In the earlier years of use (1985-89) there were typically only two out of four seasons of use, with very limited use during the Spring season (1987 only). Subsequently, in the later period (2000 – 2008), use of PCMS significantly declined due to overseas rotations of units associated with the Global War on Terrorism (GWOT). During this most recent period, Brigade-sized training activities have been limited to a maximum of one season of the year, with several years experiencing no Brigade size events.

No live-firing training occurred at PCMS until 2005. In 2005 an Environment Assessment approved the construction of small arms ranges on PCMS, including a live-fire convoy range. This was a necessity required by range capacity shortfalls for through-put at Fort Carson as deploying units in the GWOT came to Fort Carson for pre-deployment training. This approval and eventual range construction marked a major change in the Army's intent and use of PCMS. This live fire range use has been limited to small-caliber, non-dud producing rounds.

## 2.3 Training Types, Current Missions, and Units by Type

### 2.3.1 Training Types[4]

The type of training occurring within a certain area is important to assessing the potential impact to the natural resources of that area. The following broad training types occur on Fort Carson and/or PCMS.

***Maneuver***

Maneuver has perhaps the greatest potential to affect land condition on both Fort Carson and the PCMS. Tactical maneuvers reduce vegetative ground cover and may increase bare ground area. As a result, the potential for soil erosion increases due to the loss of vegetation and to soil compaction. Erosion can eventually affect water quality through accelerated sedimentation and alteration of the soil horizons, making subsurface minerals and elements available.

Mounted training is difficult to quantify in terms of its effects on the land. General types of vehicles (tracked or wheeled), vehicle weight and its distribution on the land (i.e., tracked vehicles better

[4] Adapted from DECAM 2015.

distribute weight), and conditions under which a vehicle operates (e.g. wet weather increases the potential for damage) are important. Mounted maneuver can produce objectionable noise, particularly when heavy vehicles move close to boundaries at night. Both mounted and dismounted maneuver have potential to impact soils, vegetation, wildlife, and cultural resources through ground disturbance. Mounted maneuver operations have the potential to create pollution from spills of petroleum, oils, or lubricants. Installation-wide vegetation monitoring by ITAM's Range and Training Land Assessment (RTLA) program, in conjunction with as-needed surveys of wildlife, cultural resources, and soils, provide the data needed to plan for the reseeding work, erosion control projects, etc. needed to maintain both installations in a usable condition for military training for the period covered by this Integrated Natural Resource Management Plan (INRMP) and beyond.

***Dismounted***

Dismounted training areas are areas where Soldiers can move on foot but no vehicular traffic is permitted. Dismounted training areas at PCMS primarily include canyons that are unsuitable for mechanized training. Dismounted training results in environmental impacts that are similar to those caused by recreation activities, such as hiking or camping. Dismounted training seldom affects large acreages, but it can have long-term impacts on regularly used trails.

***Live Fire***

Live fire can use ammunition having projectiles that are not explosive (e.g. most rifle/pistol, machine gun, inert tank, and inert artillery rounds) in which case the impact portion of the range is not "dudded" with unexploded munitions. These impact areas can be used for other purposes when not in use for firing. Other weapons use ammunition having projectiles that are explosive and can create a "dud" (unexploded round). Access is restricted in these impact areas unless they are cleared of unexploded munitions. Most long-range weapon systems (e.g., artillery, tanks, Multiple Launch Rocket Systems) use the same impact area for explosive and inert rounds. Thus, these areas are generally not available for maneuver training or other uses.

Fort Carson has ranges and impact areas sufficient to allow firing of almost all weapons in the Army inventory, to include many types of explosive projectiles. However, at PCMS the only weapons that can be fired with live ammunition are .50 caliber machine gun and smaller (no exploding projectiles), and simulated munitions. Aviation firing of .50 caliber and smaller is also permitted at PCMS.

Surface danger zones and impact areas (large caliber, small caliber, and airburst weapons) occupy a considerable amount of land at Fort Carson. Thus, they reduce options to conduct other types of training. Also, to minimize space used and for safety reasons, live firing must be conducted from relatively close to boundaries, which increases off-post noise impacts. Types of munitions (e.g. high explosive duds virtually exclude other uses) also affect training options within impact areas and within the surface danger zones. Range locations and configurations can also reduce options for training. Range size, location, and configuration are often determined by training requirements and safety factors with few options with regard to siting. For example, the Live-Fire Maneuver Range at the PCMS affects maneuver training opportunities in a large portion of the PCMS when the range is operational.

Live firing certain munitions (e.g. incendiary, high explosive, tracer rounds) requires careful range management, since they can cause wildland fires with the potential to extend beyond the impact areas.

Construction and upgrades of ranges often involves temporary soil disturbance, thus potentially impacting wildlife and vegetation. Ground disturbance and direct destruction from ordnance impact can also impact wildlife resources. There are very few ranges where shotguns can be fired. The Army only authorizes #9 Shot and 00 Buckshot. Ranges where civilian shooting occurs, such as the Olympic range (new one in development off gate 20), shoot #2-9 with #7-9 being most common. There is limited potential for migration or leaching of this lead off firing ranges. Many research programs and site characterizations have occurred on Army ranges since the 1990s in order to both understand the fate and transport of lead associated with small arms ranges and manage that lead, keeping it on the small arms ranges and not migrating away from those ranges.

Small-arms live fire ranges can be used for maneuver training at PCMS when not active.

***Bivouac***

Bivouac sites (temporary encampments) can create damage, particularly if the activity is repeated in the same area, or the unit remains in the same bivouac area for an extended period of time. Often, the first steps in land degradation from bivouac activities are soil compaction and the loss of ground cover, which can be followed by localized erosion and possibly increases in down-watershed stream sedimentation. Ground disturbance associated with bivouac can also impact wildlife resources.

***Aviation***

Environmental impacts of aviation activities at Fort Carson and the PCMS, which consist mainly of helicopter flights, include aircraft noise, minor disturbance to landing and drop zones, potential dust issues at some landing zones, possible disturbance to nesting birds, and training activities of troops following air arrival. Some aviation operations have the potential to create pollution from spills of petroleum, oils, or lubricants. Live fire from helicopters can cause wildfires and wildlife risks. Compared to impacts of heavy units, however, the impacts of aviation operations are very light. Dust issues at landing zones can be reduced by using compounds such as magnesium chloride, or various types of soil binding agents. Vegetation damage is usually minimal, since aviation support vehicles mostly travel on existing roads and two-tracks. SOPs require containment berms, etc. at forward area refueling setups, so the risk of water pollution from a spill is very low. Therefore, an increase in aviation assets, even as large as a CAB, is not expected to have a significant impact on environmental resources. Live fire from aviation is allowed on Fort Carson and PCMS.

***Engineer Operations***

Engineer activities (e.g. digging fighting positions or tank ditches, obstacle removal, construction of forward operating bases [FOBs]) disturb soil, which can affect various natural resources. Demolition can cause noise and dust. Engineer operations have the potential for pollution from spills of petroleum, oils, or lubricants. Other combat engineer activities can be beneficial to natural resources. Combat engineers projects (e.g., training land rehabilitation, erosion control structure construction, site hardening) also can protect the environment from damage in the future. Digging is prohibited in areas where known cultural resources may be disturbed.

***Use of Smoke***

Many military operations involve using a cloud of smoke that is artificially generated in order to obscure the enemy’s ability to observe friendly activities. Fog oil operations have the potential to create pollution from spills of fog oil or petroleum, oils, or lubricants used by vehicles in the operations. Procedures in support of air quality regulations must be followed to avoid smoke drifting off the installation.

### 2.3.2 Current Missions

***Fort Carson***

Fort Carson is used for live-fire gunnery and is best suited for squad- to battalion-sized maneuvers and lane training of both reserve and active components. However, brigade-size exercises are sometimes conducted at Fort Carson. Training is nearly continuous year-round. The majority of training at Fort Carson is confined to live-fire ranges, either for live-fire exercises, or occasional maneuver training in larger ranges when not being used for live-fire exercises. The majority of vehicles use established roads, which limits the environmental impact from training at Fort Carson (DPW 2015).

***PCMS***

The PCMS is best used for battalion- and brigade-sized maneuvers, lane training, small arms live-fire ranges, and force-on-force exercises, usually by mechanized infantry. Since 2002, military units have been deployed resulting in less training on PCMS. However, more military units are now stationed at Fort Carson, and deployment schedules are expected to slow down somewhat (DPW 2015).

### 2.3.3 Current Military Units

This baseline was used in the PCMS Training and Operations Draft EIS and confirmed by ITAM personnel in 2015 (Table 3) (Potomac-Hudson Engineering, Inc. 2014) and is realistic in terms of overall troop levels and training needs. The stationing of units, however, is dynamic, and the description of the force structure described here might not depict the on the ground conditions at Fort Carson and related training schedules at PCMS.

**Table 3. Current military units stationed at Fort Carson / PCMS.**

| Unit | Soldiers | Wheeled Vehicles | Tracked or Stryker Vehicles | Annual Training Days | Training Types |
|---|---|---|---|---|---|
| 1st Stryker Brigade Combat Team (1SBCT) | 4,454 | 588 | 366 | 25 | Mounted and dismounted maneuvers, mounted occurs primarily on existing roads and trails |
| 2nd Infantry Brigade Combat Team (2IBCT) | 4,296 | 800 | 12 (Engineer equipment) | 25 | Dismounted Maneuvers |
| 3rd Armored Brigade Combat Team (3ABCT) | 4,655 | 830 | 316 | 25 | Mounted Maneuvers |
| 4th Combat Aviation Brigade | 2,700 | 113⁺ | - | - | Use of Landing Zones; potential for infantry transport to lettered training areas at PCMS |

### 2.3.4 Current Patterns of Use and Training Loads

***Fort Carson***

Military use on Fort Carson is primarily in the form of live-fire ranges. Live-fire training is conducted at ranges designed specifically for the weapon or weapon system being used within it. Large scale maneuvers cannot be conducted in many areas at Fort Carson. Most of the interior of the installation is used for impact areas, firing range safety fans, and developed areas (such as the catonment). The maneuver training that does occur on Fort Carson is relegated to the boundary areas in the south and west of the installation.

***PCMS***

The majority of current use at PCMS in terms of environmental impact is in Training Areas 7 and 10, followed by 12 (Figure 5). Training Areas 7 and 10 provide a large "corridor" where brigade level training can be conducted over long distances and large areas. These training areas are used for brigade-level maneuver training using tanks and Strykers. Dismounted and aviation training occurs in lettered training areas. Training loads have not exceed the loads described in the 1980 Land Acquisition EIS (Potomac-Hudson Engineering, Inc. 2014) and in fact have been substantially lower due to near constant deployments to the Middle-East since 2002. In June 2015, a battalion level Stryker exercise was conducted at the PCMS. This exercise was done after a substantial rainfall period and caused considerable damage (Rick Doom, ITAM Coordicator, personal communication).

### 2.3.5 Anticipated Future Missions, Patterns of Use, and Training Loads[5]

Units may change in the future, but there are no known plans to change the general types of military training activities conducted at Fort Carson and the PCMS. However, the intensity may vary, depending on training needs, world conditions, and budgetary constraints. Currently, the Army is in the process of increasing the dwell time (time on duty at home station rather than deployed) of all units, and expanding training to cover all of its units' potential missions, not just the limited scope required in the current theater of operations. Assuming that this process is implemented, and assuming that training is not curtailed by budgetary pressures, this may mean a gradual increase in training at both installations, which could cause greater impact on vegetation, soils, etc. Heavy maneuver training events will likely occur more regularly than in the past decade, but are not expected to increase beyond historically analyzed levels. Also, in terms of both installations, the ITAM program as well as the DPW Conservation Branch programs are scalable; i.e. they can be expanded as the need arises, if funding and position authorizations are made available by higher headquarters.

## 2.4 Potential Training Impacts

### 2.4.1 General Ecological Impacts from Military Training in Semi-Arid Environments

Military training impacts include soil compaction and loss, reduced hydrologic/site stability associated with vegetation loss and soil disturbance, reduced infiltration and increased runoff, increased fire frequency from military ignition sources, and damage to native vegetation, including promotion of weed establishment through soil disturbance and seed transport. The most significant sources of damage to upland vegetation are off-road vehicle maneuvers and administrative or support activities. In terms of

[5] Adapted from DECAM 2015.

maneuver damage, tracked vehicles are responsible for the majority of damage, but significant disturbance can also result from wheeled vehicles, especially during wet soil conditions when rutting is more likely. Ecological damage from maneuver training tends to be patchy, with small areas of intense impact surrounded by large areas with little to no damage (Figure 7).

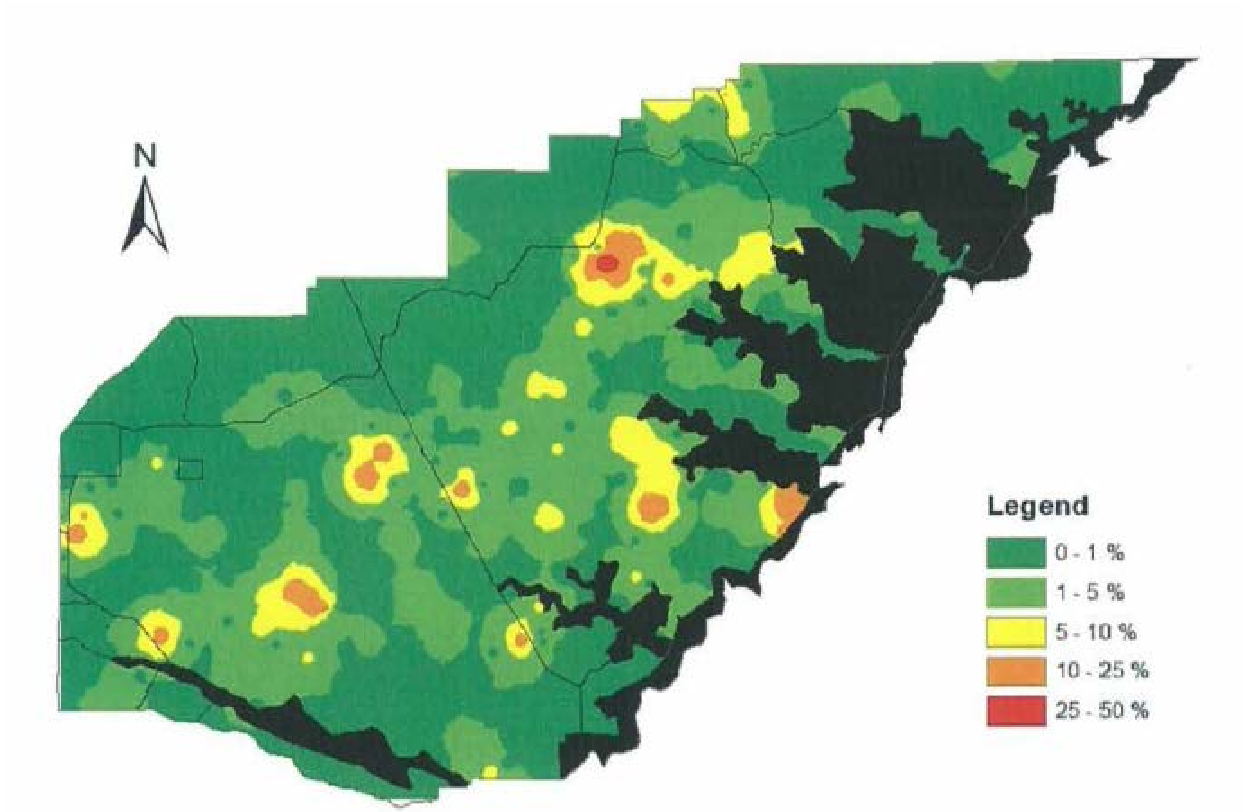



**Figure 7. Maneuver disturbance at PCMS, 2012.** Source: Schulte 2012.

Numerous studies have documented the effects of tracked vehicles on soils and vegetation in military training areas (see reviews in Anderson et al. (2005) and Guretzky et al. (2005)). However, more information is needed on vegetation response and recovery rates following military disturbance in shortgrass steppe environments. Military vehicle traffic impacts to soil physical properties include increased bulk density (soil compaction), decreased surface soil strength, and decreased hydraulic conductivity (Braunack 1986, Thurow et al. 1995). Soil compaction affects erosion potential by altering the stability and size distribution of soil aggregates, and increasing soil bulk density and penetration resistance (Figure 8) (Thurow et al. 1995, Gatto 1997). The susceptibility of a soil to compaction is primarily a function of soil moisture, texture, and organic matter (Koolen 1987, Unger and Kaspar 1994). Loamy and clayey soils and soils with a mixture of particle sizes are more susceptible to compaction than sandy soils (Webb 1982, Unger and Kaspar 1994).

Increases in soil bulk density and penetration resistance are generally minimal at the surface, where recovery is more rapid, but are more pronounced and may persist for longer periods at depths ranging from 10-50 cm (Prose 1985, Gatto 1997). Braunack (1986) found that the magnitude of tracked vehicle impact was dependent on the soil type, number of passes, and whether the vehicle was turning or traveling in a straight line. These changes in soil physical properties can increase interrill erosion rates on western grasslands (Thurow et al. 1995). Soil property changes may also retard or prevent reestablishment of the original plant communities (Shaw and Diersing 1990). Impacts to soils from a single tank pass may persist for decades in fragile ecosystems (Prose 1985). Weakened soil aggregate stability and disturbance to microphytic soil crusts following vehicle maneuvers can also increase wind erosion potential (Grantham et al. 2001, Belnap et al. 2007). Soil moisture conditions at the time of

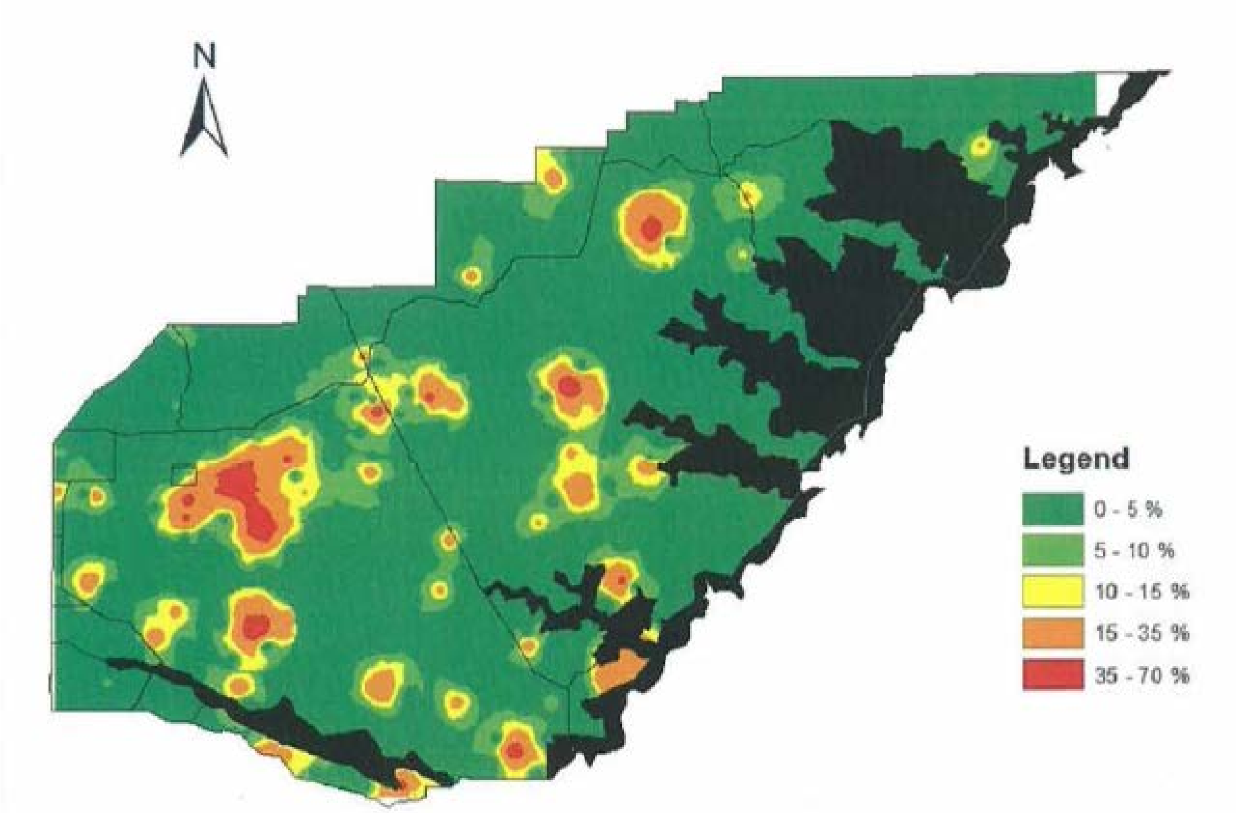



**Figure 8. Erosion disturbance at PCMS, 2012.** Source: Schulte 2012.

tracking can influence the post-tracking hydrological characteristics of soils (Thurow et al. 1995, Halvorson et al. 2001, Jones 2003, Althoff and Thien 2005), with higher indices of compaction associated with moist soil conditions.

Tracked vehicle damage to vegetation includes crushing and shearing of above-ground plant parts (Figure 9) and damage or destruction of roots and other below-ground structures (Figure 10). Vegetation loss may be influenced more by shearing forces exerted by the vehicle on the soil surface than by soil compaction caused by ground pressure forces (Ayers 1994). Military vehicle impacts to vegetation communities include decreased woody plant density and canopy cover (Wilshire and Nata 1976; Jones and Bagley 1998; Watts 1998), loss of native bunchgrasses (Thurow et al. 1995, Jones and Bagley 1998, Watts 1998, Jones 2003), an increase in non-native annual grasses and forbs (Goran et al. 1983, Shaw and Diersing 1990, Thurow et al. 1995, Watts 1998, Jones 2003), and decreased plant diversity (Lathrop 1983). In a shrub-grassland community in southeastern Colorado, Milchunas et al. (1999) found that increasing disturbance by tracked vehicles was associated with reduced vegetation basal cover and litter ground cover, and the replacement of long-lived perennials with short-lived perennials. In a southeast Montana rangeland community, Leininger and Payne (1980) found that off-road traffic in moist soil conditions resulted in significantly more vegetation damage than in drier conditions. However, in a study in a central Texas grassland, Thurow et al. (1995) found that reduction of late-succession bunchgrass cover was related to the number of passes and was not affected by soil moisture status at the time of vehicle tracking. Similar results were reported for wet tracking treatments in sagebrush steppe at Yakima Training Center using M1A1 and M2A2 vehicles (Jones and Bagley 1998). Damage to vegetation and biological crusts from tracked vehicle neutral-steer turns (i.e., severe scraping, rutting, and mounding) is generally more severe than damage resulting from straight-line travel (Watts 1998; Haugen et al. 2003).

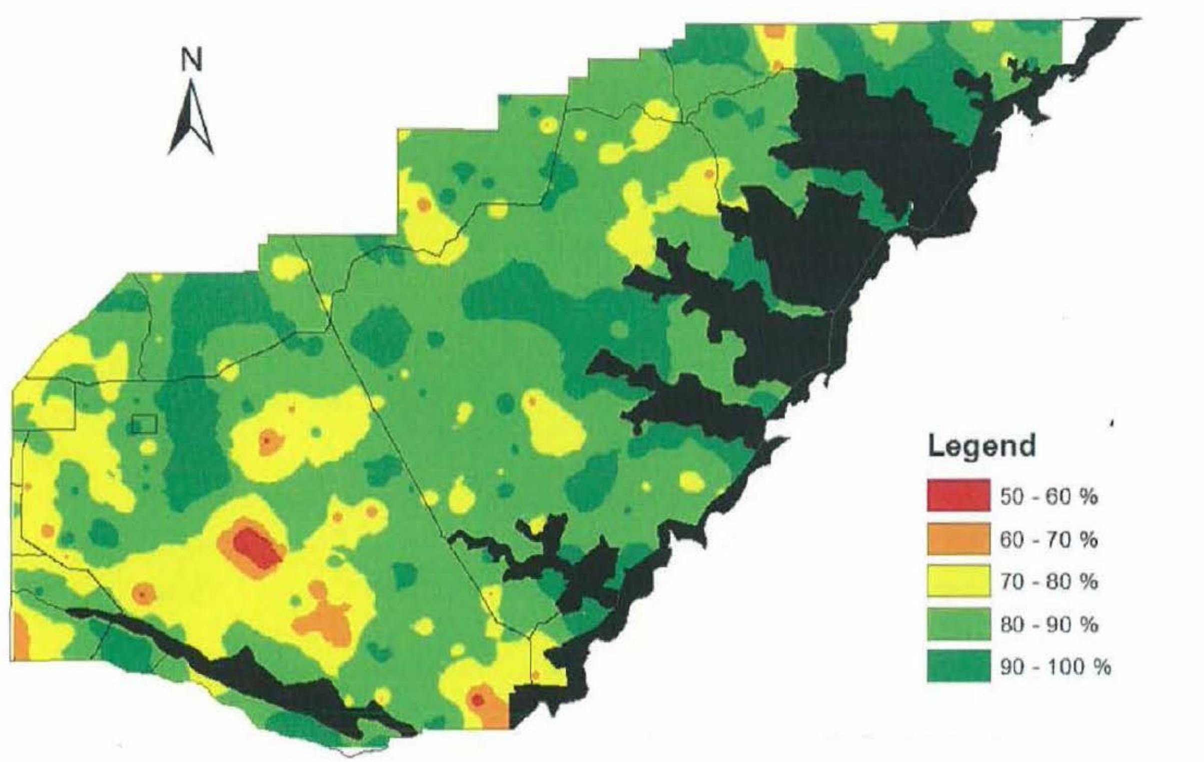



**Figure 9. Total Cover at PCMS, 2012.** Source: Schulte 2012.

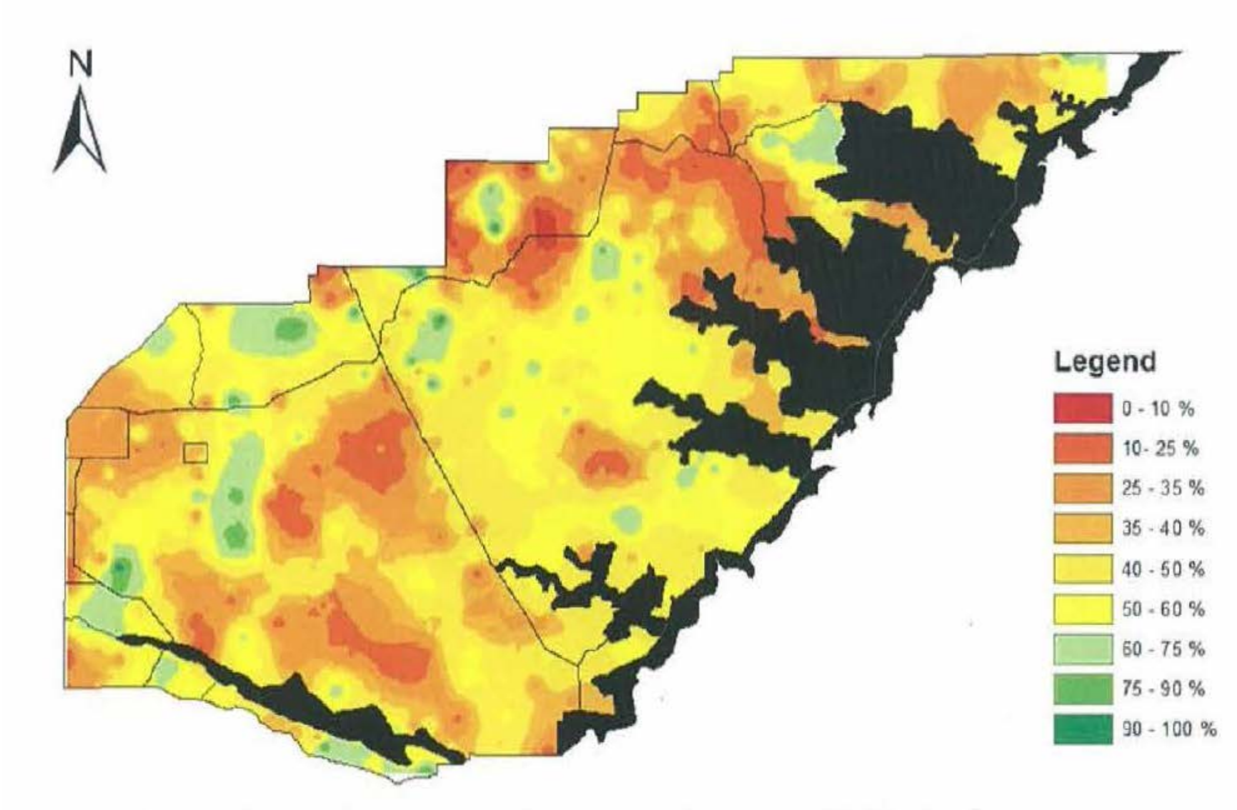



**Figure 10. Ground Cover at PCMS, 2012.** Source: Schulte 2012.

Disturbance to native vegetation may lead to the establishment of non-native species that out compete native species for resources such as physical space, moisture, nutrients, and sunlight (Figure 11). Where non-native annual species colonize disturbed areas, the lack of year-round foliage results in poor, short-term soil surface protection. Site conditions may become more extreme (i.e., elevated temperatures and more xeric) due to reduced microclimatic influences of larger perennial vegetation thus inhibiting germination and establishment of some species (Wight et al. 1991). In a study at Fort Hood, TX, repeated military tracking resulted in significant shifts in herbaceous communities from relatively large perennial plants to relatively small stature annual plants. Woody species composition was relatively unchanged but density and cover were significantly reduced (Severinghaus et al. 1981). Although total plant cover may recover to pre-disturbance levels, species composition may significantly shift from native perennial species to invading early successional species (Jones 2003). In many cases, annual plants provide reduced above and below-ground structure, groundcover, and soil stability compared to larger perennial plants. Loss of vegetation also increases erosion rates due to decreased rainfall interception and lower infiltration rates resulting from straight-line travel (Watts 1998; Haugen et al. 2003).

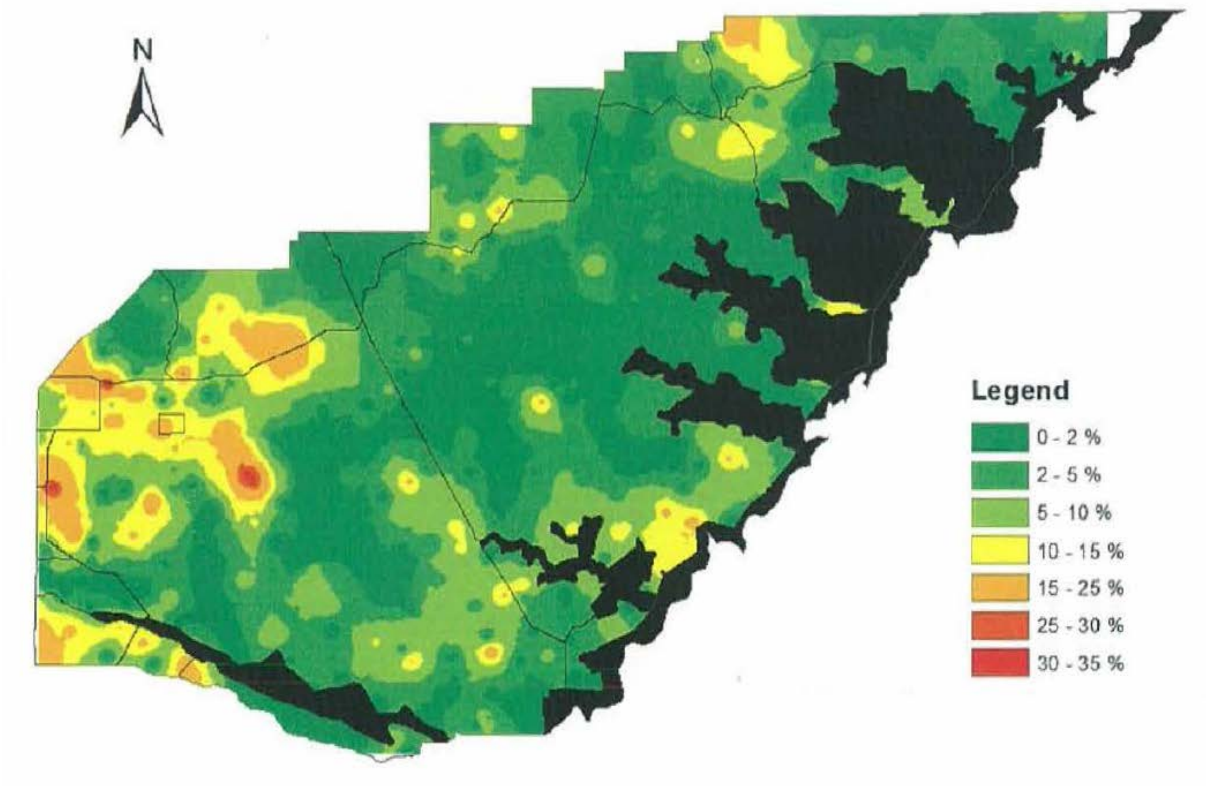



**Figure 11. Invasive Species at PCMS, 2012.** Source: Schulte 2012.

Based on observations at Fort Carson, CO, Goran et al. (1983) hypothesized that semi-arid vegetation communities appear to have a lower tolerance to military disturbance than either the more xeric shrublands of installations in Texas and California or the more mesic grasslands and woodlands of installations in the eastern U.S. This low tolerance may arise from several factors, including narrow ecological tolerance ranges of native plants near the edge of their geographic range, and susceptibility to weed invasion following disturbance. The response of shrub communities to disturbance is highly influenced by the adaptations of individual species (e.g., sprouting ability). An analysis of RTLA data by Milchunas et al. (1999) concluded that plant communities at semi-arid Fort Carson appear highly resistant to vehicle disturbance, but show low resilience once the community is altered beyond a particular ecological threshold. Once initiated, shifts in community composition may take decades or longer to return to the original vegetation, or may result in alternative potential communities.

## 2.4.2 Soils

***Resource Overview – Fort Carson***

Thirty-four soil categories and 65 soil associations have been identified on Fort Carson. Predominant soil associations are the Penrose-Minnequa Complex, Penrose-Rock Complex, Schamber-Razor Complex, and Razor-Midway Complex. A high shrink-swell capacity is the result of montmorillonitic clays dominating most soil complexes. Soil erosion, primarily from water runoff, is a significant problem on the installation. Soils of greatest concern for erosion control are clays, silty clays, and clay loams. Specific information concerning soils can be obtained from the soil surveys of El Paso, Pueblo, and Fremont counties, Colorado (available through the Natural Resources Conservation Service)(DPW 2015).

***Resource Overview – PCMS*** [6]

There are 31 soil associations recognized on the PCMS. Specific information concerning soils can be obtained from the Soil Survey of Las Animas County, Colorado. The western part of the PCMS is dominated by a flat to gently sloping plain. Soils in this portion are formed in wind-deposited lifts with occasional small ridges of limestone outcropping in some areas. Soils are generally silty and weakly developed and are calcareous throughout. One small area of sand dunes crosses midway through this landscape type. Range sites dominating this landscape are Loamy Plains on upland flats, Saline Overflow in depressions and along intermittent drainages, and Sandy Plains in sand dunes. This range site generally has a medium stability rating and will experience moderate soil losses by water erosion and high soil losses by wind erosion if disturbed.

The PCMS contains four major landscape types. Each landscape type has a characteristic pattern of soils as described briefly below. The first landscape type, located in the western part of the PCMS, is dominated by a flat to gently sloping plain. Soils in this portion are formed in wind-deposited lifts with occasional small ridges of limestone outcropping in some areas. Soils are generally silty and weakly developed and are calcareous throughout. One small area of sand dunes crosses midway through this landscape type. Range sites dominating this landscape are Loamy Plains on upland flats, Saline Overflow in depressions and along intermittent drainages, and Sandy Plains in sand dunes. This range site generally has a medium stability rating and will experience moderate soil losses by water erosion and high soil losses by wind erosion if disturbed.

The second major landscape type is composed of Limestone Ridges, which cross the northwestern corner of the PCMS and form a small divide oriented to the south in the western portion of the training area. Bear Springs Hills is the most notable feature in this landscape area. Soils are commonly stone-covered with limestone at 20 inches or less in areas supporting stands of pinyon pines and one-seed junipers and silty soils with limestone at 30 inches or more in gently rolling grassy areas. Soils are generally weakly developed, silty soils, calcareous, and contain low amounts of organic matter. Major range sites are Limestone Breaks on steep sideslopes, and Saline Overflow along intermittent drainages. This range site generally has a low stability rating and will experience high soil losses by water erosion and moderate soil losses by wind erosion if disturbed.

The third major landscape type occurs between the limestone ridges and the Purgatoire River. It is composed of a wide valley that crosses the PCMS from southwest to northeast. Soils in this area range from silty soils in flat areas, which are formed in a thin layer of wind-deposited silt, to clayey soils formed in weathered shale in broad concave areas. Soils adjacent to intermittent drainages range from deep medium textured soils in areas where soil has been deposited by water to shallow soils formed directly on shale at the heads of drainages where downcutting into the shale has occurred. Major range sites in this landscape type are Loamy Plains, Alkaline Plains, and Saline Overflow. The stability rating in this landscape type ranges from medium to low. Soils will experience moderate water erosion losses in most areas and moderate to high wind erosion rates if disturbed.

The fourth landscape type occurs where the canyon of the Purgatoire River and associated side canyons form a series of steep rock-strewn cliffs and rolling mesa tops. Steepest portions of the canyons contain

[6] Adapted from DECAM 2007 and DPW 2015.

cliffs and stony soils with dark colored noncalcareous surface layers, while associated rolling hillslopes have moderately deep silty soils with noncalcareous surface layers and some areas of stony soils and sandstone outcrops. Range sites occurring in this landscape are Pinyon-Juniper-Rockland and predominantly Loamy Plains and Sandstone Breaks, with some areas of Saline Overflow, and Salt Meadow. This landscape type has a medium stability rating in gently sloping areas and a low stability rating in steep areas. Water erosion rates range from moderate in gently sloping areas to very high in steep areas, and wind erosion losses will be moderate to high on almost all soils of this type if disturbed.

### *Impacts*[7]

Significant adverse impacts to soils could occur from increased BCT training within PCMS. Heavy tracked and wheeled vehicles associated with ABCT and SBCT training could potentially cause high levels of soil disturbance. Maneuvering with tracked and wheeled vehicles in fragile soils during unfavorable soil moisture conditions, as well as increasing Soldier and equipment densities during BCT training events, could potentially cause excessive soil loss that permanently impairs plant growth. Mitigation measures would reduce impacts; however, impacts may not be reduced to less than significant depending on training activities and the condition of the soil. In some instances, mitigation measures could require years of effort and could be dependent on available funding to be fully and successfully implemented.

Military ratings include vehicle trafficability for Type 1 and 5 vehicles in wet conditions/seasons for an average of 50 passes in the same area. Military category Type 1 vehicles are lightweight vehicles with low contact pressure (less than 2.0 pounds per square inch). Military category Type 5 vehicles are most all-wheel-drive trucks and a great number of trailed vehicles (trailers) and heavy tanks. Soils trafficability during the wet season is the capacity of soils to support vehicles in said category (Type 1 or 5). Relationships that describe the soil-vehicle interactions are based on soil strength, slipperiness, stickiness, large surface stones, and slope, and are the basis for soil trafficability interpretations. Characteristics of soils found on PCMS and their response to military vehicle training can be found in Table 3.5-2 of Potomac and Hudson Engineering, LLC 2015.

Soil erosion was and is a problem on PCMS from past range and grazing activities, to current maneuver training. While some of PCMS soils are relatively stable and level, composed of medium textured particles, many of the soils are highly erosive, situated on steep slopes, and/or composed of small particles that become easily detached. Five basic management techniques can be used to minimize military training effects to the soil and vegetation resources: (1) limit total use, (2) redistribute use, (3) modify kinds of use, (4) alter the behavior of use, and (5) manipulate the natural resources for increased durability.

The effects of military training and vegetation management on soil erosion vary widely depending on the type and intensity of the activity and the location of the activity in respect to soil stability and slopes. Flash flood events are not uncommon at PCMS, and gully erosion is often a natural result of the combination of erosive soils and fast flowing, high volumes of water. This erosion can be accelerated by training activities and by construction (DPW 2015). The PCMS vegetation cover change study, however, indicates that the vegetation within areas of disturbance is cumulatively the same or better than in 1984. Rest, rotation, and land rehabilitation programs (Section 3.3) in place at PCMS have aided in recovery (VersarGMI, 2015).

[7] Adapted from Potomac-Hudson Engineering, Inc. 2014.

Maneuvering heavy wheeled or tracked vehicles causes a high level of disturbance to soil and vegetation, and causes accelerated wind- or water-related soil erosion (Shaw and Diersing, 1989). In particular, repeated maneuvering on a smaller area would create the most disturbances to that area, especially locations with fine-textured soils which can be difficult to rehabilitate. As the vegetation coverage decreases and soil disturbance increases as a function of maneuver passes, threshold windspeed, an indicator of soil surface wind erosion stability, decreases (Grantham et al., 2001). Vegetation management (clearing) within the training areas can also impact soil stability. Tracked vehicles cause a decrease in soil strength and an increase in soil bulk density (decrease in soil pore spaces) (Braunack, 1986). Firing of munitions into the soil causes soil disturbance and increases the potential for wind and water erosion around heavily targeted areas. Munitions firing increases the potential for fire and in turn increases the potential for soil erosion due to lack of vegetative cover.

Shaw et al. (1989) conducted a study of soil capacity and tracked vehicle training at PCMS, and developed allowable use estimates based on soil properties and vegetative cover. The USLE was used to calculate soil erosion tolerance rates. The study found that the high and moderate carrying capacity soils typically were upland soils, gently sloping, and supported grassland and shrubland vegetation. The low or no carrying capacity soils had shallow, rocky profiles and steeper slopes. The authors recommended that training should be concentrated on the high and moderate carrying capacity soils, and avoided on the low or no carrying capacity soils. The techniques presented in the Shaw et al. (1989) study, along with those presented in a study on tracked vehicle impacts on vegetation at PCMS (Shaw and Diersing 1990) were refined and used to develop the LCTA (Land Condition Trend Analysis) program, that later became the RTLA program under ITAM (see Section 3.1.3) (Fort Carson 1989).

Wang et al. (2007) conducted a study at Fort Riley, Kansas, and reported that military training takes place unevenly in space, and therefore, causes variable disturbances to ground and vegetation cover. While some areas receive high levels of disturbance, other areas are not disturbed at all, and soil and vegetation conditions improve over time. The authors proposed using soil erosion status (ES) maps developed from applying algorithms modeled from plot data and Landsat Thematic Mapper images. Using such maps would give land managers a useful tool for deciding on individual training locations and rotation of land at rest. PCMS management is currently not using ES maps when making training area decisions, however, PCMS uses other tools to accomplish similar analyses.

Soil disturbances in general are correlated with a loss of vegetative cover. Several studies have found, however, that some soil disturbance is necessary in order to maintain biodiversity. Leis et al. (2005) analyzed the effects of term disturbance from military maneuvers on vegetation and soils in a mixed prairie area, using track disturbance and soil organic matter as a measure of short- and long-term disturbance. The authors found that plant species' richness peaked at intermediate levels of soil disturbance compared to low and high levels of disturbance, and that disturbance up to intermediate levels can be used to maintain biodiversity. Odmand et al. (2012) similarly found that severely disturbed habitats such as military training areas contribute to species diversity. Highly disturbed areas were found to host rare species not otherwise found in undisturbed areas. The authors concluded that soil disturbance can be used as a restoration measure particularly in dry sandy grasslands. Careful management, however, must ensure invasive exotic plants do not quickly invade the disturbed ground (VersarGMI, 2015).

### 2.4.3 Watersheds

***Resource Overview – Fort Carson***[8]

Fort Carson lies within the Arkansas River basin. Fountain Creek is the major surface drainage feature that receives runoff from the northeastern portion of the installation. Streams flow from the northwest to the southeast. The intermittent streams of Rock Creek and Little Fountain Creek converge and drain into Fountain Creek 2-3 miles east of Fort Carson. Turkey Creek, Red Creek, and Beaver Creek flow through the Installation and enter the Arkansas River to the south. The combined inflow upstream from Fort Carson of Little Fountain, Little Turkey, Rock, and Turkey creeks is estimated to average 8.64 cubic feet/second. The actual inflow to Fort Carson is less than this quantity because of stream flow diversions for municipal and domestic water supplies. Pumping groundwater from alluvial aquifers upstream from Fort Carson also reduces the quantity of stream flow entering the installation. The average water flow on and near Fort Carson is about 2-5 cubic feet/second. Some streams can be expected to have no flow at some time during the year. There are approximately 146 surface acres in 12 reservoirs for fishery and wildlife resources. The closest surface waters to the main post area are man-made impoundments that are primarily used for recreational fishing, including Haymes, Townsend, Womack, and Northside reservoirs. Teller Reservoir, located in the southern portion of the installation (south of Range 143 - Multi-Purpose Range Complex), provides erosion and sediment control and recreational fishing when water is present.

***Resource Overview – PCMS***[8]

The PCMS also is in the Arkansas River basin. The PCMS has fewer drainages than Fort Carson. The Big Arroyo drainage system is located in the northwest region and flows into Timpas Creek, approximately three miles northwest of the PCMS. The Purgatoire River and numerous ephemeral, intermittent, or perennial tributaries are also located within and adjacent to the PCMS. The Purgatoire River, which flows in a northeasterly direction, is a seventh-order tributary of the Arkansas River. Elevation differences in the Purgatoire River basin cause climatic variations, which, in turn, affect stream flow. During years with average and above-average snowpack, such as occurred in 1984, 30-50 percent of the annual stream flow of the Purgatoire River occurs during April and May. During the rainfall-runoff period, May through October, flash floods occur intermittently. Releases from Trinidad Reservoir, located about 53 miles upstream from the stream flow gauging station on the Purgatoire River near Thatcher, affect stream flow on an intermittent basis (Von Guerard et al. 1987).

***Impacts***

Military training activities can alter the watershed response from rainfall events due to compaction of the soil from vehicles, which decreases soil infiltration and increases surface runoff (Doe 1992). A scientific study of tracked vehicle impacts using test plots and a rainfall-runoff model for the Taylor Arroyo watershed indicated that soil compaction can increase rainfall-runoff significantly in areas where soils have been compacted (Doe et al. 2008). While increased runoff will typically increase soil detachment and sediment flux, the actual increase in sediment discharge from streams depends highly upon the soil characteristics and infiltration rates downstream of the impacted areas (Doe 1992).

[8] Adapted from DECAM 2015.

A 1993 USGS study entitled Assessment of Effects of Military Maneuvers on the Stream Flow, Water Quality, and Sediment Yields at PCMS, Las Animas County, Colorado (USGS 1993) analyzed the in stream water quality data during the pre- and post- military maneuver periods at PCMS from 1982 to 1985 and 1985 to 1987, respectively. Statistical analysis was used to determine the effects of military maneuvers on stream flow quantity and quality. The study indicated no statistically significant change in stream flow quantity or quality between the preand post-maneuver periods for the Purgatoire River and its tributaries within PCMS. Additionally, the study found that the largest correlation to sedimentation of the Purgatoire River is the number of large storm events received in the vicinity of PCMS, not the frequency of use of PCMS by the military (Doe et al. 2008).

### 2.4.4 Vegetation

***Resource Overview – General***[9]

Shortgrass prairie grasslands comprise about 48% and 41% of undeveloped lands on Fort Carson and PCMS, respectively. Major grasses include blue grama, western wheatgrass, galleta, sideoats grama, dropseeds, buffalo grass, little bluestem, and needle and thread grass. Various shrubs scattered throughout the grasslands are prickly pear cactus, cholla cactus, yucca, four-winged saltbush, rabbitbrush, and skunkbush sumac.

Shrublands, which typically contain a grass understory, comprise about 15% of the vegetation of Fort Carson and 33% of the vegetation on PCMS. Deciduous shrubland, whose species include Gambel oak, salt cedar, and willow, is found along major drainages.

Forest/Woodlands constitute about 37% and 17% of undeveloped lands on Fort Carson and PCMS, respectively. Ponderosa pine, piñon pine, and one-seed juniper are the dominant species of higher elevation woodlands on rocky and steeper slopes, and cottonwood, willow, and cherry dominate woodlands near or along drainages.

The Fort Carson, Colorado: Terrain Analysis (Dames and Moore 1978) and Plant Community Associations of Fort Carson, Colorado (Polzin 2000) have additional descriptions of Fort Carson floral resources. Polzin recognized 45 vegetation communities on Fort Carson. Plant Communities, Ecological Checklist and Species List for the U.S. Army Piñon Canyon Maneuver Site, Colorado (Shaw et al. 1989) recognizes 26 vegetation communities. The vegetation communities of interest for this assessment (pinyon-juniper woodland, shortgrass prairie, and cliff and canyon systems) are described thouroughly within their respective chapters.

There are currently 71 state-listed weed species designated for containment, control or eradication. At least 30 of these state-listed noxious weeds have invaded both natural and urbanized landscapes at Fort Carson and PCMS. The state “A” list is comprised of species of the highest concern, to be eradicated immediately upon detection. There has been one “A” list species found at PCMS and one found at Fort Carson. Both have been eradicated but are being monitored as per their respective eradication plans (see Appendix 2 of DPW 2015 for information on how to review those Plans). Of the 39 species on the Colorado Department of Agriculture “B” list there are 20 plant species found on Fort Carson and PCMS

[9] Adapted from DPW 2015.

with the majority being found only on Fort Carson. List "C" species are considered to be lower priority for control based on the high populations found within the state. Of the 14 species on this list, 8 are found on Fort Carson and/or the PCMS.

***Impacts***

On-going military training activities resulting in significant disturbance of soil, vegetation, and water resources can upset the natural balance of native communities, thereby impacting DPW's ability to sustain quality Training Areas. Some Training Areas are fragile and difficult to restore following disturbance. Other Training Areas can be quite resistant and resilient to disturbance, but negative impacts can occur if the frequency or intensity of disturbance is high. Degradation of soil not only affects the land surface but also causes watershed output in the form of sediment and nutrients that can adversely impact adjacent resources (DECAM 2005).

### 2.4.5 Wildlife Species and Habitat

Over 300 species of vertebrates have been documented on Fort Carson and PCMS (DECAM 2007, U.S. Army 2007). Gene Stout and Associates (2008) summarized research and management documents, including wildlife-related subjects. This is the single most comprehensive source of information about projects and research that have been undertaken at PCMS (Doe et al. 2008).

***Federally Listed Species***

The Mexican Spotted Owl is the only listed species on Fort Carson. Critical habitat was proposed for the Mexican Spotted Owl in 2000. Fort Carson biologists developed management guidelines for protecting the owl, precluding the need to designate critical habitat on the installation. In response to USFWS concerns of the owl entering live fire areas, Fort Carson biologists conducted day and night telemetry demonstrating the species did not leave Booth Mountain and that live fire in adjacent ranges did not change the behavior of the owl. Booth Mountain is the primary location where the owls have been seen. Mexican Spotted Owl roost trees at Fort Carson have a 200m protection buffer preventing vehicle use, but foot training is allowed.

There are no federally threatened or endangered animals on PCMS. In June 2007, the Interior Department delisted the Bald eagle, which was previously a listed threatened species. Bald eagles are winter residents and migrants on PCMS, primarily using the southwestern grassland portion of the installation. The black-footed ferret, federal- and state-listed as endangered, is not currently known to occur on PCMS. PCMS was considered a future release site for black-footed ferrets, but due to the limited acreage and distribution of prairie dog colonies on the installation, the proposal has been suspended (U.S. Army 2007).

***Other Species***

The black-tailed prairie dog, a keystone species of conservation concern integral to the survival of other sensitive species, is monitored annually for persistence in the training environment and the presence of plague. Species dependent on prairie dogs on Fort Carson and the PCMS are Golden and Bald Eagles, Ferruginous Hawk, Mountain Plover, and the Burrowing Owl.

***Habitats***

Wildlife habitats are diverse and cover large tracts of relatively undeveloped land. Land-use impacts are different from the residential, agricultural and grazing activities common to the region, and maintaining wildlife habitats requires active management. The two most significant habitats on Fort Carson and PCMS are pinyon-juniper woodlands and savannas, and shortgrass prairie. See Chapters 5 and 8 for information on these ecosystems, respectively.

### 2.4.6 Fire[10]

***Resource Overview***

Wildland Fires generated by military training activities occur on a regular basis due to the nature of the munitions used. The Fire Management program on Fort Carson and the PCMS is focused on containing and responding quickly to these wildland fires and using prescribed fires to reduce the chances of catastrophic wildland fires while managing natural resources. The Fort Carson Fire Department (Fort CarsonFD) is the primary proponent of the wildland fire program. Personnel from DPW actively partner with the Fort CarsonFD with wildland fire suppression and prescribed fire planning and management. Resource experts within DPW serve as on-site advisors to the Incident Commander and recommend fire suppression options as they relate to natural resource protection. Natural resource personnel also suggest areas to burn to accomplish objectives related to this INRMP (e.g., invasive weed control, ecosystem management, forestry). For more information about fire management at Fort Carson/PCMS see DPW 2015, Section 4.

***Impacts***

Wildfires may be started by military training (e.g. tracer rounds, flares) or other causes (e.g. lightning, arson, hot catalytic converters). The elevated frequency and shortened regenerative growth cycle created by these wildland fires has a potential to cause damage to natural resources. In areas where a high level of protection is identified, fire suppression consists of responses that usually completely suppress or control the fire. Other fires in areas that do not pose a risk to structures, training, life, natural or cultural resources, or escape of installation boundaries, may be used to accomplish defined fuel management objectives, as per a written Incident Action Plan.

[10] Adapted from DECAM 2015.

# 3 Military Context: Training Constraints for Resource Protection

No acres on either Fort Carson or PCMS are permanently restricted due to natural resource issues. However, temporary restrictions on training are sometimes necessary for long-term sustainment of training capabilities and ecosystem protection. Restrictions on troop training on Fort Carson and the PCMS are found within Fort Carson Regulation 350-10 (Maneuver Damage Control Program), Fort Carson Regulation 385-63 (Firing Ammunition for Training, Target Practice, Administration and Control of Ranges and Training Areas), Fort Carson Regulation 350-1 (Mountain Post Training), Fort Carson Regulation 350-4 (Training at the PCMS), and supplemental maps of both installations which delineate off-limits and limited-use areas and are updated periodically. Other documents, such as Fort Carson Regulation 350-1, Mountain Post Training, also contain some training restrictions (DECAM 2015).

Troop units using either Fort Carson or the PCMS must coordinate with DPTMS for site-specific restrictions needed for safety and compliance purposes (e.g. permission to dig large excavations, precluding hitting buried utilities and archeological sites). Troops are briefed regarding current training restrictions, such as a no-fly buffer if an eagle nest is occupied, via regularly scheduled Maneuver Damage Control classes and/or informed during the scheduling process (DPW 2015).

The use of PCMS training areas to meet tactical unit training objectives is predicated on the sustainment of a quality training environment. Thus, land and resource stewardship practices are directly related to this objective. In general, the attributes of such environments include (Doe et al. 2008):

- A variety of terrain complexes (e.g., slope, vegetation, etc.) to provide unit leaders and vehicle drivers/gunners with realistic conditions they must adapt to for maneuver, simulated fire and engagement of the enemy, and communication.
- Availability of terrain suitable to cross-country maneuver by a variety of vehicles under varying ground conditions, with minimal safety and operational hazards (e.g., deep gullies, cliffs, etc.).
- Availability of space to allow use of prescribed tactical doctrine and unit tactical procedures.

In order to sustain the land needed to meet these objectives, temporary or ongoing constraints to training must occasionally be implemented. The following sections describe some of the methods used to assess training area condition as well as ensure the land and terrain will remain suitable for training in the future.

## 3.1 Off-Limits, Limited Use Areas, and Training Restrictions

Military assembly areas, excavation training, and the movement of vehicles are the major sources of maneuver damage. As part of the MDCP, the following use areas were established within training areas in order to protect resources and for rehabilitation following maneuver training.

### 3.1.1 Off-Limits Areas (Restricted Areas [ground])

Training in off-limits areas is prohibited. These areas are designated on overlays and are marked with off-limits signs. Some of these areas contain serious safety hazards and others are protected by Federal law (e.g., select cultural resources).

### 3.1.2 Limited-Use Areas

Training areas are designated as limited-use areas following training events that would require rest and rehabilitation to provide for the sustainment of training lands. Units may drive through limited-use areas on existing routes or trails, and may conduct dismounted training off the routes. Units cannot dig, bivouac, or maneuver vehicles off the routes or trails in limited-use areas. The areas are surrounded by limited-use signs. These areas are the most impacted sites in the training areas, and are being rehabilitated for continued, sustainable training use or for other administrative reasons such as test, experimentation, and evaluation. In general, three years are required to establish new stands of native grasses to meet the minimum 65 to 70 percent vegetation coverage before removing lands from rehabilitative state and placing back into the training inventory. Rehabilitation efforts, however, are highly dependent on precipitation amounts and time of year of precipitation events. Due to these factors, rehabilitation duration can be correspondingly shorter or longer than three years.

***Dismounted-Only Areas***

Training in dismounted-only areas must be limited to dismounted training activities only and all ground-disturbing activities must be requested through DPTMS, Range Division for coordination and permission in advance of the training exercise. Vehicle traffic is restricted to existing routes and trails. Major dismounted-only areas are designated with Letters A through H. Training areas with lettered designation are permanently restricted to dismounted-only training. Mechanized training areas (i.e., numbered training areas) can be temporarily downgraded to dismounted-only training following a maneuver exercise. Dismounted-only training locations in the numbered training areas are identified by the placement of Seibert Stakes, fencing with signs, signage, or boulders to designate areas that should be avoided. Within these marked areas, no digging and no vehicle traffic is authorized.

***Restrictions Related to Fire***

As fire hazard conditions increase, military personnel are required to take appropriate precautions to limit potential fire-producing activities. In accordance with FC Reg 350-4, Training at PCMS, when the fire danger class rises to Class 4 or above (see Table 3.7-1 in Potomac-Hudson Engineering, LLC 2015), use of incendiary training aides (e.g., pyrotechnics, artillery simulators and smoke-producing devices), demolitions, explosive ammunition, flame producing ammunition (e.g., tracers) or similar would cease. Such activities could only resume when the fire danger class drops below Class 4 (Potomac-Hudson Engineering, LLC 2015).

***Fort Carson***

Fort Carson limits the training use of certain sensitive areas to minimize environmental effects of training (Figure 12). Limited use areas include (DECAM 2007):

The **Bird Farm** (634 acres) is adjacent to Highway 115, north of Training Area 9 and west of Training Area 5. It is off-limits to most military training. Bird Farm lakes are closed to dog training during the waterfowl-nesting season.

The **Cottonwood-Prairie Conservation and Education Area** (246 acres) is in the southwestern corner of Training Area 8; it was formally known as the Wildlife Demonstration Area. It is used to train dogs, for conservation education, and as a waterfowl nesting refuge. All vehicles are restricted to established parking areas unless authorized by the DECAM. It is closed to dog training during the waterfowl nesting season. Tactical military training and hunting are prohibited activities.

The **West Haymes Wildlife Conservation Area** (219 acres) is on the eastern side of Training Area 7. It is used for conservation education, a waterfowl nesting refuge, and low impact outdoor recreation, such as nature photography and birding. The area is off-limits year-round to most military training and most outdoor recreation, including dog training, hunting, and fishing.

The **Turkey Creek Recreation Area** (1,235 acres) is adjacent to Highway 115, north of Training Area 20. It is used for birding, photography, picnicking, camping, trail rides, and similar events. This area is home to the Fort Carson Mounted Color Guard. The area is closed to hunting and most types of military training.

The **Turkey Creek Protected Species Area** (70 acres) is just southeast of Turkey Creek Recreation Area. The area is primarily used as a refuge for the greenback cutthroat trout and Arkansas darter. This refugium hosts one of the most biologically diverse riparian breeding bird communities in the Pikes Peak region and is the site of the DECAM MAPS bird banding station.

The **Quarry Pond**, located in the southeastern corner of Training Area 45, supports one of the largest populations of the southern redbelly dace in Colorado. Dace from Quarry Pond are transplanted by the CDOW to other sites within the geographic range of the species.

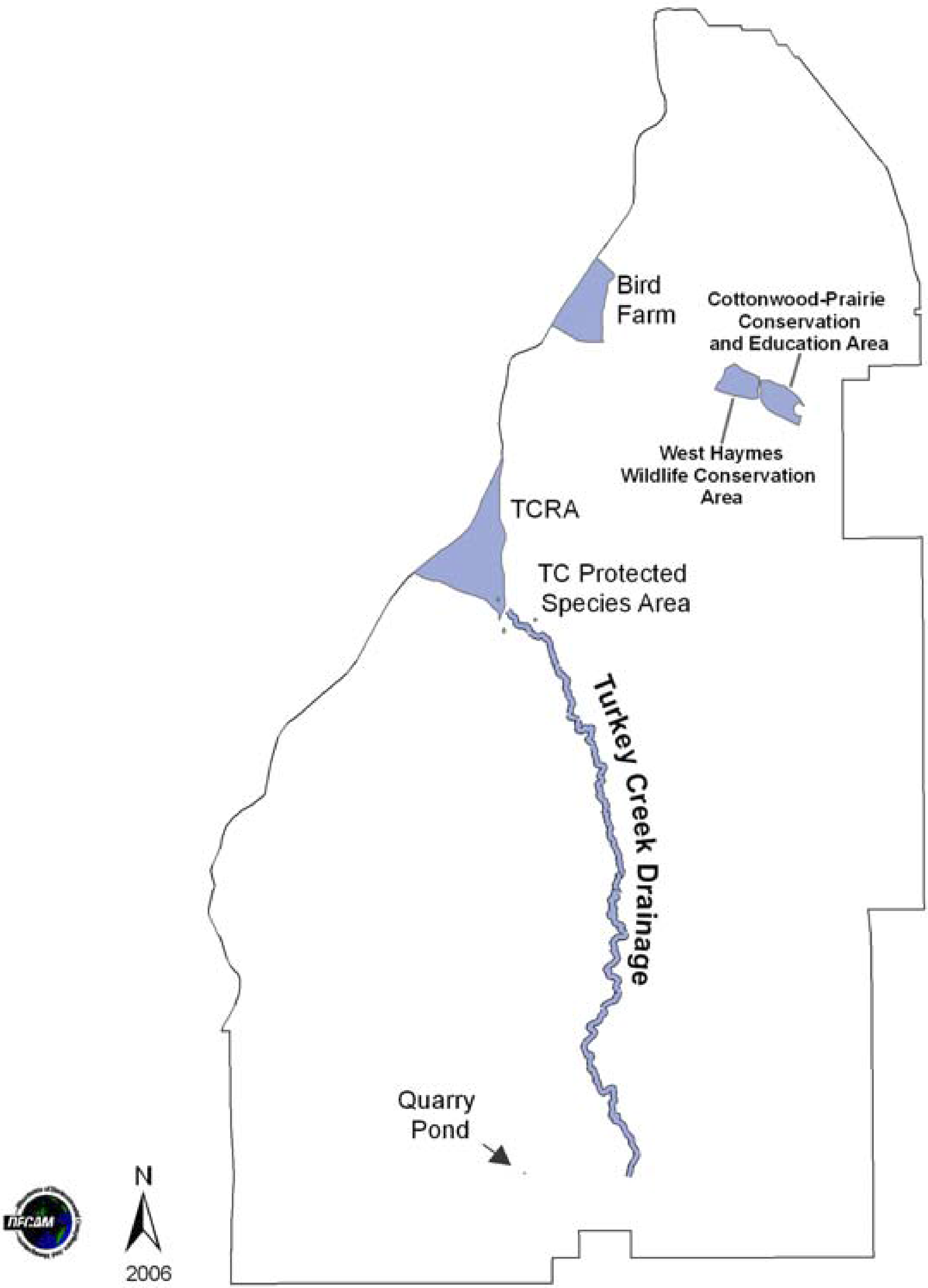



**Figure 12. Special Interest Areas on Fort Carson.** Source: DECAM 2007.

***PCMS***

Limited use areas include (Figure 13) (DECAM 2007) the following:

**Soil Protection Areas** (4,191 acres) are off-limits to mechanized military maneuver and have very limited administrative vehicular access due to fragile soils in this area.

**Canyonlands** (29,452 acres) along the Purgatoire River are off-limits to mechanized military maneuver and have very limited administrative vehicular access due to their fragile soils, cultural resources, steep topography, and wildlife/ecosystem values.

**Gilligan's Island** (58.55 acres) in Training Area 7 is off-limits to mechanized military maneuver because of extremely fragile soils and incidentally provides protection for round leaf four o'clock plant.

The **Hogback** (3,778 acres) is off-limits to mechanized military maneuver and has very limited administrative vehicular access, primarily due to its cultural resources but in part due to its overall ecosystem values.

The **Wildlife Protection/Buffer Area** (10,731 acres) is between the boundary fence and the legal property line. It is off-limits to military training.

**No-dig Areas** include all of the above areas on the PCMS plus much smaller areas designed to protect isolated features, generally cultural resources. No-dig restrictions are imposed to protect cultural resources and sensitive soils.

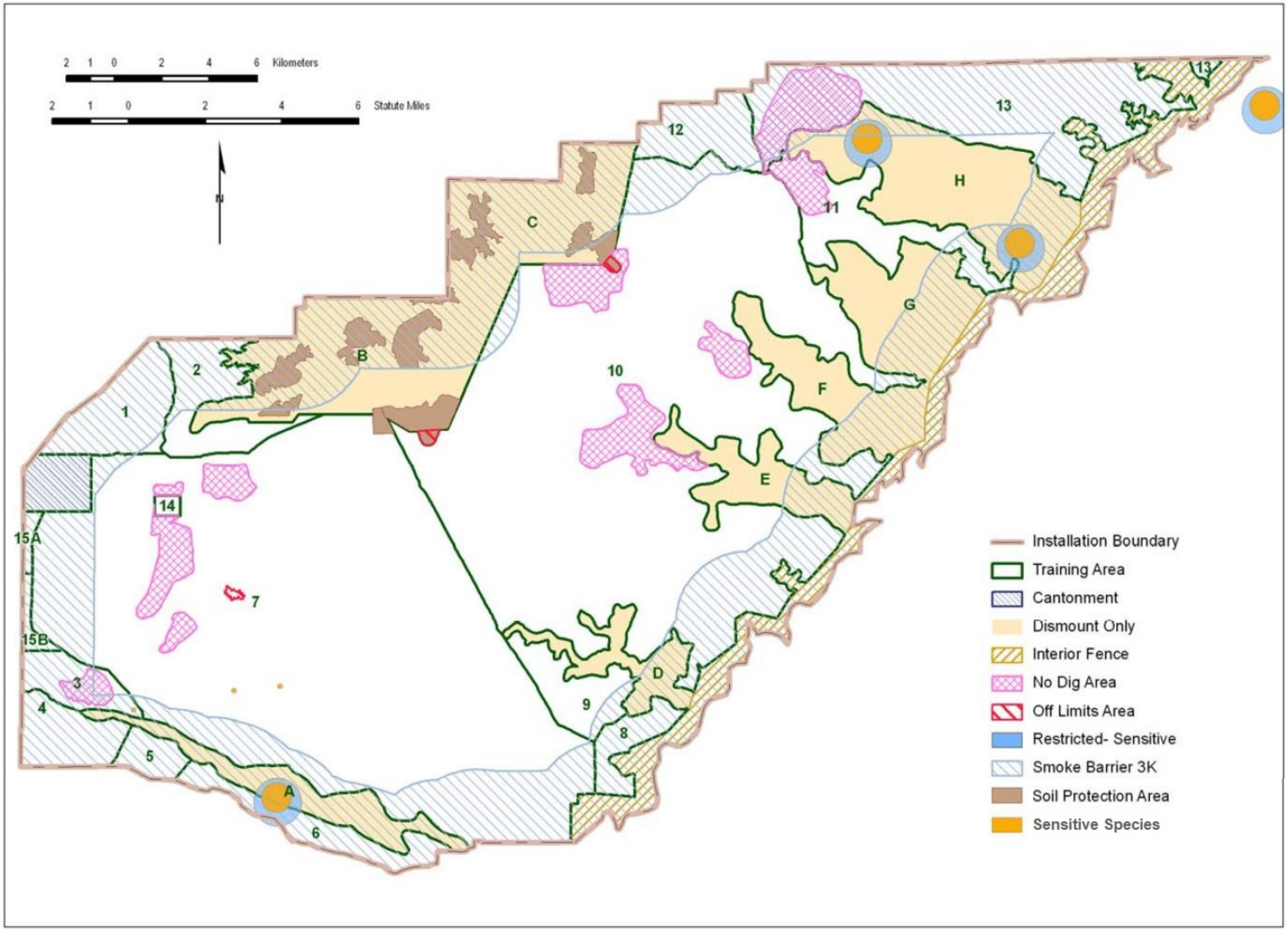



**Figure 13. Selected sensitive resource areas and associated training constraints on the PCMS.** Note: Training Areas B & C are now part of Training Areas 2, 7, 10, and 16. Only the Soil Protection Areas (brown polygons) within these Training Areas are restricted use. Source: Doe et al. 2008.

### 3.1.3 Integrated Training Area Management (ITAM)[11]

The ITAM Program is an Army-wide program to provide quality, sustainable training environments to support the Army's military mission and help ensure no net loss of training capability (a Sikes Act requirement). The ITAM program was initiated with the realization that Army training lands were being degraded to the point where their capabilities to sustain military missions were in jeopardy. In other words, training lands are long-term assets that have to be managed so that they are available for both present and future training needs. Proper management to support both the military mission and other activities is a challenge unique to Defense among managers of public lands.

ITAM provides Army range officers with the capabilities to manage and maintain training lands and support mission readiness. ITAM integrates mission requirements derived from the Range and Training Land Program with environmental requirements and environmental management practices. It establishes policies and procedures to achieve optimum, sustainable use of training and testing lands by implementing a uniform land management program. Several documents provide policy and procedural guidance for the ITAM program.

The ITAM program includes the following five component areas (modified from Integrated Training Area Management (ITAM) Program Strategy (Department of the Army 1995)):

- The Range and Training Land Assessment (RTLA), formerly Land Condition Trend Analysis (LCTA) component, is used to inventory and monitor physical and biological resources to meet the multiple-use demands of Fort Carson.
- The Training Requirements Integration (TRI) component integrates Fort Carson military training requirements for land use with natural resources conditions and capabilities to support these requirements.
- The Sustainable Range Awareness (SRA), formerly Training Sustainment Awareness and prior to that Environmental Awareness component improves land user understanding of the impacts of their activities on the environment and how to use the land more efficiently.
- The Land Rehabilitation and Maintenance (LRAM) component includes programming, planning, designing, and executing land rehabilitation and maintenance projects to support and sustain the military mission.
- The Geographic Information System (GIS) supports planning decision processes to effectively manage land use and natural resources.

## 3.2 Maneuver Damage Program[11]

The Fort Carson Maneuver Damage Control Program (MDCP) is an important component of the land management program. Specific components of the MDCP can be found in Fort Carson Regulation 350-10, *Maneuver Damage Control Program*.

[11] Adapted from DECAM 2007

The native range resource is one of the most significant assets for meeting the military training goals at Fort Carson and the PCMS. Historically, both Fort Carson and the PCMS were misused in terms of land utilization. Today, established principles of land management are being applied to maintain or improve the range resource and ensure that military training goals are met. Some maneuver damage is unavoidable as part of the training objective; however, the MDCP is used to minimize unnecessary maneuver damage. Coordination among the DECAM, DPTM/G3 (Range Control Division/ITAM), and land users will ensure the accomplishment of goals of both proper land conservation and the training mission.

### 3.2.1 Wet Weather Deferment

In the past, military training at Fort Carson was conducted in virtually all weather conditions. Soils and vegetation at Fort Carson and the PCMS are susceptible to maneuver damage when the soils are wet. The PCMS is protected from unnecessary wet weather maneuvering through provisions outlined in the PCMS Environmental Impact Statement (U.S. Army 1980).

Since 1985, training at the PCMS has been accomplished with the understanding that damage due to military training activities is directly related to soil moisture conditions. Land resource damage attributable to military training use is highest when soil moisture content is the greatest. Presently, when soil moisture conditions are determined to be too wet, it is suggested that training activities be suspended or shifted in scope and/or extent until soil conditions are determined to be more optimal. When compatible with training urgency, from a natural resource conservation perspective, it is within the best interest and welfare of the land and the military to restrict off-road use of training lands during these periods of wet and/or thawing soils.

Fort Carson also has a wet weather deferment program as part of the MDCP. As part of standard operating procedures to train, military units are required to obtain the concurrence of DECAM prior to training in Amber or Red conditions. The Commanding General, Fort Carson, is the final approval authority for same.

### 3.2.2 Training Guidelines

Guidelines regarding vehicular movement have been developed and are incorporated into Fort Carson Regulation 350-10. These guidelines include responsibilities to be aware of Environmental Awareness materials, minimization of unnecessary off-road maneuver, Limited Use Area restrictions, avoidance of erosion and sediment control structures, cultural resources site protection, digging restrictions, pollution prevention, tree protection, and similar items.

### 3.2.3 Maneuver Damage Assessments

When training on Fort Carson and the PCMS, military troop units are responsible for reimbursement to rehabilitate sites damaged through negligence or malice. Such damage includes such items as tree loss, damage to facilities, wetland damage, fence or sign damage, damage in off-limits or limited use areas, unfilled excavations, etc. This process achieves two objectives. First, a mechanism is provided to expedite the rehabilitation of disturbed land by making the user responsible for the necessary land restoration. Next, overall damage is reduced by emphasizing the importance of maneuver damage avoidance. In other words, if the user is careful, less damage will be inflicted on the land resources and less cost will be incurred to repair the land.

DPW personnel physically inspect Training Areas after completion of all significant (battalion task force or larger) field exercises. Damage is mapped, and if it is deemed excessive, costs are estimated to mitigate damage. Units are assessed costs via memoranda from the Director, DPW to unit commanders. There is a dispute resolution process for disputed costs. Funds collected are used by the DPW to transplant trees, evaluate damaged cultural sites, replace fences, signs, etc., or conduct similar mitigation.

### 3.2.4 Immediate Damage Repair

The smoothing/filling/seeding of ruts, hull defilades, tank traps, neutral pivot steers, etc. are conditions that require immediate reclamation. These areas need to be reseeded immediately to prevent soil erosion, dust pollution, and prevent the establishment of noxious weeds. Immediate repair of this damage will be accomplished using procedures within the Land Rehabilitation and Maintenance program (LRAM).

### 3.2.5 Long Term Replacement of Destroyed Trees

The replacement of destroyed trees using transplants is described in Section 4.3 of the 2007-2011 Fort Carson/PCMS INRMP (DECAM 2007). Funding for this program is derived from the MDCP.

### 3.2.6 Unit Participation

Fort Carson military personnel play an active role in the reduction of maneuver damage through the implementation of the Unit MDCP. Each company-sized or larger unit that uses downrange, including National Guard and Reserve units, must have one person attend MDCP training. MDCP training is offered monthly and more often as needed with DPW and ITAM personnel generally rotating training responsibilities. Combat engineer units have provided extensive support to the erosion control program by building and maintaining erosion control structures. All units reclaim areas impacted by creation of fighting positions, tank traps, and vehicle concealment excavations.

Each unit is required to have a certified MDCP Officer (E7 or higher) when training downrange. Certification lasts for one year. While deployed, the unit MDCP Officer briefs unit commanders regarding maneuver conditions (i.e., green, amber, red), which are based on soil moisture. The MDCP Officer also ensures spills are cleaned-up and Training Areas are policed prior to troops leaving the field. Units must also have internal Maneuver Damage Repair Teams, which have the capability to repair relatively minor damage to training lands, fences, etc. This team's responsibility also includes small spill cleanup and after-action area police.

## 3.3 Rest/Rotation/Deferment Program[12]

An essential component of the land management program is to provide a means to reduce military impacts to Training Areas or portions of Training Areas during which repairs can be implemented

[12] Adapted from DECAM 2007.

or natural restoration processes can occur. The rest/rotation/deferment program provides such benefits to training land sustainability at Fort Carson and the PCMS.

The term "rest" refers to withdrawal of an area from mechanized maneuver; other military activities may occur in many cases. The term "rotation" refers to regularly resting areas on a rotational basis to avoid cumulative damage that is time consuming or expensive to repair; rotations may also allow certain types of training (typically dismounted) during rest periods. The term "deferment" refers to removing a specific damaged area from certain types of training (typically mechanized maneuver) to either rehabilitate or allow natural restoration.

***Fort Carson***

Because of the limited land available for military training activities at Fort Carson, a rest/rotation program was not feasible. Therefore, Fort Carson initiated a deferment program in 1989, which rests areas identified as critical. The deferment program allows for approximately 8,000 acres to be set aside from use for three years or more. Approximately 7,000 acres were deferred from use in 1989. Restricted area signs were posted, and portions of these areas were reseeded in 1989 and 1990. Then in 1992, approximately 6,000 acres were rested for three years, and the original 7,000 acres were returned for use. The program currently has about 400 acres deferred.

Vehicles may pass through these areas on existing roads and trails, but only dismounted training is permitted within the balance of the area being rested. The selection process for the area to be rested is based on current condition and location relative to sensitive areas, such as wetlands and important habitat, while taking into consideration impacts to military training opportunities. Areas identified to be included into the deferment program are selected in close coordination and consultation among DPW, G3/DPTM, and unit personnel. During this selection process, all parameters are considered, such as:

- condition of the land;
- compliance with current DoD, DA, federal, state and local laws and regulations; and
- impacts to the attainment of the training mission.

Once all areas identified for rest are delineated and signs are posted in the field, maps are provided to the G3/DPTM by the DPW.

***PCMS***

In 1985 a rest/rotation program was implemented for the five large Training Areas at the PCMS as was detailed in the PCMS Environmental Impact Statement (U.S. Department of Army 1980). This system allowed for approximately three-fifths of trainable lands on the PCMS to be rested for two entire growing seasons. Lands were rested for two years and then rotated into use as other lands that had been in use were rotated back into rest. This system conserved training lands, but its limitations on military training options were too severe to allow the Army to meet its training needs.

In 1990 the system was changed. The PCMS was divided into 24 Training Areas to allow for greater flexibility and deferment of approximately 50% of the available Training Area at any given time.

Dismounted training was allowed in areas deferred from mechanized training, and a new rotation was implemented (DECAM 1990). Beginning in fall 1992, approximately 92,000 acres of available maneuver lands were being rested for a period of two years.

In 1997 the system was again adjusted to provide more site-specific rehabilitation options and increase military training options. The 24 designated Training Areas were unchanged; however, units could use a combination of Training Areas to form a maneuver box, such as is often used in Training Areas 7 and 10, to accommodate certain larger area, training requirements. Certain Training Areas are available only for dismounted training (those designated with letters). Lettered areas are always available for dismounted training. Smaller, numbered Training Areas (1, 2, 3, 4, 5, 6, 8, and 9) are rested as needed.

There is also a provision to use deferment designations to protect site-specific rehabilitation sites in damaged portions of maneuver boxes. The end result of the rest/rotation/deferment program at the PCMS is that virtually all areas of the PCMS (except the Cantonment Area and the Wildlife Area/Safety Buffer along the canyon rim) are open to some types of training virtually all of the time. Damaged areas are identified and referred to ITAM for repair, and sensitive areas are protected from potentially damaging training.

Restricted Training Areas B and C were formerly the Soil Protection Area. The Soil Protection Area was off-limits to all training from 1983 until 1990 when it was open to dismounted-only training through 2004. However, since the area has recovered over the past 20 years, most of it was opened to mechanized military maneuver in 2005. Remaining protection areas (dismounted training only) consists of Soil Protection Sites.

## 3.4 Examples of Rare Species Restrictions[13]

The 2013-2017 INRMP (DPW 2015) for Fort Carson and PCMS provides detailed information on management of wildlife, including surveys and seasonal use restrictions, for listed species, Species at Risk, and other wildlife species.

Critical habitat was proposed for the Mexican Spotted Owl in 2000. Fort Carson biologists developed management guidelines for protecting the owl, precluding the need to designate critical habitat on the installation. In response to USFWS concerns of the owl entering live fire areas, Fort Carson biologists conducted day and night telemetry demonstrating the species did not leave Booth Mountain and that live fire in adjacent ranges did not change the behavior of the owl. Booth Mountain is the primary location where the owls have been seen. They are only known to be present during the winter, and they are not present every year.

Military training on the southern portion of Fort Carson was threatened by the presence of several sensitive, candidate, and proposed species. The only site for nesting Mountain Plovers was at the base of Range 123, a live fire jet bombing range. Fort Carson biologists studied the relationship

[13] Adapted from DECAM 2015.

between the plover and jet fly-over and determined the short-term behavior of the plover did not change in response to the jets.

Four species of rare endemic plants occur near the southern boundary of the installation. Fort Carson biologists, in cooperation with the Colorado Natural Heritage, surveyed for the species on Fort Carson, and determined these species were widely distributed on the installation and located at several locations not likely to be impacted by maneuvers. Biologists also surveyed portions of the adjacent buffer zone properties for the plant species and candidate and proposed wildlife species. By acquiring the buffer zone under the Army Compatible Use Buffer (ACUB) program, the Army can continue to train on our southern Training Areas, because the Walker Ranch contains habitat for those species and other sensitive species.

Banksloping and construction of erosion control dams by DPTMS usually enhances training by allowing maneuver in directions that may have been previously unavailable due to gullies.

# 4 Study Approach

One of our goals in developing our approach to this study was to build off of a considerable body of previous work that has been done on the target ecosystems and species. We have applied updated information, filled analysis gaps (e.g., climate change), and evaluated threats at multiple scales to better assist installation natural resource managers in applying the principles of ecosystem management.

It is important to note that many of the land uses discussed in this report as “threats” are desirable and necessary activities from the standpoint of human society. In addition, some human land uses, such as cropland, offer habitat benefits (e.g., food resources) for some wildlife species. However, these activities have legitimate adverse impacts on native species and ecosystems that must be recognized if species, ecosystems, and the ecosystem services they provide are to be conserved.

We evaluated ecological systems according to basic physical and biological factors, ecological processes, and vulnerability to potential effects of incompatible land uses and environmental change. For each ecological system, we compiled information from peer-reviewed literature, unpublished documents, and expert opinion. We used this information to characterize the origins, distribution, species composition, climate and dynamics, land use, and current condition of each ecosystem, both across its range and for the system as it occurs within or near Fort Carson, PCMS, and the Air Force Academy. We then evaluated threats (i.e., incompatible land uses and other stressors) by 1) mapping the ecological systems and calculating extent of potential impacts using readily available spatial data in GIS, or 2) where spatial data were not available, addressing potential impacts narratively using available published and unpublished references and professional judgment. Most of the information specific to climate change was adapted from our previous work, with some additional analyses added for this project, as described in Section 4.2.3.

For species, we compiled current information on distribution, conservation status, select life history requirements, and threats from peer reviewed literature, State Wildlife Action Plans, and other references and planning documents. In addition, we included a preliminary climate change vulnerability assessment for the target species, as described in Section 4.2.3 and (also see Appendices A and B), as well as results of previous vulnerability assessments and modeling efforts by others, as reported in the literature.

Using the information compiled in these steps, we identified:

- Suggestions and recommendations to address potential management issues on the installations, and
- Options for contributing to proactive conservation of ecosystems and species.

Profiles, results, and recommendations for ecosystems and species follow in Sections 5-12.

## 4.1 Mapping Ecosystem Distributions

The distributions of ecological systems were derived from the GAP Land Cover v2.2 (USGS 2013). For shortgrass prairie, we selected prairie vegetation within the Central Shortgrass Prairie and Southern Shortgrass Prairie ecoregions (Figure 14). We mapped pinyon-juniper based on the current distribution of two-needle pinyon pine (*Pinus edulis*) (Figure 15). Distributions of the focal ecosystems in relation to the installations are presented in Figures 16-18. Since small patch and linear land cover types (including the cliffs, canyons, and outcrops ecosystem of interest to Fort Carson and PCMS) are not well depicted by the GAP dataset, we added steep slope areas (slope $\geq$35 degrees) from a slope raster derived from the National Elevation Dataset. We also included shale barrens (including "pine barrens") in the cliffs, canyons, and outcrops ecosystem. These were digitized from 2013 NAIP imagery for southeastern Colorado. These mapped barrens are essentially limited to shale outcrops formed in the Niobrara shale. Outcrops formed in other geologic formations that may occasionally include a shale component are not included.

**Note that by selecting out steep slopes to map the cliffs and canyons system, some vegetated areas are represented on our maps as cliffs and canyons rather than the relevant vegetation type**. These areas include some portions of the grass/tree and shrub/tree mosaics on the southern end of Fort Carson and along the northwestern side of PCMS. These installations have vegetation mapped at a finer scale, but those maps do not include an elevational component. Also, in order to evaluate potential land-use impacts at the ecoregion scale, it was necessary to use a consistent land cover dataset that covered the entire region.

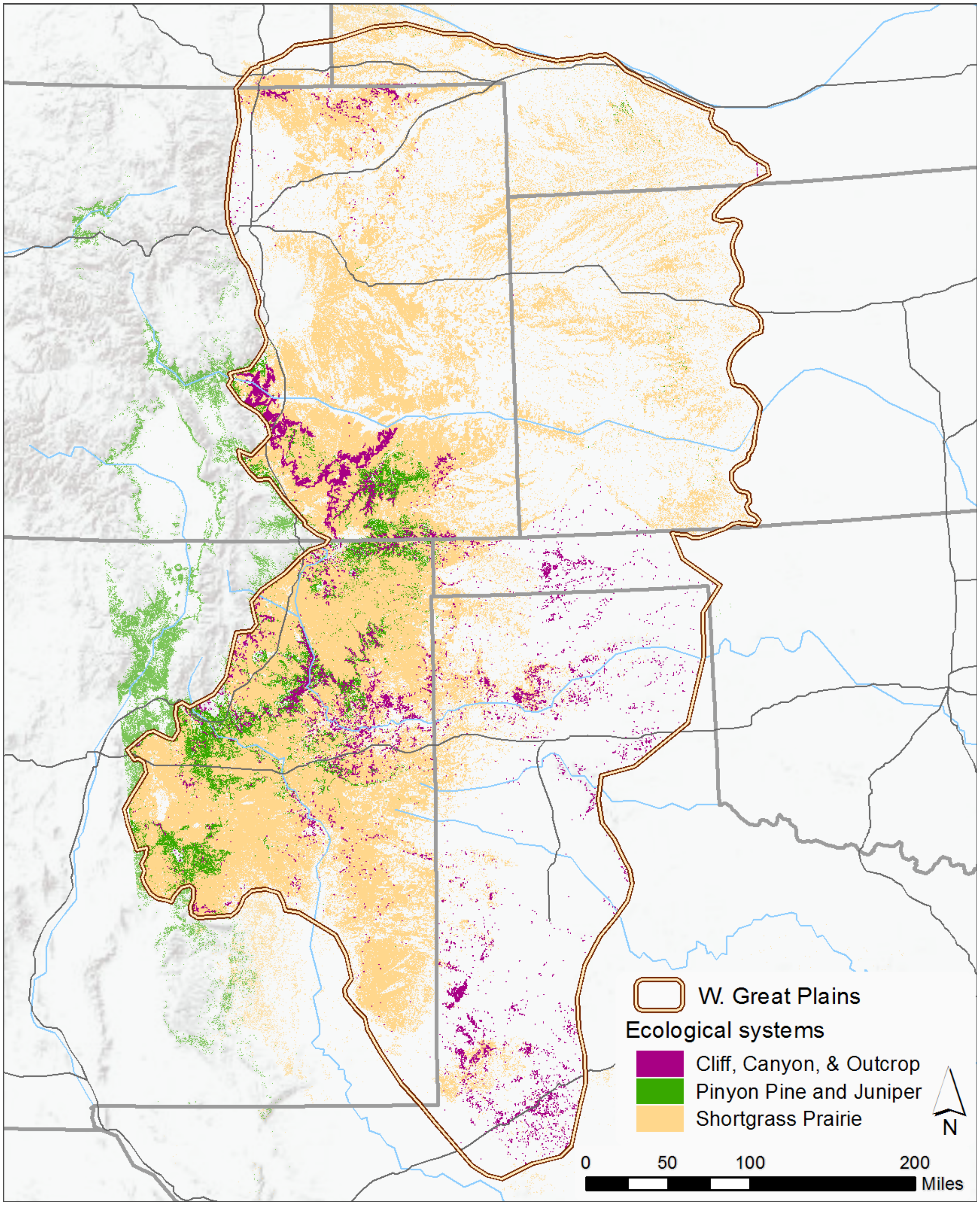



**Figure 14. Distribution of focal ecological systems within the primary study area (Central and Shortgrass Prairie ecoregions.**

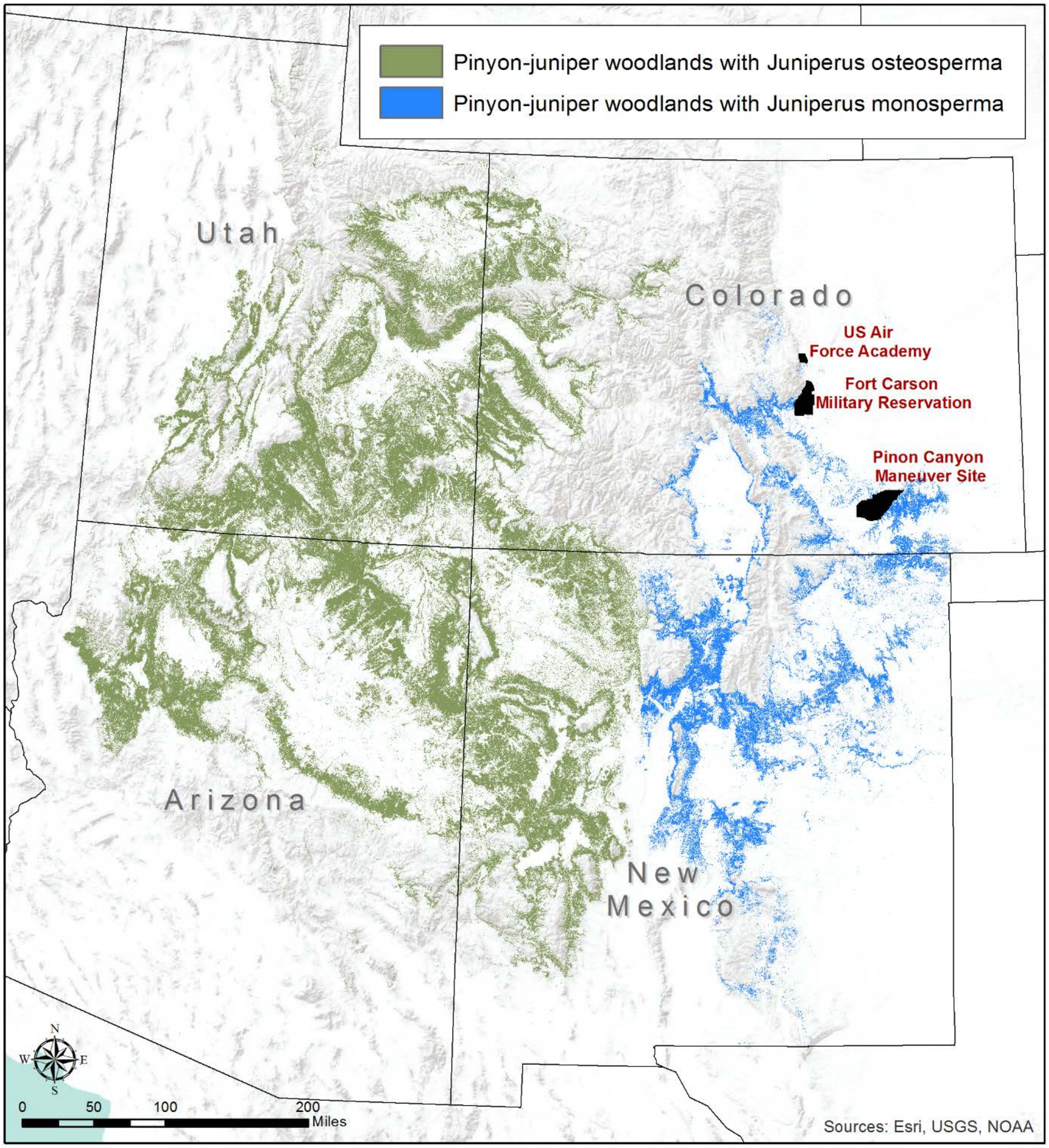



**Figure 15. Extent of woodlands co-dominated by two-needle pinyon (*Pinus edulis*) and either Utah juniper (*Juniperus osteosperma*) or one-seed juniper (*J. monosperma*).**

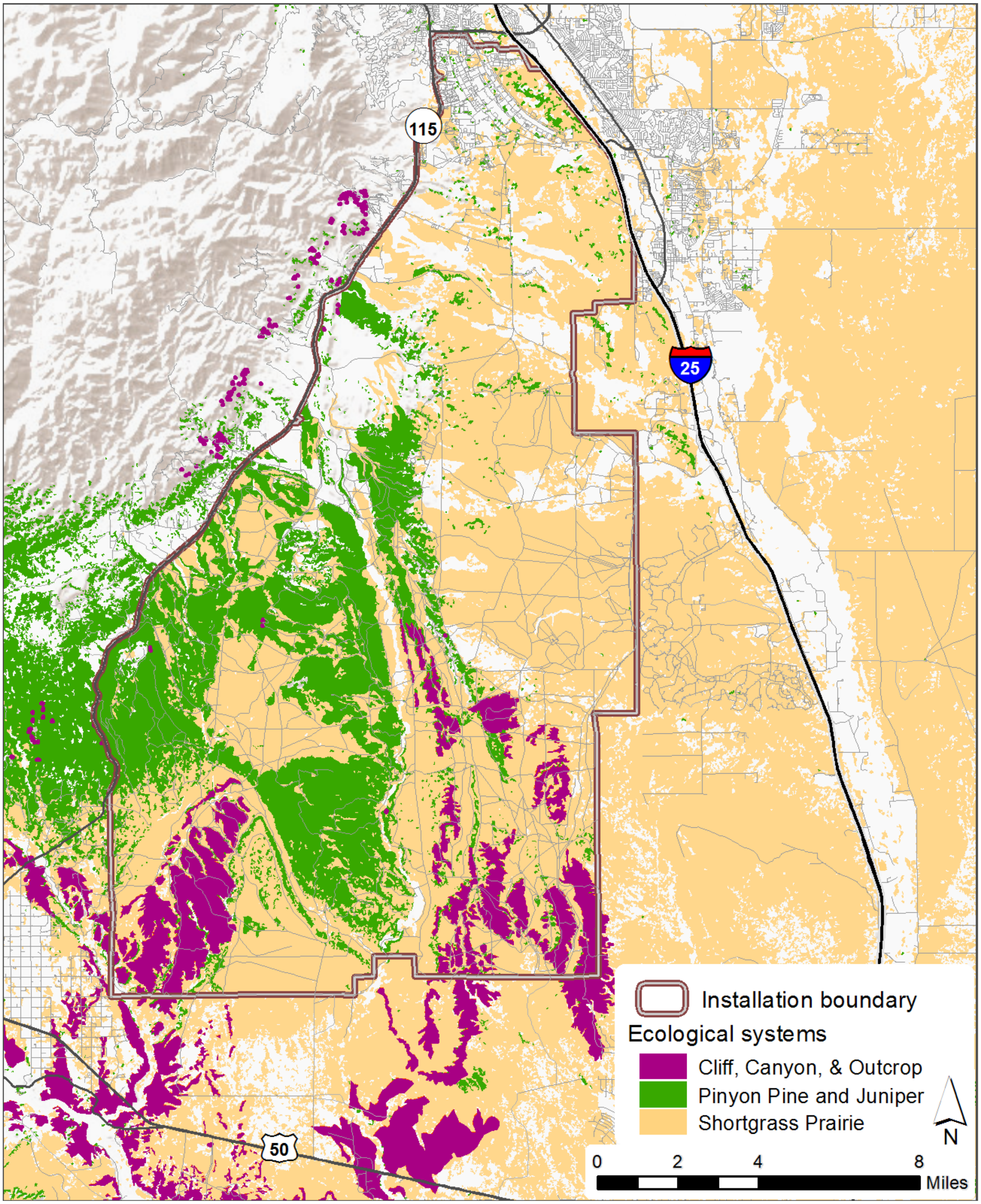



**Figure 16. Simplified distribution of focal ecological systems on Fort Carson.**

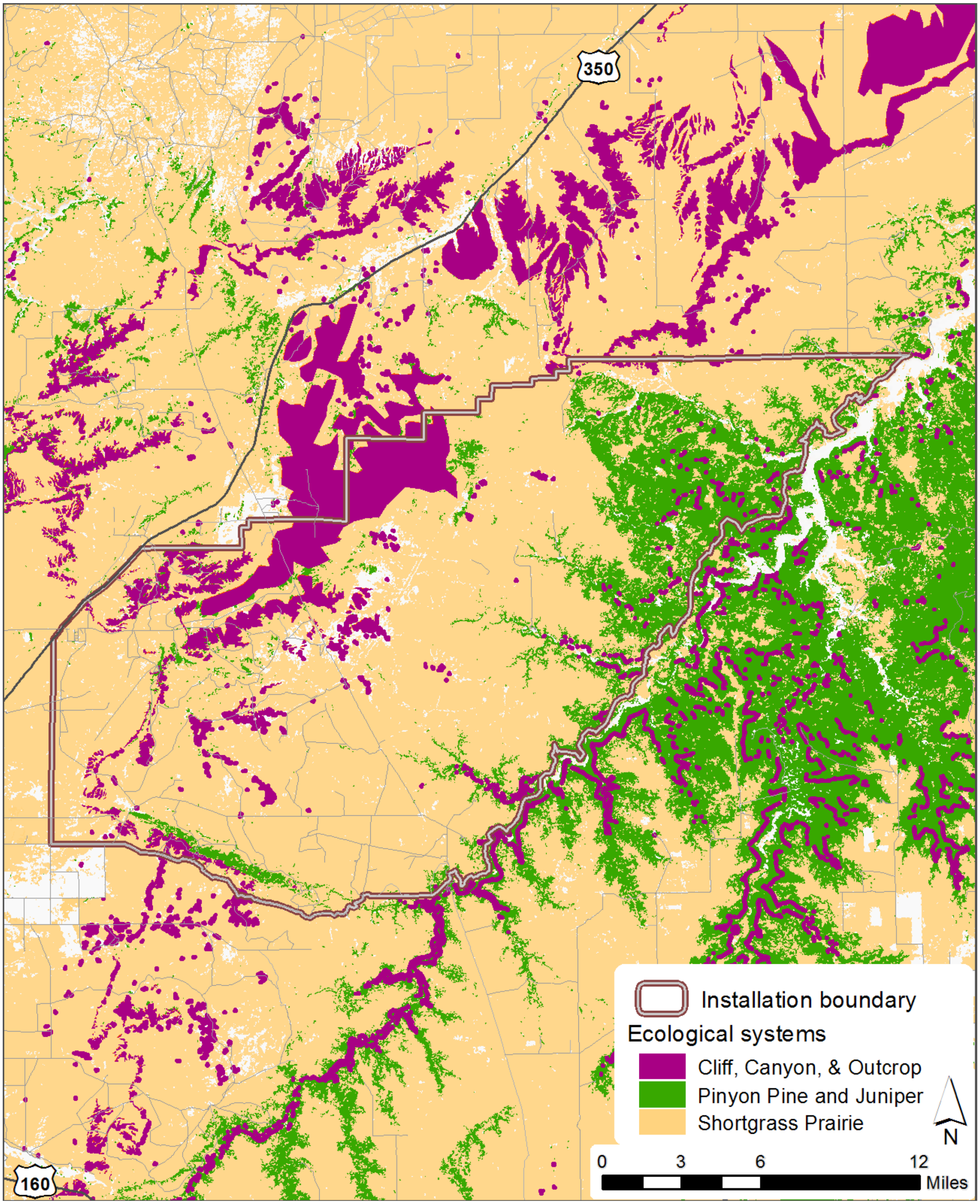



**Figure 17. Simplified distribution of focal ecological systems on Piñon Canyon Maneuver Site.**

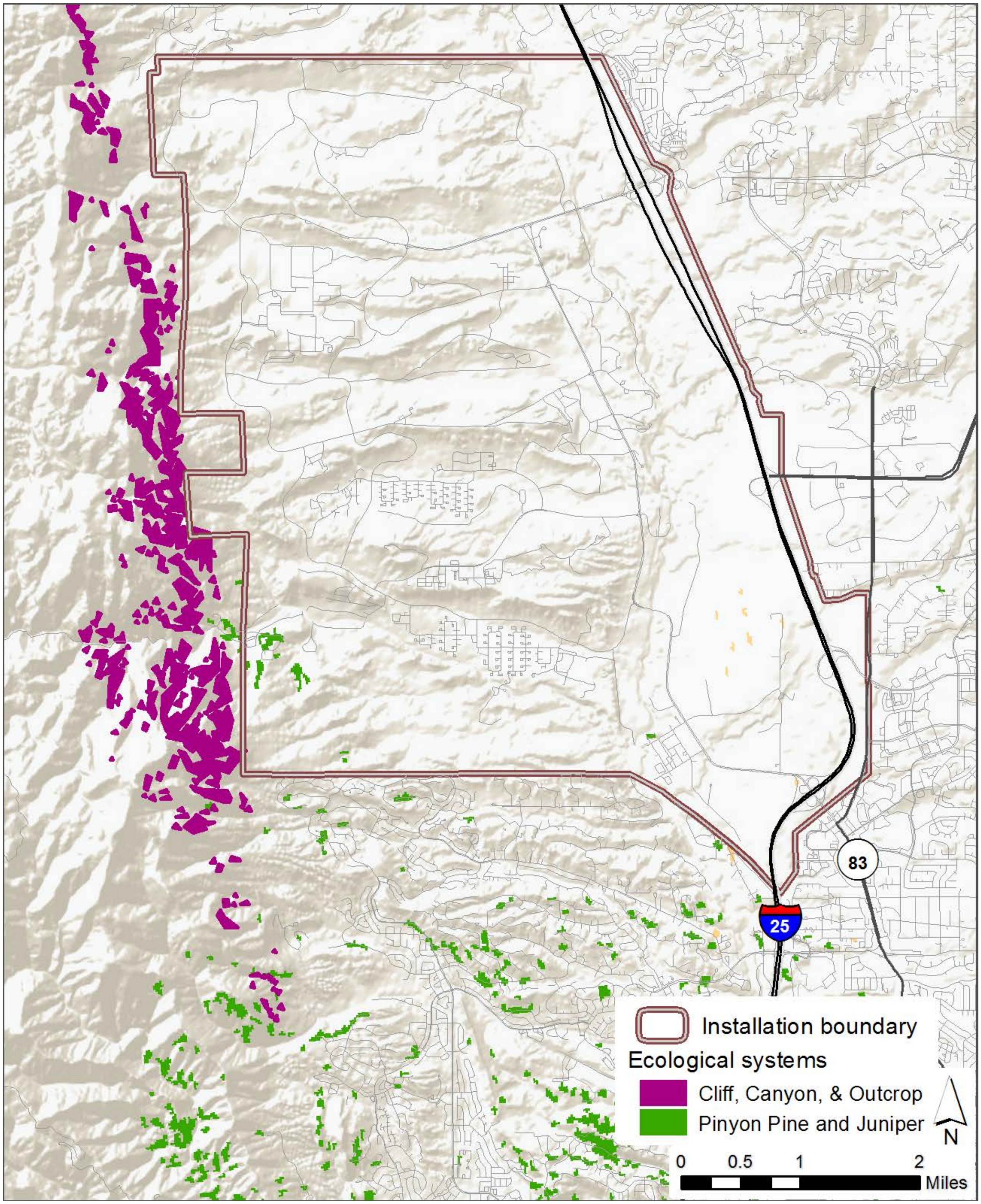



**Figure 18. Simplified distribution of focal ecological systems on and near the U.S. Air Force Academy.** Though grasslands occur on the Academy, they are classified as piedmont grasslands, not the shortgrass prairie that was the focus of this project.

## 4.2 Assessing Threats

### 4.2.1 Threats Lexicon

Threats to each system were summarized according to the "Unified Classification of Direct Threats," which was developed by Salafsky et al. (2008) and is maintained by the Conservation Measures Partnership as part of the Open Standards for the Practice of Conservation (cmp-openstandards.org). The purpose of this classification is to standardize terminology used to describe threats to biodiversity, and to improve the ability of resource managers, researchers, and conservation practitioners around the world to consistently compare threats across multiple scales. This classification is used by the International Union for Conservation of Nature, The Nature Conservancy, the U.S. Fish and Wildlife Service, and other members of the Conservation Measures Partnership. This classification has been promoted by the U.S. Fish and Wildlife Service as the standard for State Wildlife Action Plans (SWAPs), and was used in the recently revised SWAPs of Colorado and most of the other states relevant to one or more of the ecosystems and species addressed in this report. The full threats lexicon is presented in Appendix A.

### 4.2.2 Spatial Analysis of Incompatible Land Use Threats

Where existing spatial data allowed, we used GIS data analysis to evaluate threats at a regional scale, and to characterize the local landscape context of each installation. All GIS analyses used raster format data in ArcGIS 10.2.2 (ESRI 2014); data sources are listed in Table 4. For some threats, geospatial data were either not available, or did not adequately cover the area of interest. In these cases, we evaluated the threats narratively using published literature, unpublished reports, and expert input. Landscape scale threats for which appropriate spatial data were available were:

- Residential and commercial development
  - *High intensity* (highly developed areas where impervious surfaces account for 80-100 % of total land cover + medium intensity areas, mostly single-family housing) where impervious surfaces account for 50-79% of total land cover)
  - *Low intensity* (single-family housing where impervious surfaces account for 20-29% of total cover + open areas where most land cover is lawn grasses, e.g., large-lot single-family housing, parks, golf courses)
- Cropland
- Energy (oil and gas, wind)[14]
- Transportation and service corridors
  - *Major roads* (primary and secondary roads, including interstates, state highways, and main arterials)
  - *Minor roads* (all other roads)

Impacts from these land uses were assessed by calculating the number of acres and percentage of total ecosystem area located within one mile of each mapped threat. The one-mile buffer represents the approximate distance beyond which direct impacts from incompatible land uses would be

[14] Spatial data depicting the distribution of active solar and other renewable energy facilities across our area of interest were not readily available.

estimated as zero. This distance is consistent with previous similar work by Neely et al. 2006 and Rondeau et al. 2011. To provide a sense of cumulative impact, we calculated impacts to each ecological system across its range. To evaluate the local landscape context of each installation, we calculated the percentage of area within one mile of each installation for each of the last uses listed above.

**Table 4. Sources of spatial data.**

| Data Layer | Source(s) |
|---|---|
| Ecological system distribution | USGS GAP Land Cover v2.2 (USGS 2013) |
| Residential and commercial development | USGS GAP Land Cover v2.2 (USGS 2013) |
| Crop agriculture | CropScape - Cropland Data Layer (USDA-NASS 2015) |
| Energy production and mining | U.S. Oil and Gas production data (Biewick 2008) |
| Transportation and service corridors | US Census Bureau TIGER/Line roads (USCB 2015) |

### 4.2.3 Climate Change

Climate change is emerging as one of the defining conservation issues of this century. Methods and data for assessing vulnerability and devising adaptation strategies comprise a relatively new field of scientific inquiry which is rapidly evolving as new data are gathered.

Full climate change vulnerability assessments entail investigations into the potential exposure to changing climate conditions across the study area, intrinsic ecological factors governing how sensitive species may be to those changes, and the ability of species to adapt to changes. Approaches to vulnerability assessments may include spatial analyses in GIS, qualitative rankings and descriptions in narrative format, or often, a combination of quantitative and qualitative methods. This level of inquiry fell outside of the funding priorities under which our scope of work was developed. However, threats assessments that fail to consider climate change are, by today's standards, incomplete. Thus, for this study, we used readily available spatial data and methods previously developed (Decker and Fink 2014, Colorado Natural Heritage Program 2015) to address the first step in a vulnerability assessment – exposure – to estimate how severe and/or widespread changes in climatic conditions may be for ecological systems within our areas of interest.

***Climate Change within the Western Great Plains***

To estimate the degree to which climate change may constitute a threat to systems within the western Great Plains, we adapted a previously developed model of future climate conditions for Colorado and expanded it to cover the Central and Southern Shortgrass Prairie ecoregions. Differences at the installation scale cannot be reliably distinguished at the scale used for climate projection models, but climate conditions at individual installations are expected to be essentially the same as conditions within the region.

Technical methods are detailed in Colorado Natural Heritage Program (2015). In brief, we used future climate projections from the 800 m NASA Earth Exchange (NEX) Downscaled Climate Projections (NEX-DCP30) for the Continental U.S. The NEX-DCP30 provides an ensemble average of the 34 General Circulation Models (GCM) developed for the World Climate Research Programme's Coupled Model Intercomparison Project Phase 5 (CMIP5). The ensemble average model was run under two emissions scenarios: RCP8.5 (increasing greenhouse gas emissions over time) and RCP4.5 (greenhouse gas emissions stabilize shortly after 2100). These scenarios represent worst case and best reasonable case projections for greenhouse gas emissions. We focused our analysis on the 30-year period centered on 2050 (i.e., 2035 – 2064). This analysis period is consistent with other vulnerability assessments conducted in the region, and represents a planning horizon that most land managers can grasp.

***Climate Change within the range of Pinyon-Juniper***

For the pinyon-juniper ecosystem we were fortunate to have potential future distribution modeling available from other ongoing work in the San Juan region of southwestern Colorado. In the interest of providing installation managers with as much information as possible, we expanded that model statewide to include the portion of pinyon-juniper distribution on Colorado's eastern slope. Technical methods are detailed in Rondeau et al. (2017). In brief, we overlaid the Colorado distribution of pinyon-juniper onto two plausible future climate scenarios – "hot and dry" and "warm and wet." Each scenario is represented by a single GCM rather than an ensemble average. These GCMs, which were selected in consultation with a research scientist at the North Central Climate Science Center, represent potential future climate conditions above (i.e., worse case) and below (i.e., better case) the multi-model ensemble mean for temperature and precipitation (Table 5). Neither scenario represents the most extreme models available from the CMIP5 model set. These particular models were chosen, at least in part, because they more or less maintain the temperature and precipitation characteristics (degree of hot and dry) across the century (2000 – 2100). Although multi-model ensemble averages are considered to provide a "best estimate" forecast (IPCC 2014), it is difficult to characterize the variation around the mean that is inherent in the ensemble forecast in a way that is meaningful for natural resource planning. As the scenario approach was more understandable to the land managers in the San Juan region, who expressed a strong desire to be able to plan for alternative futures, we judged this approach as likely to also be more understandable to DoD natural resource managers.

**Table 5. Climate change scenarios used to project future suitability for the pinyon-juniper ecosystem.**

| Hot and Dry<br>HADGEM2-ES.1.RCP85 | Warm and Wet<br>CNRM-CM5.1.RCP45 |
|---|---|
| Annual temperature increase of 5°F (2.8°C), with a 3 week increase in growing season.<br><br>Annual precipitation decrease of 10%, with much earlier and lower runoff, more frequent drought years | Annual temperature increase of 2°F (1.1°C), with a one week increase in growing season.<br><br>Annual precipitation increases of 10%, with a slightly earlier runoff, fewer instances of multi-year drought, but some increase in drought intensity. |

***Climate Change Vulnerability for Species***

To help us better understand relative vulnerability of focal species to climate change, we evaluated 21 direct and indirect factors related to species distribution, habitat connectivity, and life history using NatureServe's Climate Change Vulnerability Index tool (CCVI). The CCVI is a Microsoft Excel-based calculator that assesses vulnerability according to **exposure** of the species to climate change (e.g., a highly sensitive species will not suffer if the climate where it occurs remains stable) and **sensitivity** of the species to climate change (e.g., an adaptable species will not decline even in the face of significant changes in temperature and/or precipitation). Appendices B and C, respectively, provide the full CCVI results for each species and additional detail on the CCVI tool.

# Pinyon-Juniper Ecosystem, Pinyon Jay, and Gray Vireo

# 5 Pinyon Pine and Juniper Woodlands and Savannas

Pinyon pine and juniper woodlands and savannas occur in a variety of forms across the landscape, and may include both pinyon pine and juniper species together, or juniper species alone. For the purposes of our analysis, we focus on the distribution of two-needle pinyon (*Pinus edulis*) and use the term "pinyon-juniper" to refer to both pinyon-juniper woodlands and pinyon-juniper savannas, unless otherwise specified. We likewise use the term "juniper woodland" to refer to both juniper woodlands and juniper savannas, unless otherwise specified. From a wildlife perspective, particularly with regard to some bird species, it is important to distinguish between pinyon-juniper woodlands and juniper woodlands. The information in the following sections applies to both pinyon-juniper and juniper, except where noted. The manifestations of this ecological system are highly variable across its range, and many of the studies referenced here were conducted in different regions and in different types of pinyon-juniper. The degree to which any particular data can be extrapolated to the pinyon-juniper in the vicinity of the Front Range installations is unknown.

## 5.1 Origins, Distribution, and Composition

### 5.1.1 Origins

Evidence from pollen and plant macrofossils preserved in packrat middens indicates that juniper was present by 7,000 years ago in the mid to late Holocene (Anderson and Feiler 2009). In contrast, pinyon pine did not establish in the area until the last millennia. During the last glacial period (until about 12,000 years before the present), pinyon pine grew at the southern edge of its current range in southern New Mexico and adjacent southwestern Texas (Thompson et al. 1993, Cole et al. 2013). Pinyon pine gradually expanded its range to the north as conditions warmed during the Holocene (beginning about 11,700 years ago), moving at a rate of 20-60 m per year (Cole et al. 2013). Occurrences in the southwestern Great Plains were established only within the past 1,000 years (Betancourt et al. 1990, Anderson and Feiler 2009), so that in this region pinyon-juniper associations are comparatively recent.

### 5.1.2 Distribution

The current distribution of two-needle pinyon pine (*Pinus edulis*, hereafter pinyon or pinyon pine) is centered on the Colorado Plateau in the Four Corners states (Utah, Colorado, Arizona, and New Mexico). Pinyon pine forms woodlands in co-dominance with a variety of juniper species where these intersect its range, primarily Utah juniper (*Juniperus osteosperma*) and one-seed juniper (*J. monosperma*) (Figure 15). Within the Great Plains, where Fort Carson, PCMS, and the USAFA are situated, pinyon-juniper is confined to the southern and western portions, not extending north of the Arkansas River drainage in Colorado, except in a few isolated stands north along the mountain front. Pinyon-juniper occurs primarily in southeastern Colorado and northeastern New Mexico, with a few stands in the Oklahoma and Texas panhandles. The majority of these are dominated by junipers.

The various juniper species also form woodlands and savannas where they occur beyond the range of pinyon. These juniper communities occur within the semiarid grassland matrix or adjacent to more wooded areas, where they may be intermediate in the grassland-forest continuum. In the driest areas, a few scattered juniper are embedded in a grassland matrix; in more mesic areas grassland is found as small patches in juniper woodland matrix (Van Auken and Smeins 2008). Until fairly recently, juniper communities of the western Great Plains were largely confined to rocky or shale outcrops in areas where local topography acted as a fire break within the grassland matrix, or along the mountain front. Over the past century, many of these communities have extended their distribution as more individual trees become established and persist further out into the grassland (Van Auken and Smeins 2008).

Fort Carson and PCMS are the only installations within the Great Plains or Colorado that contain significant acreage of pinyon-juniper (Table 6), which comprises the majority of forest and woodland acres on these installations. All three types of pinyon-juniper described by Romme et al. (2009) – persistent woodlands, savannas, and wooded shrublands – occur on both installations (J. Zayatz, pers. comm.). On Fort Carson, pinyon-juniper occurs primarily in the foothill drainages on the western side. Juniper woodlands and savannas occur in the southern and southwest. At PCMS, pinyon-juniper occurs on the northern and western sides, with juniper woodlands and savannas primarily to the east. The SWReGAP vegetation map shows a small amount of pinyon-juniper in the extreme southwest corner of the USAFA, but this ecosystem type is not recognized as present on the Academy in its INRMP.

**Table 6. Extent of pinyon-juniper on focal DoD installations** as mapped by USGS GAP Land Cover v2.2 (USGS 2013).

| Installation | Approximate acreage of Pinyon-Juniper |
|---|---|
| Fort Carson Military Reservation | 23,580 |
| Piñon Canyon Maneuver Site | 36,108 |
| U.S. Air Force Academy | 35 |

### 5.1.3 Composition – Soils and Vegetation

At the western edge of the Great Plains, pinyon-juniper occurs on mountain foothill slopes, mesas, cuestas, broad basins, and valley floors. These communities occupy a broad zone of intermediate moisture and temperature conditions between the warmer, drier grasslands of lower elevations and the cool mesic forests of higher elevations (Romme et al. 2009). In general, woodlands occur more often on shallow or very shallow, rocky soils (i.e., rarely burned sites), while savannas occupy areas of deeper, fine-textured soils (West 1999a). Most soils supporting pinyon-juniper in the region are formed in material weathered from sedimentary substrates, especially shale and sandstone, or from the basalt mesas, plateaus and lava flow outcroppings that characterize the Raton-Clayton volcanic field in northeastern New Mexico and adjoining areas in Colorado and Oklahoma.

Woodlands are dominated by pinyon pine (*Pinus edulis*) and/or one-seed juniper (*Juniperus monosperma*). At higher elevations in Colorado, Rocky Mountain juniper (*Juniperus scopulorum*) may be present with or instead of one-seed juniper. There is a tendency for pinyon to be more dominant at higher sites, and juniper relatively more dominant at lower sites (West 1999b). Martens et al. (2001) found that this spatial segregation is primarily among larger, older trees, suggesting that the divergence is due to differential mortality of pinyons and junipers at higher or lower elevations, rather than differences in seedling establishment requirements. Both pinyon pine and juniper are fairly slow growing, and can live for hundreds of years, a life cycle that is well adapted to xeric habitats, but is less suitable for quickly changing conditions. Although individuals of both species become reproductive after a few decades, most seed production is due to mature trees of 75 years of age or older (Gottfried 1992).

Understory layers in Great Plains pinyon-juniper are variable and generally similar in species composition to adjacent forest, shrubland, or grassland communities. Pinyon-juniper woodlands of the foothills may include Bigelow sage (*Artemisia bigelovii*), mountain mahogany (*Cercocarpus montanus*), Gambel oak (*Quercus gambelii),* Scribner needlegrass (*Achnatherum scribneri*), black grama (*Bouteloua eriopoda*), blue grama (*Bouteloua gracilis*), Arizona fescue (*Festuca arizonica*), littleseed ricegrass (*Piptatheropsis micrantha*) or James' galleta (*Pleuraphis jamesii*) as common understory species. In lower elevation woodlands or where widely spaced mature juniper trees form a savanna with shortgrass prairie, typical graminoid species are blue grama and James' galleta. Yucca and prickly-pear (*Opuntia*) species, as well as younger juniper trees form a shrubby layer in some areas. Scarp woodlands of juniper and/or pinyon with sparsely vegetated understories are included as part of the cliff, canyon, and outcrop ecosystem in this report, but these woodlands often intergrade with pinyon and juniper woodlands as described herein.

According to Romme et al. (2009), some areas (e.g., the Great Basin), have experienced a significant increase in tree density and canopy cover over the past 150 years. In other places (e.g., the Uncompahgre Plateau in Colorado), some infill and expansion has occurred at local scales, but change at the landscape scale has been minimal (Manier et al. 2005, Romme et al. 2009). Likewise, some areas, but not others, have experienced conversion of adjacent grasslands and/or shrublands to savannas or woodlands. However, many areas have also experienced significant mortality in the past decades, especially with respect to the 2002-2004 drought and subsequent beetle infestation that impacted pinyon-juniper across the southwest. Increasing tree density and expansion into adjacent habitats is often attributed to past fire suppression and grazing. These issues are discussed further in the following sections.

## 5.2 Primary Ecological Processes

The primary processes that influence the formation and persistence of pinyon-juniper include climate, grazing, fires, tree harvest, and insect-pathogen outbreaks (West 1999a; Eager 1999). The distribution and dynamics of this ecosystem are influenced by processes that operate at local to regional scales, and vary across the physical settings in which pinyon-juniper occurs. Romme et al. (2009) distinguish different types of pinyon-juniper vegetation, and propose that each type experiences ecological processes differently. According to their characterizations, persistent woodlands generally occupy sites with shallow, coarse soils that support only sparse understory but climate and disturbance regimes are favorable for tree growth. Pinyon-juniper savannas are typically found on gentle topography where soils favor well-developed grass/forb cover, and trees occur in low to moderate densities with only a minor shrub component. Wooded shrublands are those pinyon-juniper stands where there is a well-developed shrub component, with variable grass/forb cover and density of trees increasing and decreasing over time in response to climate and disturbance events. Though each of these types is especially prevalent in certain regions (e.g., persistent woodlands on the Colorado Plateau, savannas in southern New Mexico, wooded shrublands in the Great Basin), all are found in appropriate settings throughout the West (Romme et al. 2009).

The perceived expansion of pinyon and juniper trees into adjacent shrubland or grassland communities is topic of widespread interest in western rangeland management (Knight 1994, Van Auken and Smeins 2008, Redmond et al. 2014). Although woody species encroachment into grasslands has been observed worldwide, it is by no means universal, and opinions regarding the mechanisms and causes of the trend are still evolving.

According to Romme et al. (2009), some cases that appear to be expansion of trees into shrub or grass habitats may, in fact, be former woodlands recovering from past severe disturbance, or may simply be natural range expansion. For example, recovery of pinyon-juniper woodlands that were chained in the mid-1900s (as evidenced by piles of dead trees, stumps, and seeded non-native grasses) may on the surface appear to be an expansion into grasslands or shrublands. Natural range expansions of both pinyon and juniper have been occurring throughout the Holocene, and this expansion continues at the edges of range for pinyon and/or juniper species in Colorado, Wyoming, Utah, and Montana. Given the enormous variation in stand structure and composition of pinyon-juniper across its distribution, it is difficult to determine whether or not the presence of scattered trees constitutes "encroachment" in the absence of historical knowledge and local study (Romme et al. 2009). This condition is variable by region, and probably represents a complex combination of factors.

Brunell et al. (2014) summarized potential causes of woody plant expansion into grasslands:

- One possibility is that cover of woody plants increases and decreases as part of a natural range of variation over time. This is unquestionably true for very long time scales, but may not adequately explain recently observed increases in woody cover in some places.
- Changes in climate that affect water availability (e.g., drought, El Niño-driven fluctuations in patterns seasonal precipitation patterns) may affect the balance of woody vs. herbaceous species.
- Increasing levels of atmospheric CO2 may result in reduced transpiration by grasses, potentially making more soil moisture available for other plants, including shrubs and trees.
- Changes in fire regime, in particular the widespread fire suppression of post-settlement years, is believed to contribute to the persistence and expansion of woody species into grasslands of North America.
- Extensive grazing of domestic livestock beginning in the mid-1800s in the western U.S. is also identified as contributing to the reduction in grassland cover and consequent expansion of woody species.

Brunelle et al. (2014) concluded that, for Cloverdale Ciénega in southwestern New Mexico, the observed increase in woody plant pollen over a 5,500-year sediment record is primarily explained by increasing CO2 and coincident high-intensity grazing of domestic livestock. Van Auken and Smeins (2008) note that an increase in juniper establishment that began in the mid- to late-1800s in northern California coincided with the introduction of heavy season-long livestock grazing, which tended to reduce fine fuel loads and lower fire frequency.

### 5.2.1 Fire and Grazing

Both pinyon and juniper reproduce only from seeds, and do not re-sprout after fire. In addition, both species are relatively intolerant of fire due to their thin bark and low crowns (Romme et al. 2009). There is evidence that piñon-juniper savannas have been altered and have encroached into new areas over the last century (Miller and Tausch 2001), likely the result of fire suppression and grazing. The fire return interval in these ecotonal areas, where piñon-juniper borders grasslands (prairie), is much longer than in typical piñon-juniper woodland habitat (Gottfried et al. 2008).

Romme et al. (2009) and Baker and Shinneman (2004, 2009) propose that low intensity surface fires that kill predominantly small trees was not characteristic of the historical fire regime in persistent pinyon-juniper woodlands and wooded shrublands. Rather, when fires occurred in these types, most or all trees within burn areas were killed, and shrubs were top-killed. The degree to which this is true of pinyon-juniper savannas is less certain. Their rationale is that the fine fuels needed to carry surface fires are discontinuous in pinyon-juniper, and that the major fuel sources are the crowns of trees and shrubs. This perspective is supported by the complete lack of fire scar evidence in many stands across the range of this system. The end result is usually complete or almost complete tree mortality in burned areas; this is true of recent fires and is probably true of historical fires as well. Fire rotations may have been on the order of centuries (400-600 years), and many stands show no evidence of past widespread fire (Romme et al. 2009). Romme et al. (2009) goes on to note that fire rotations may be getting shorter, though it is unclear whether the increase in large fires since the 1980s is due to recent changes in climate and fuels, or is simply an infrequent but natural event – and that, regardless, increasing temperatures, increasing tree density at some sites, and expansion of weeds that promote fire (e.g., cheatgrass) may result in a dramatic upsurge in fires over the coming century.

Fire suppression has been proposed as one of the potential drivers for increasing density and expansion of pinyon-juniper. The general rationale is that the suppression of frequent, low intensity fires which would have killed pinyon and juniper allowed trees to proliferate. However, the few studies of fire history in pinyon-juniper suggest that frequent fire was probably not a component of this system (Romme et al. 2009). The empirical data needed to confirm or refute the role of fire in pinyon-juniper expansion do not currently exist (Romme et al. 2009).

The role of fire in maintaining herbaceous cover and suppressing woody vegetation is well demonstrated in most prairie systems. Although fire is the primary direct agent in removing woody vegetation in prairies, interaction with the effects of heavy and continuous grazing by domestic livestock is also believed to play a role in the maintenance and expansion of pinyon-juniper and juniper woodlands in the western Great Plains (Knight 1994). Grazing acts on the herbaceous component of the community, reducing the frequency and intensity of fire by preventing fine fuel buildup, and tending to shift the herbaceous community toward more ephemeral species (Fuhlendorf et al. 2008). This effect is more pronounced in drier, less productive sites, especially in combination with drought, which further reduces already low fuel loads. Regardless of precipitation levels, heavy grazing always reduces the effectiveness of fire in eliminating trees (Fuhlendorf et al. 2008). However, patterns of precipitation and temperature (i.e., cool, wet periods) appear to be more important in recruitment events than history of livestock grazing (Barger et al. 2009).

Romme et al. (2009) point out that other potential effects of grazing related to pinyon-juniper expansion may include enhanced tree seedling survival due to reduced competition from the herbaceous layer and increased shrub cover forming “nurseries” that provide shade and protection for fragile seedings. Not surprisingly, available data present conflicting results. Shinneman and Baker (2009) found pinyon density greater in grazed than in ungrazed areas in western Colorado. Other studies found comparable pinyon-juniper density increases in grazed and ungrazed sites in Utah (Harris et al. 2003) and in Idaho (Burkhardt and Tidale 1976). Burkhardt and Tisdale (1976) suggested that juniper establishment appeared to be influenced more by soil characteristics than by the influence of grazing on vegetation. Knapp (1996) concluded that grazing was not the primary factor in pinyon-juniper expansion in Oregon.

Other studies suggest that climate is a more important driver of woodland dynamics than land use (e.g., fire suppression, grazing) (Barger et al. 2009, Shinneman and Baker 2009, Clifford et al. 2011). Shinneman and Baker (2009) found establishment of pinyon and juniper associated with multi-decadal drought cycles. Clifford et al. (2011) found that canopy cover and density were more impacted by drought than by fire, and that many pinyon-juniper woodlands may be in a “constant flux of recovery from droughts.”

### 5.2.2 Drought and Insect Outbreaks

Drought can result in widespread tree die-off, especially of the more susceptible pinyon pine (Breshears et al. 2008). Native juniper species are generally more drought tolerant than pinyon, and more likely to persist under drought conditions. Clifford et al. (2013) detected a strong mortality threshold at 23.6 in (60 cm) cumulative precipitation over a two-year drought period (i.e., essentially normal annual precipitation) for pinyon pine. Clifford et al. (2011) suggested that differences in pinyon and juniper mortality could result in shifts in dominance within woodlands, and potentially also alter associated communities dependent on these species. Gaylord et al.'s (2013) experimental drought study showed that drought with 45% less than ambient precipitation over one or more years will kill pinyon, and that the same drought treatment over three years will cause substantial canopy loss of one-seed juniper, with increased mortality suggested for the future. They also demonstrated that even one year of drought predisposes pinyon to attack by insects and increased mortality.

Insect and disease mortality is a natural ongoing process, usually at a low level, but occasionally as more severe episodic outbreaks. The southwest experienced a severe drought during 2002-2003, which resulted in an explosion in the population of the native Ips beetle (also known as pinyon engraver beetle, *Ips confusus*). Greater than 90% of pinyon pine trees died within 15 months in northern New Mexico (Francis et al 2011 citing Breshears et al. 2005), and 32% of pinyon pines died over one year in northern Arizona (only 5% juniper mortality was documented in these locations) (Mueller et al. 2005), reducing Arizona's pinyon-juniper canopy cover by 55% (Johnson et al. 2015 citing Clifford et al. 2011). In Colorado, an estimated one million trees were killed, with up to 90% loss of mature pinyon in some parts of the state, including both southwestern and southeastern Colorado, and the southern Front Range (Colorado State Forest Service 2003, 2004). Floyd et al. (2009) found that pinyon mortality at three sites in southwest Colorado, northern Arizona, and northern New Mexico was greatest (60-94%) in older, reproductive trees, and that juniper mortality was much lower than pinyon mortality. With extreme mortality rates in pinyon, dominance in some stands has shifted to juniper (Mueller et al. 2005, Romme et al. 2009).

Redmond and Barger (2013) pointed out that future stand composition in pinyon-juniper will depend on recruitment rates for pinyon pine and juniper species. In their study of stands in Colorado with post-2003 pinyon mortality ranging from 10-100%, they found that new pinyon recruitment was strongly associated with density of live, adult pinyon trees. Sites where adult pinyon mortality was high had low levels of pinyon recruitment, potentially due to limited seed availability and/or loss of canopy microsites. The viability of pinyon seeds declines quickly after one year (Meeuwig and Bassett 1983), and establishment and survival of pinyon seedling establishment is greater under tree or shrub canopy (Mueller et al. 2005), where shading provides cooler soil temperatures, less evapotranspiration, and higher organic matter and nutrient availability (Padien and Lajtha 1992, Breshears et al. 1997, Chambers 2001). Redmond and Barger (2013) also documented that survival of pinyon seedlings and saplings that were already established before the 2003 mortality event was positively associated with density of pinyon trees present when they established, but was not affected by post-establishment loss of adult pinyon. Thus, they suggested that where there is advanced regeneration of pinyon, future dominance may not transition to juniper. On the other hand, future loss of more microsites as dead pinyon snags fall may shift the balance of pinyon and juniper juveniles. Their final conclusion was that pinyon-juniper appears to have some resilience to recent mortality events due to a high density of juvenile trees surviving the drought, but that microsites provided by tree and shrub cover may be increasingly important for pinyon recruitment in the future as aridity increases in the southwestern U.S.

### 5.2.3 Generalized Conceptual Ecological Model for Pinyon-Juniper Forests and Woodlands

A generalized, management-oriented conceptual model for pinyon-juniper on PCMS and Fort Carson illustrates communities, ecological states, ecosystem drivers, and possible pathways or transitions (Figure 19). We recommend that this framework be modified and expanded once the stand exam and new forest management plans are completed. An update model could include persistent pinyon-juniper woodlands (i.e., those stands occupying specific locations or soil types that are characterized by old-growth trees, little herbaceous vegetation, and an absence of fire) and wooded shrublands. For each community included, we recommend that a range of conditions for major structural and compositional attributes be added to each community (e.g., target basal area and trees per acre for a specific community). Desired or target fire frequency should be included for each type. All fires are assumed to be relatively low-severity surface fires.

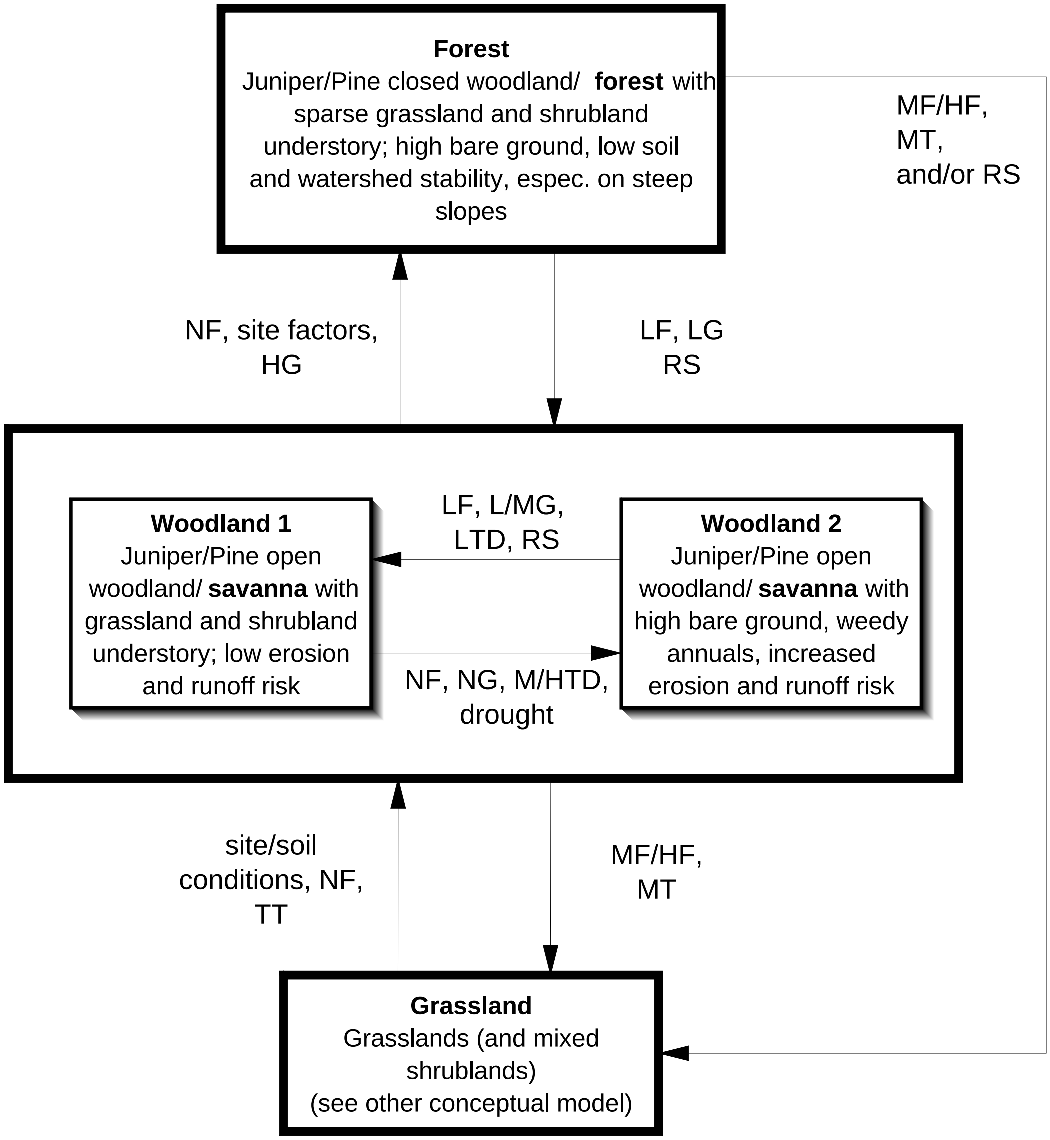



**Figure 19. Generalized conceptual ecological submodel for the pinyon-juniper ecosystem at PCMS (Doe et al. 2008). Bold boxes represent ecological states; smaller boxes within bold boxes represent communities within a state. Arrows represent drivers that can move a stand from one community or state to another. Key to drivers:** LTD=**light training disturbance,** MTD=**moderate training disturbance,** HTD=**heavy training disturbance,** NG=**no grazing (only native grazers),** LG=**light grazing (20% removal),** MG=**moderate grazing (40% removal),** HG=**heavy grazing (60% removal),** NF=**no fire,** LF=**low severity fire,** MF=**mixed-severity fire,** HF=**high severity fire (stand replacing),** PF=**prescribed fire,** MT=**mechanical thinning,** RS=**range seeding,** T=**time (<20 yrs.),** TT=**time (20-100 yrs.)**

Ultimately, the integration of management objectives into the conceptual models will facilitate making management decisions, monitoring progress toward stated ecological objectives, and understanding relationships between different pinyon-juniper communities/dtates and sensitive species.

## 5.3 Condition of Pinyon-Juniper on Fort Carson and PCMS

Current data to describe the condition of pinyon-juniper on Fort Carson and PCMS are not yet available. The installations are in the process of conducting common stand examinations to collect updated information on forest health metrics, which will be used to revise their forest management plan over the next year. The most recent field data on the health of pinyon-juniper (Betters and Reich 2002) does not present an accurate picture of existing conditions. Since that work was completed, extreme drought conditions, insect outbreaks, and a number of wildfires have altered pinyon-juniper stands. Impacts from the drought and subsequent Ips beetle outbreak of 2002-2004 were not as severe on Fort Carson and PCMS as they were in other areas. The impacts of drought on pinyon pine at Fort Carson were somewhat ameliorated by the fact that trees on that installation tend to occur in cooler niche habitats in drainages. Both installations did experience a spike in Ips beetle activity and increased mortality, but not to the extreme degree as occurred elsewhere. Both installations still have a significant pinyon pine component, and pinyon and juniper seedlings are abundant. The pinyon pine component is as high as roughly 60% in some areas on Fort Carson, somewhat lower on PCMS (J. Zayatz, pers. comm.).

## 5.4 Associated Species of Conservation Concern

In Colorado, pinyon-juniper woodlands and savannas support 41 Species of Greatest Conservation Need (SGCN) (CPW 2015) (Table 7). Of these, one species is federally listed, and almost three-quarters (28) are considered vulnerable, imperiled, or critically imperiled by NatureServe and the Colorado Natural Heritage Program. Of all the forest types in western interior U.S., only riparian forests have a higher proportion of obligate and semi-obligate bird species than pinyon-juniper (Francis et al. 2011), with over 70 bird species breeding in pinyon-juniper (Gillihan 2006). For example, Paulin et al.'s (1999) study of breeding birds in forest habitats in Utah found that pinyon-jay ranked second in percent of obligate or semi-obligate bird species, third in number of individuals counted, and fourth in species richness and diversity. Of Colorado SGCN inhabiting pinyon-juniper, this habitat type is *the* primary, or *a* primary habitat for 28 species. Of these, five have been named by DoD PIF as Mission-Sensitive Priority Bird Species: pinyon jay, gray vireo, Lewis's woodpecker, northern goshawk, and olive-sided flycatcher. See Sections 6 and 7 for information on pinyon jay and gray vireo. Lewis's woodpecker and olive-sided flycatcher are on the Partners in Flight national watchlist due to declining populations and other factors (Rosenberg et al. 2016).

**Table 7. Colorado Species of Greatest Conservation Need that occur in pinyon-juniper habitat (CPW 2015).** Table codes: **Federal listing status** – E=endangered; T=threatened. **Colorado listing status** – E=endangered; T=threatened; SC=Special Consern. **NatureServe Global Status Rank** and **Colorado Status Rank** – 1=Critically Imperiled; 2=Imperiled; 3=Vulnerable; 4=Presumed Secure; 5=Demonstrably Secure; B=breeding; N=non-breeding; T=subspecies; NR=not ranked; X=extirpated. * = species is on the Partners in Flight National Watchlist.

| Common Name | Scientific Name | Pinyon-Juniper is a primary habitat? | Federal Listing Status | Colorado Listing Status | Other State Listings | Colorado SGCN Tier | SGCN in Other States | Colorado Trend | NatureServe Global Status Rank | NatureServe Colorado Status Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| Great Basin spadefoot | *Spea intermontana* | X | | | | 2 | AZ | Unknown | G5 | S3 |
| Plains Spadefoot | *Spea bombifrons* | | | | | | UT | Unknown | G5 | S5 |
| | | | | | | | | | | |
| American peregrine falcon | *Falco peregrinus anatum* | | | SC | | 2 | AZ | Increasing | G4T4 | S2B |
| Band-tailed pigeon | *Patagioenas fasciata* | X | | | | 2 | AZ, NM, UT | Unknown* | G4 | S4B |
| Boreal owl | *Aegolius funereus* | | | | NM | 2 | NM, UT | Declining | G5 | S2 |
| Cassin's finch | *Peucaea cassinii* | X | | | | 2 | | Declining* | G5 | S4B |
| Ferruginous hawk | *Buteo regalis* | | | SC | | 2 | AZ, NM, UT | Stable | G4 | S3B,S4N |
| Golden eagle | *Aquila chrysaetos* | | | | | 1 | AZ, NM, UT | Unknown | G5 | S3S4B,S4N |
| Gray vireo | *Vireo vicinior* | X | | | NM | 2 | AZ, NM | Unknown* | G5 | S2B |
| Juniper titmouse | *Baeolophus ridgwayi* | X | | | | 2 | AZ, NM | Declining | G5 | S4B |
| Lazuli bunting | *Passerina amoena* | X | | | | 2 | AZ | Declining | G5 | S5B |
| Lewis's woodpecker | *Melanerpes lewis* | X | | | | 2 | AZ, UT | Declining* | G4 | S4 |
| Mexican spotted owl | *Strix occidentalis lucida* | X | T | T | UT | 2 | AZ, NM, UT | Unknown | G3G4T3T4 | S1B,SUN |
| Northern goshawk | *Accipiter gentilis* | X | | | | 2 | AZ, NM | Unknown | G5 | S3B |
| Olive-sided flycatcher | *Contopus cooperi* | X | | | | 2 | AZ, NM, UT | Unknown* | G4 | S3S4B |
| Pinyon jay | *Gymnorhinus cyanocephalus* | X | | | | 2 | AZ, NM | Unknown* | G5 | SNR |

| Common Name | Scientific Name | Pinyon-Juniper is a primary habitat? | Federal Listing Status | Colorado Listing Status | Other State Listings | Colorado SGCN Tier | SGCN in Other States | Colorado Trend | NatureServe Global Status Rank | NatureServe Colorado Status Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| Prairie falcon | *Falco mexicanus* | | | | | 2 | AZ | Unknown | G5 | S4B,S4N |
| Virginia's warbler | *Oreothlypis virginiae* | X | | | | 2 | AZ | Stable* | G5 | S5 |
| | | | | | | | | | | |
| Comstock's hairstreak | *Callophrys comstocki* | X | | | | 2 | | Unknown | G3G4 | S1 |
| Early elfin | *Incisalia fotis* | | | | | 2 | | Unknown | G3G4 | S2S3 |
| Moss's elfin | *Callophrys mossii schryveri* | X | | | | 2 | | Unknown | G4T4 | S2S3 |
| Spalding's blue | *Euphilotes spaldingi* | X | | | | 2 | | Unknown | G4G4 | S3S3 |
| Xanthus skipper | *Pyrgus xanthus* | | | | | 2 | | Unknown | G3G4 | S3 |
| | | | | | | | | | | |
| Allen's big-eared bat | *Idionycteris phyllotis* | X | | | | 2 | AZ, NM, UT | Unknown | G4 | SNR |
| Big free-tailed bat | *Nyctinomops macrotis* | X | | | | 2 | AZ | Unknown | G5 | S1 |
| Botta's pocket gopher (rubidus ssp) | *Thomomys bottae rubidus* | | | | | 2 | UT | Unknown | G5T1 | S1 |
| Common hog-nosed skunk | *Conepatus leuconotus* | X | | | | 2 | AZ | Unknown | G4 | S1 |
| Dwarf shrew | *Sorex nanus* | | | | | 2 | AZ, UT | Unknown | G4 | S2 |
| Fringed myotis | *Myotis thysanodes* | X | | | | 1 | AZ, UT | Unknown | G4 | S3 |
| Hoary bat | *Lasiurus cinereus* | X | | | | 2 | AZ | Unknown | G3G4 | S5B |
| Little brown myotis | *Myotis lucifugus* | | | | | 1 | UT | Unknown | G3 | S5 |
| Spotted bat | *Euderma maculatum* | | | | NM | 1 | AZ, NM, UT | Stable | G4 | S2 |
| Townsend's big-eared bat ssp. | *Corynorhinus townsendii pallescens* | X | | SC | | 1 | AZ | Unknown | G3G4T3T4 | S2 |

| Common Name | Scientific Name | Pinyon-Juniper is a primary habitat? | Federal Listing Status | Colorado Listing Status | Other State Listings | Colorado SGCN Tier | SGCN in Other States | Colorado Trend | NatureServe Global Status Rank | NatureServe Colorado Status Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| Black-necked gartersnake | *Thamnophis cyrtopsis* | | | | | 2 | AZ, UT | Unknown | G5 | S2? |
| Long-nosed leopard lizard | *Gambelia wislizenii* | X | | SC | | 2 | AZ | Unknown | G5 | S1 |
| Midget faded rattlesnake | *Crotalus oreganus concolor* | X | | | | 2 | UT | Unknown | G5T4 | S3? |
| Milksnake | *Lampropeltis triangulum* | X | | | | 2 | AZ, UT | Unknown | G5 | S5 |
| New Mexico threadsnake | *Rena dissectus* | X | | | | 2 | | Unknown | G4G5 | S1 |
| Night snake | *Hypsiglena chlorophaea* | X | | | | 2 | AZ | Unknown | G5 | S3 |
| Round-tailed horned lizard | *Phrynosoma modestum* | X | | SC | | 2 | AZ | Unknown | G5 | S1 |
| Smith's black-headed snake | *Tantilla horbartsmithi* | X | | | | 2 | | Unknown | G5 | S2? |

## 5.5 Incompatible Land Uses and Other Stresses

Pinyon-juniper is a widespread ecological system within the western U.S. In contrast to the eastern U.S., much of the interior west is characterized by vast expanses of open space and distribution of large-scale, intensive human development is patchy. Nonetheless, land uses that may be incompatible with this system and the wildlife who rely on it are pervasive across the landscape, though many of them are comparatively low-density and dispersed. Specific direct and indirect impacts from these land uses and other stresses are highly variable, depending on a multitude of factors such as timing/duration, method of implementation, and specific species of interest, not to mention the biotic and abiotic setting in any given place. Adverse impacts to some species may be neutral or positive for other species. Taking the perspective that all these activities across the landscape are likely to be having some impact(s), even if we aren't certain of exactly what, it is noteworthy that only 11% of land cover mapped as pinyon-juniper forests and woodlands occur further than one mile away from any mappable threats (Table 8). In terms of the mappable land uses that we analyzed, that number is a conservative (worst-case) scenario since it represents land uses *within a mile* of pinyon-juniper. However, it does not reflect stresses from other activities for which we did not have spatial data, including livestock grazing, recreation, and solar energy developments. Surrounding land uses with the greatest potential to influence Fort Carson and the Air Force Academy are residential/commercial development and roads (Table 9). Based on the fact that PCMS is entirely surrounded by private ranchland, the land use with the greatest potential to influence habitats on PCMS is livestock grazing.

**Table 8. Acres of pinyon-juniper within one mile of mappable incompatible land uses.**

| Pinyon-Juniper Forests and Woodlands<br>Total acres: 30,747,812 | | |
|---|---|---|
| **Land Use** | **Acres of PJ Vulnerable (within 1 mile)** | **% of total** |
| Development - High Intensity | 1,367,163 | 4% |
| Development - Low Intensity | 1,264,660 | 4% |
| Agriculture (crops) | 1,411,980 | 5% |
| Energy - Oil and Gas | 5,788,575 | 19% |
| Energy - Wind | 37,575 | 0.1% |
| Transportation – Major Roads (interstates, state highways, roads with four or more lanes) | 3,434,678 | 11% |
| Transportation – Minor Roads (local roads with fewer than four lanes) | 27,124,381 | 88% |
| **Total Acres *Not* within one mile of a mappable current threat** | **3,235,900** | **11%** |

**Table 9. Percentage of landscape within one mile of each installation in each disturbance category.**

| Installation | Development Intensity | | Agriculture (cropland) | Energy | | Transportation (roads) | |
|---|---|---|---|---|---|---|---|
| | High | Low | | Oil/Gas | Wind | Major | Minor |
| Fort Carson | 2.9% | 5.9% | 0.0% | 0.7% | 0.0% | 1.0% | 2.7% |
| Piñon Canyon Maneuver Site | 0.0% | 0.0% | 0.3% | 0.8% | 0.0% | 0.1% | 0.3% |
| US Air Force Academy | 5.6% | 18.0% | 0.0% | 2.8% | 0.0% | 0.3% | 5.4% |

## 5.5.1 Residential and Commercial Development

High intensity urban residential and commercial development occurs primarily near the edges of pinyon-juniper distribution (Figure 20). Lower intensity development (exurban, rural) development is similar in total acreage to urban development, but is much more widespread in its distribution, occurring across the range of pinyon-juniper. Pinyon-juniper near developed areas are most likely to be affected by the effects of fire suppression, but may also experience impacts such as increased weed cover and altered animal community interactions (e.g., predator-prey dynamics, loss of easily disturbed species), among others. Activities intended to reduce the threat of wildfire to residential and commercial developments often involve severe alteration or complete removal of woodland stands within the wildland-urban interface (WUI). Clearing or thinning interrupts the natural seral progression of the impacted stands, and may degrade the usefulness of the remaining woodland for wildlife. For example, small, fragmented patches of habitat are undesirable for some pinyon-juniper bird species due to the loss of deep woodland interiors and closer proximity to disturbaces, more predators (e.g., domestic cats, corvids, raccoons, skunks), and greater potential for brood parasitism by cowbirds (Gillihan 2006). With the significant increase in occurrence of very large-scale wildfires over recent decades, fire mitigation, especially in the WUI, will continue to be a high priority for woodland management in accordance with the National Fire Plan. Future land use changes are most likely to convert areas of previously low intensity development (exurban or rural) into higher intensity residential development (suburban), contributing to a gradual increase in habitat fragmentation, and eventual loss of high quality habitat.

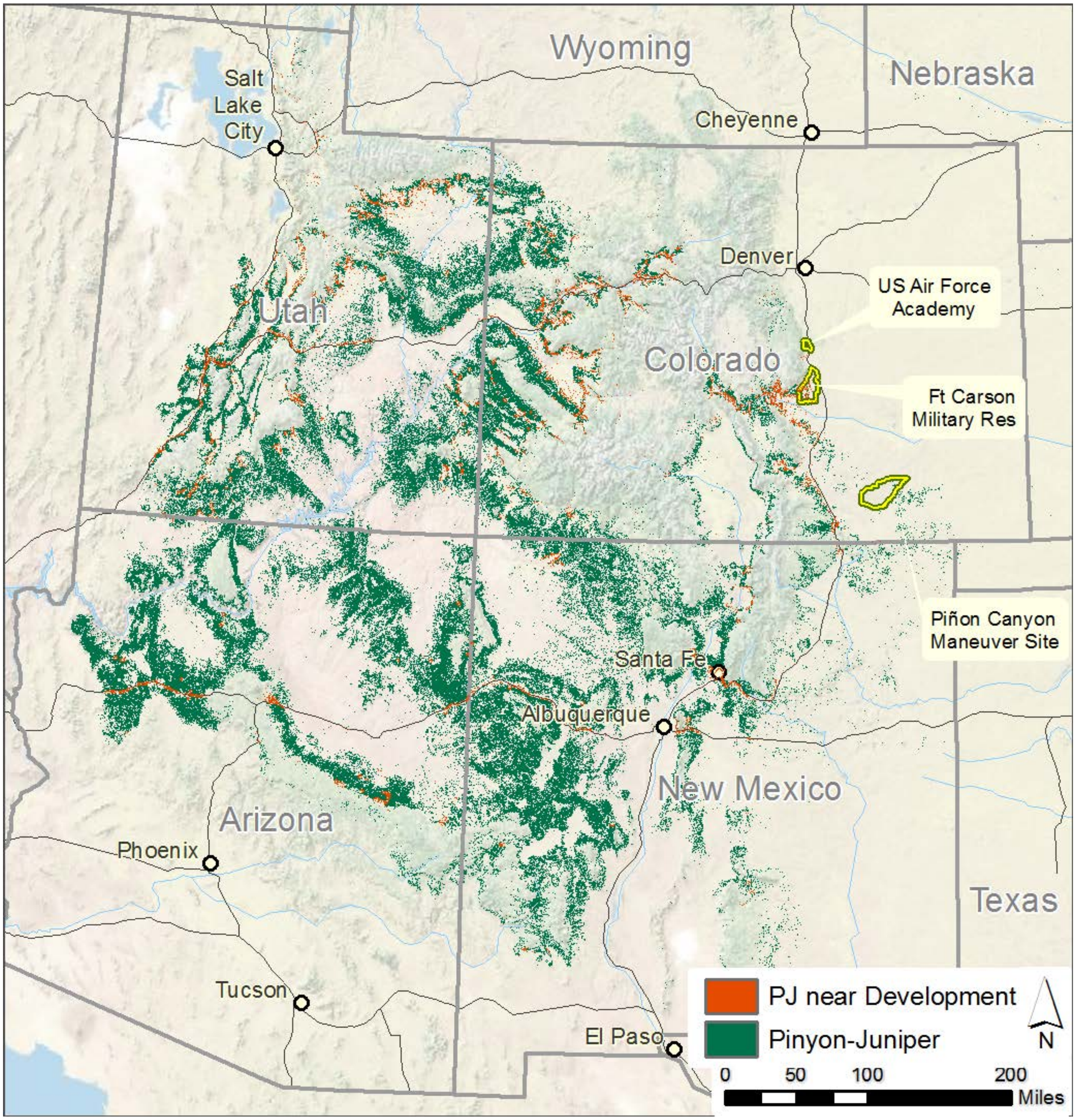



**Figure 20. Distribution of pinyon-juniper within one mile of residential and commercial development (low and high intensity combined).**

Within the range of this ecosystem, about 1.3 million acres of this habitat are within one mile of high intensity development, and about 1.2 million acres are within one mile of low intensity development (Table 8).

***Installation Management for this Threat***

The ACUB Program has been used successfully at Fort Carson to alleviate the potential for development on adjacent properties, and could continue to be employed where need and opportunity exist. The location of PCMS, fairly remote from existing residential centers and surrounded by large private ranches, renders this issue largely moot, at least for the time being. However, it should be noted that pinyon-juniper woodlands are often desireable for exurban/ranchette development – the current situation could change, though such change is not expected in the foreseeable future. The Air Force Academy is already surrounded by residential and commercial development to the north, east, and south and protected by Pike National Forest to the west; thus, potential for this type of program to be effective is limited. However, very little pinyon-juniper occurs on this installation and the Academy's responsibility for management of this system or its associated species is negligible.

### 5.5.2 Incompatible Agriculture

The "incompatible agriculture" category includes both crop farming and livestock farming and ranching. Direct conversion of pinyon-juniper to row crop agriculture is not typically a significant concern due to the fact that the physical setting of most pinyon-juniper would be incompatible with growing crops. Though cropland offers some habitat benefit (e.g., food resources in grain fields) to some wildlife species, this is not generally true of pinyon-juniper birds (Gillihan 2006). Pinyon-juniper in proximity to cropland still provides suitable habitat for wildlife species, but some concerns may include impacts to birds from greater cowbird parasitism and increased predation often associated with increased habitat edges.

Given the relatively limited distribution of cropland compared to grazing rangeland in the west, incompatible grazing is more likely than crop agriculture to result in adverse impacts to pinyon-juniper and associated wildlife species (depending, of course, on how it is managed). Tree clearing for "range improvement" is a source of disturbance within these woodlands, and can dramatically changes the habitat where it occurs (Barnitz et al. 1990). Historically, large expanses of many pinyon-juniper woodlands were thinned, chained, or otherwise altered to improve forage for cattle, and the legacy of those actions remain with us today. Some of the primary concerns related to ongoing incompatible grazing include potential for loss of understory, increased erosion potential, introduction or spread of invasive non-natives (e.g., cheatgrass), simplification of woodland structure, and increased brood parasitism for pinyon-juniper birds.

Across the range of pinyon-juniper, approximately 5% of existing acreage is within one mile of crop agriculture (Table 8). The majority of cropland in proximity to pinyon-juniper is in western Colorado and southeastern Utah (Figure 21). Existing land use in the near vicinity of Fort Carson, PCMS and the Air Force Academy include residential/commercial development, grazing rangeland, and multiple-use public lands, but little cropland. Less than 0.5% of their pinyon-juniper woodlands are potentially vulnerable to potential effects of nearby cropland.

Spatial data depicting agricultural rangeland are not available, so we were unable to calculate acres of potential impact. Some open rangeland occurs near Fort Carson, especially to the south, and this activity is expected to continue. Fort Carson has used the ACUB program to secure easements on some of this land to avoid conversion to urban development. PCMS is essentially surrounded by open rangeland that is grazed. Thus, there is potential for impact (e.g., cowbird parasitism), especially near the boundaries of the installation.

***Installation Management for this Threat***

Although allowing grazing has been mentioned as a possible management tool for use at PCMS, there are currently no agricultural management programs at Fort Carson, PCMS, or the Air Force Academy. Shortgrass prairie areas on Front Range foothills and plains were grazed by bison prior to settlement, and subsequently by domestic livestock (primarily cattle). After acquisition, these lands were no longer grazed by livestock. The absence of significant large ungulate grazing has resulted in a buildup of standing dead biomass and litter buildup on the ground. The resulting decadence and litter accumulation is outside the natural range of variability, although areas that are periodically burned have reduced litter buildup.

The off-installation threats associated with livestock grazing in general or improper grazing (i.e., overgrazing) might be mitigated through continuation or expansion of compatible use buffering and easements. Over the long-term, such easements might minimze weed transmission and spead onto the installations, and also minimize the potential for fires that originate on an installation to become large and create concerns/hazards outside the fencelines.

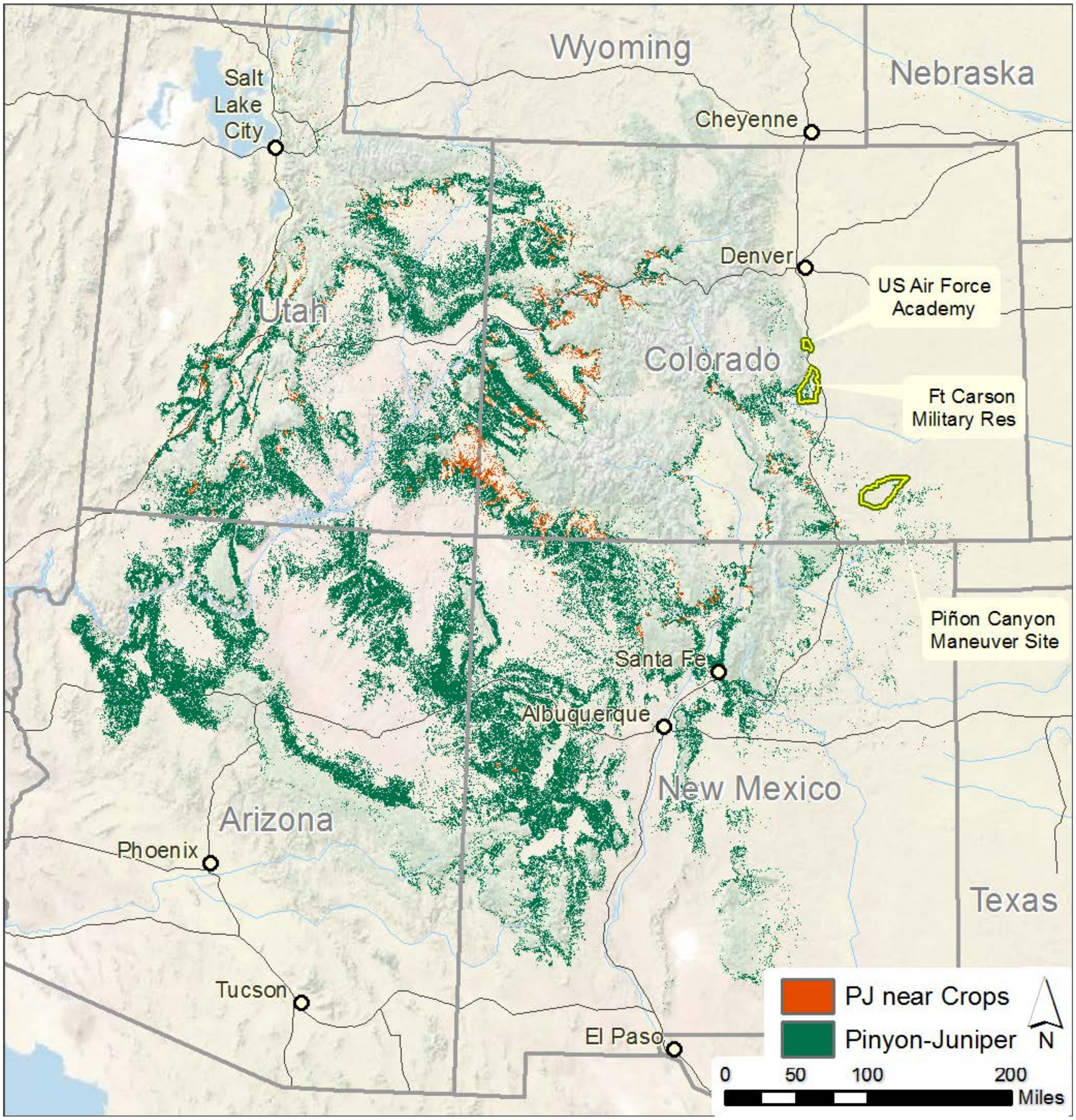



**Figure 21. Distribution of pinyon-juniper within one mile of cropland.**

### 5.5.3 Energy Production and Mining

Energy development with its associated roads, transmission and pipeline corridors, and other infrastructure, is an ongoing source of disturbance and fragmentation across the western U.S. These activities result in loss of ecosystem area, and may disturb the functioning of systems and wildlife through road development and traffic, noise and disturbance, water use, altered surface flows around utility-scale developments, pollution, spread of invasive species, direct mortality (e.g., collision with power lines, wind turbines), increased predation, increased stress and altered behavior in animals, reduced reproductive success, and local extirpations (AGFD 2012, CPW 2015, NMDGF 2016). Impacts are, of course, highly variable depending on many factors including size of footprint, density of infrastructure, timing and method of operation, siting, and sensitivities of species or ecosystem of interest, among others.

***Oil and Gas Development***

Oil and gas development is widespread across the western U.S., and ongoing extraction of these resources is likely to continue. In relation to the distribution of pinyon-juniper, the majority of the oil and gas developments are concentrated in western and southern Colorado, northwestern New Mexico, and northeastern Utah. At a landscape scale, these developments are more often found in open habitats adjacent or in proximity to pinyon-juniper rather than *in* pinyon-juniper. However, incompatible land uses in these open habitats can influence pinyon-juniper associated wildlife species, and may also encourage additional destruction of trees in pinyon-juniper savannas. In fact, the greatest impact from oil and gas development on pinyon-juniper may be the perceived need to eradicate more acreage to mitigate impacts to, or improve nearby habitats for, sage-grouse and other species.

***Renewable Energy Development***

The southwestern U.S. offers by far the best opportunities for solar energy development in the country (Figure 22), and much of this area overlaps with the current distribution of pinyon-juniper. The best opportunities for developing wind energy are generally to the east of the pinyon-juniper distribution, across the Great Plains (Figure 23), though there is some overlap along Colorado's mountain front near Fort Carson and PCMS. Over one million acres across Arizona have been proposed for renewable energy development (mostly solar energy), where much of the development potential is in proximity to pinyon-juniper (AGFD 2012). There are currently 60 active or under-construction commercial solar power generation sites scattered across New Mexico, as well as 17 active or under-construction commercial wind energy facilities, primarily in eastern New Mexico (NMDGF 2016). In Colorado, there are at least eight large wind farms with thousands of turbines. These are primarily on the eastern plains, but some are sited along the mountain front between Fort Carson and PCMS. Forests and woodlands are not appropriate sites for wind and solar installations, but pinyon-juniper is often adjacent to the kinds of open landscapes that would be suitable for these types of developments. We expect to see ever-increasing efforts to expand production of these resources in the future. Thus, potential for adverse impacts to pinyon-juniper associated species exists, and may worsen.

Across the range of pinyon-juniper, nearly 6 million acres (19%) of this habitat are within one mile of existing oil and gas development, and more than 37,000 acres (<1%) are within one mile of a wind turbine facility (Table 8, Figures 24 and 25). Fort Carson and PCMS have only small percentage (just under 1% each) of their pinyon-juniper woodlands at risk of potential impacts from oil and gas development.

***Installation Management for this Threat***

Although not specifically used for energy development, the ACUB Program could be used in relation to efforts to prevent this type of development from occuring near the borders of Fort Carson and PCMS. Stormwater management and water quality monitoring programs at Fort Carson/PCMS and the Air Force Academy could be used to detect sedimentation or chemical contamination of aquatic habitats, which could lead to the contamination and degradation of food sources for the raptors and other SAR.

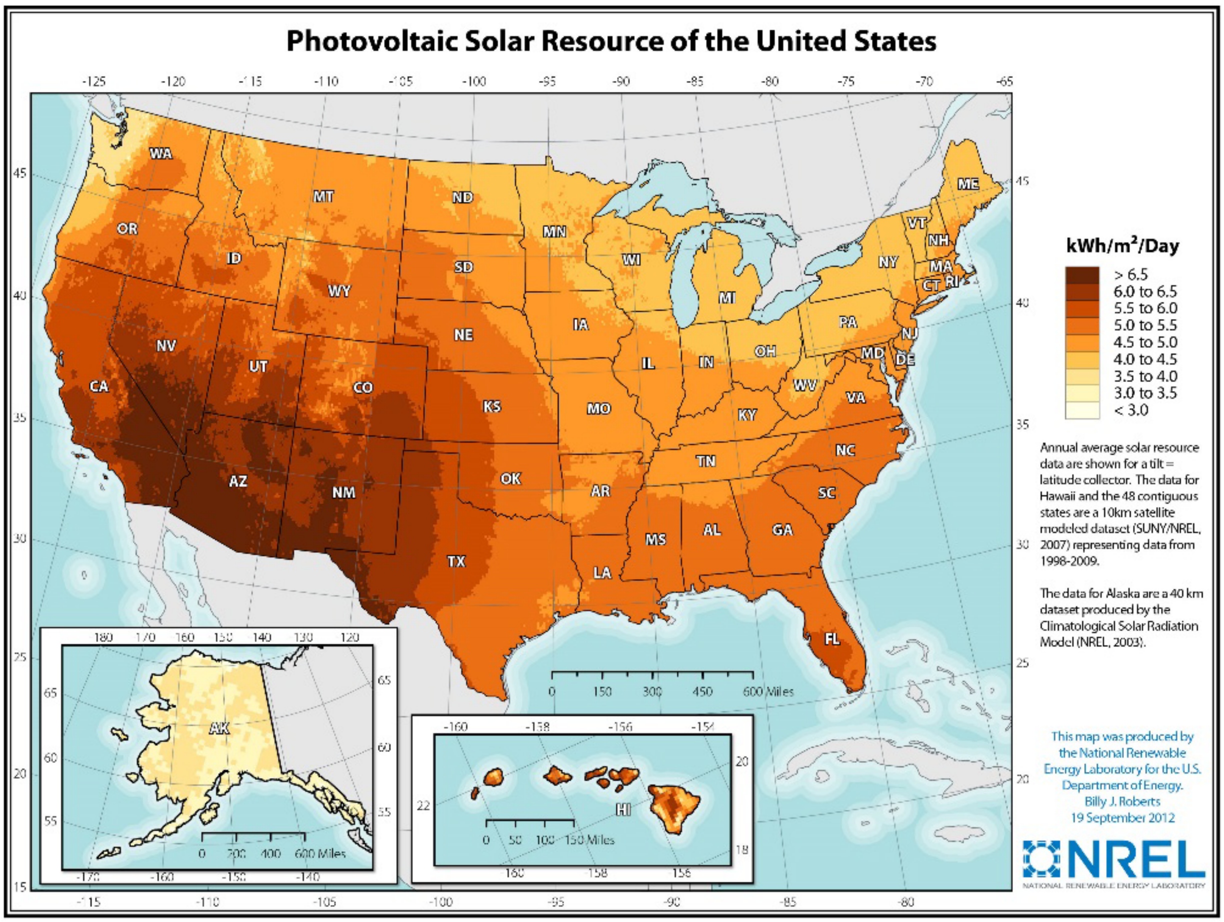



**Figure 22. Map showing potential for solar energy development.** The distribution pattern of concentrating solar resource is essentially the same as that of the photovoltaic solar resource within the range of pinyon-juniper. Source: http://www.nrel.gov/gis/solar.html

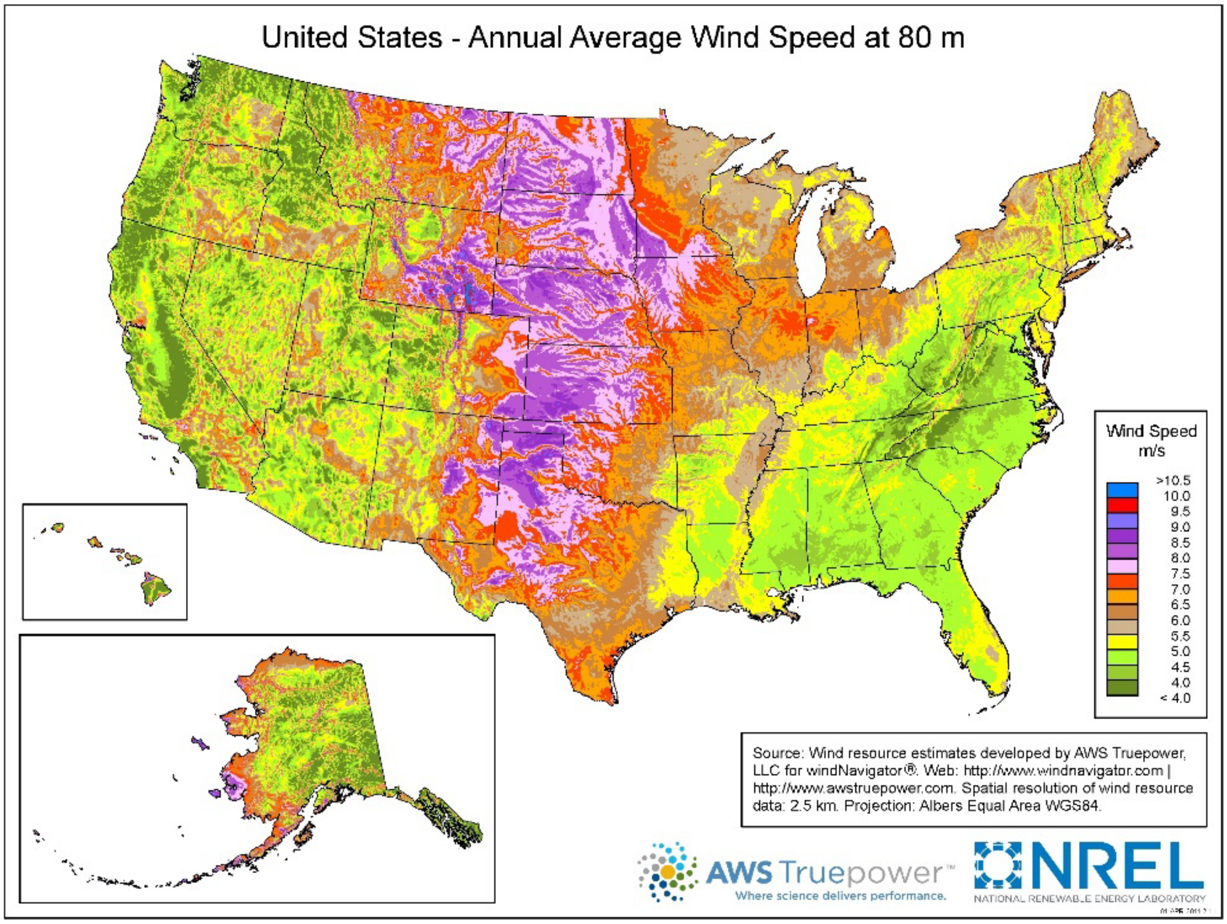



**Figure 23. Map showing potential for wind energy development.** Source: http://www.nrel.gov/gis/wind.html

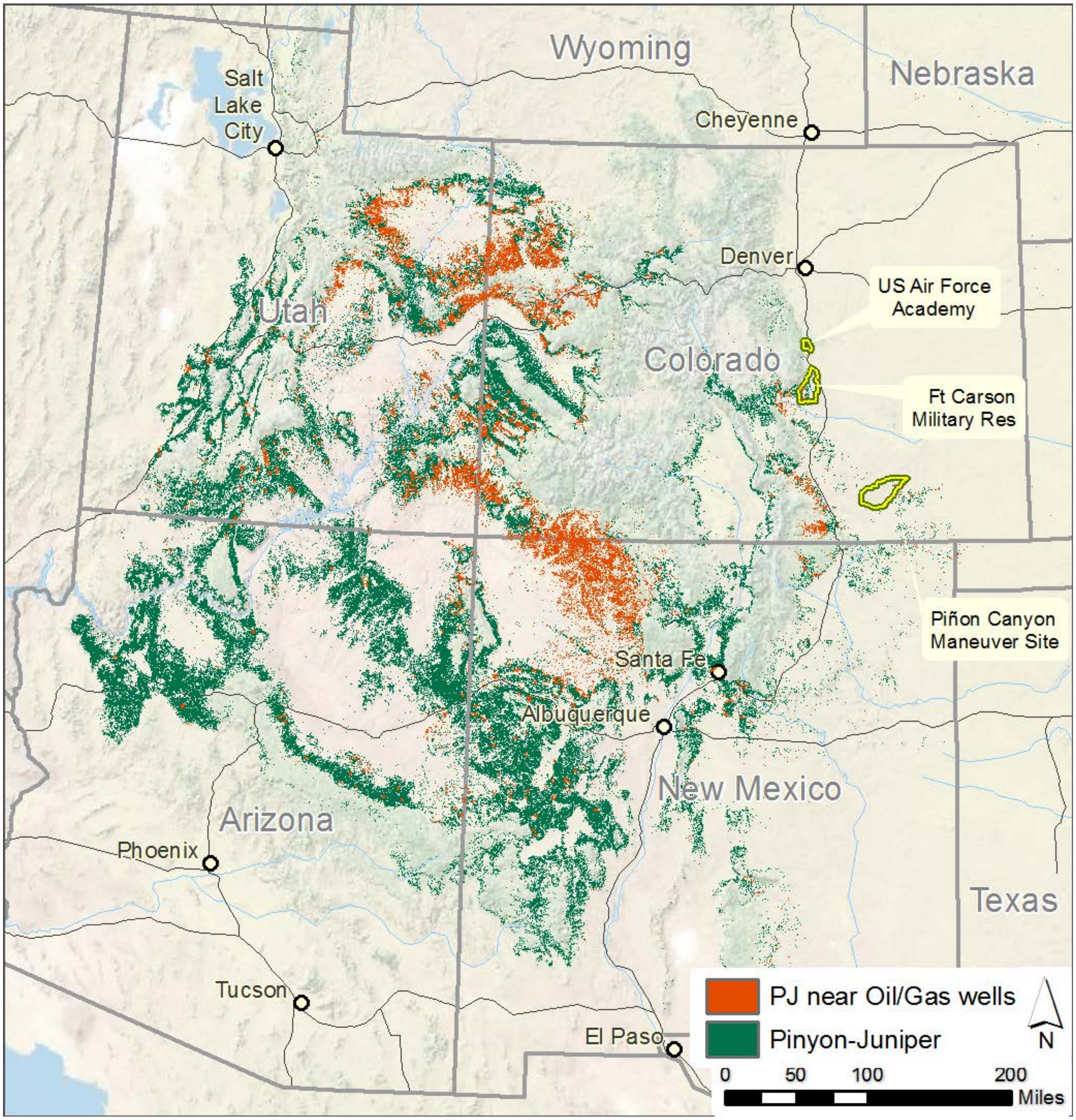



**Figure 24. Distribution of pinyon-juniper within one mile of existing oil and gas sites.**

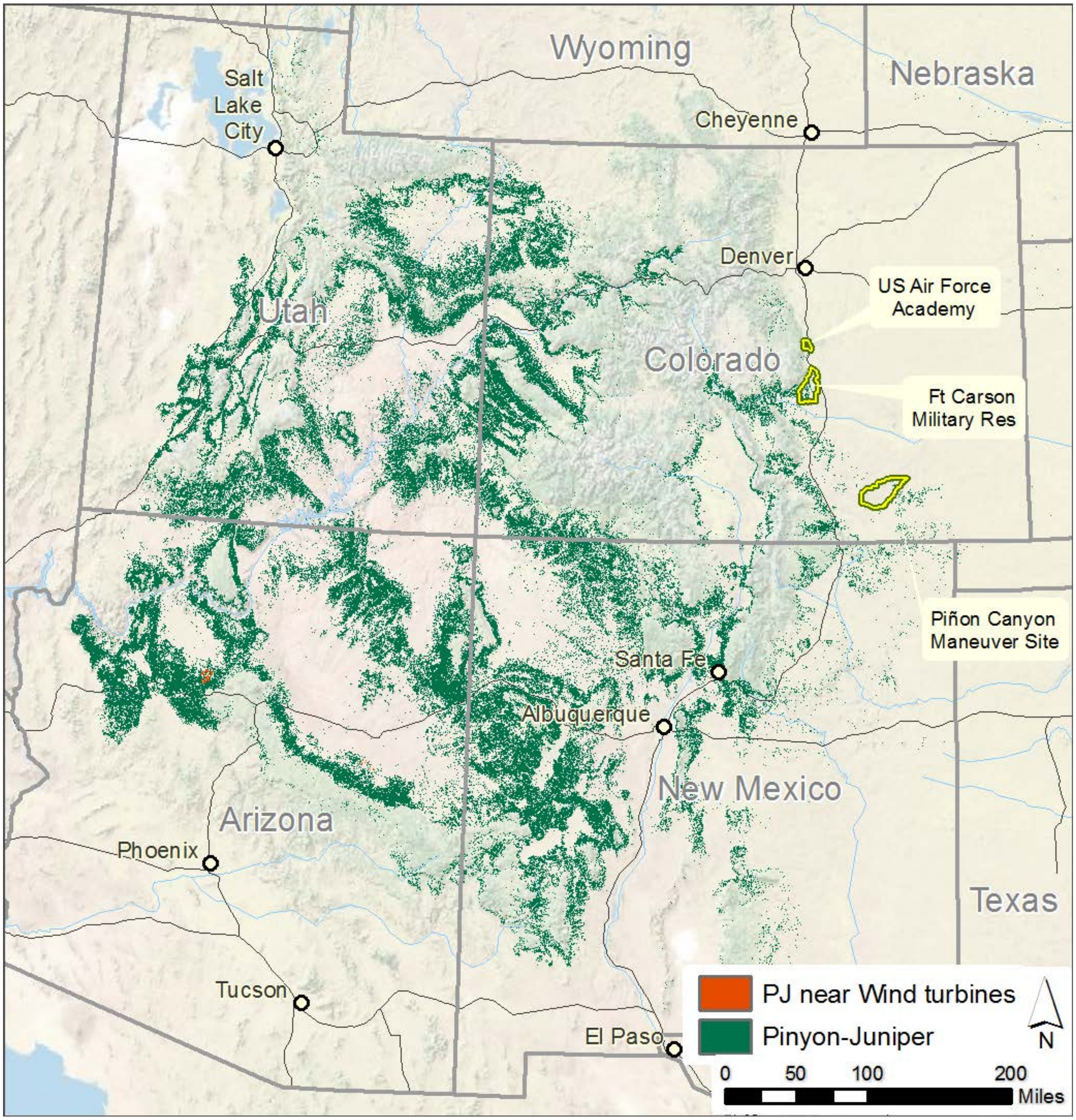



**Figure 25. Distribution of pinyon-juniper within one mile of existing wind facilities.**

### 5.5.4 Transportation and Service Corridors

Roads associated with residential and energy development, as well as public lands access and use, are a source of habitat loss and fragmentation for pinyon-juniper in many areas. The amount of direct loss is variable depending on the size of the road and its right-of-way, but for example, a 16-foot wide road converts approximately two acres of native habitat per mile (Arizona Game and Fish 2012). Major highways with high traffic loads are somewhat limited in extent within the distribution of pinyon-juniper. However, the density of smaller roads is significant, and these are pervasive throught the pinyon-juniper ecosystem. Some of the many impacts of roads of any size include alteration of local hydrology (e.g., altered surface flows, altered stream characteristics at crossings), increased erosion, and spread of invasive species. Due to the sparseness of ground cover in some pinyon-juniper stands, these woodlands can be especially prone to erosion, and so are vulnerable to increased erosion from roads and off-road motorized recreation. Depending of the extent, use patterns, and associated fencing, roads of any type can be a source of increased disturbance and mortality for wildlife.

Roads are, by far, the greatest source of stress on pinyon-juniper woodlands in terms of acres potentially impacted. Within the range of the pinyon-juniper ecosystem, about 3.4 million acres – 11% – are within one mile of a major road, but more than 27 million acres – 88% – are within one mile of a minor road (Table 8, Figures 26 and 27). Minor roads constitute 2.7%, 0.3% and 5.4% of the area within one mile of Fort Carson, PCMS and the Air Force Academy, respectively (Table 9). Major roads are a much smaller percentage of all three installations, with all three being 1% or less.

***Installation Management for this Threat***

The ACUB Program could be used to deter road construction within the vicinity of Fort Carson and PCMS. LRAM projects are occasionally completed on small roads and trails within Fort Carson/PCMS. These projects aim to reduce erosion and sedimentation, possibly reducing negative effects on burrowing species of concern (Burrowing owl) and burrowing prey of predators, including the Golden eagle.

Most of the land surrounding the Air Force Academy is already developed or a part of Pike National Forest. Nearly all roads on the installation are paved and for transportation only (no maneuvers). Installation management ability for this threat is minimal.

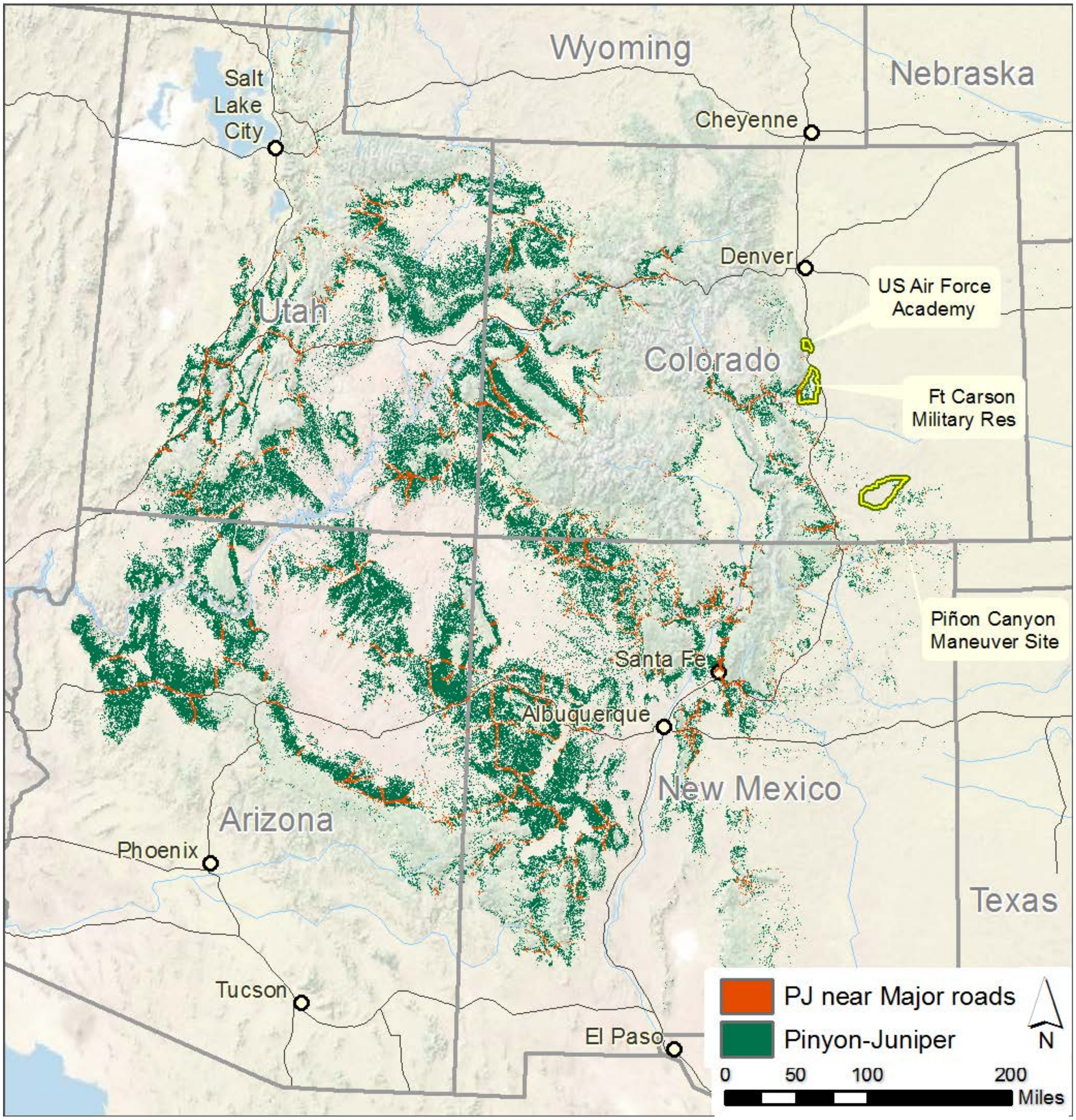


**Figure 26. Distribution of pinyon-juniper within one mile of major roads.**

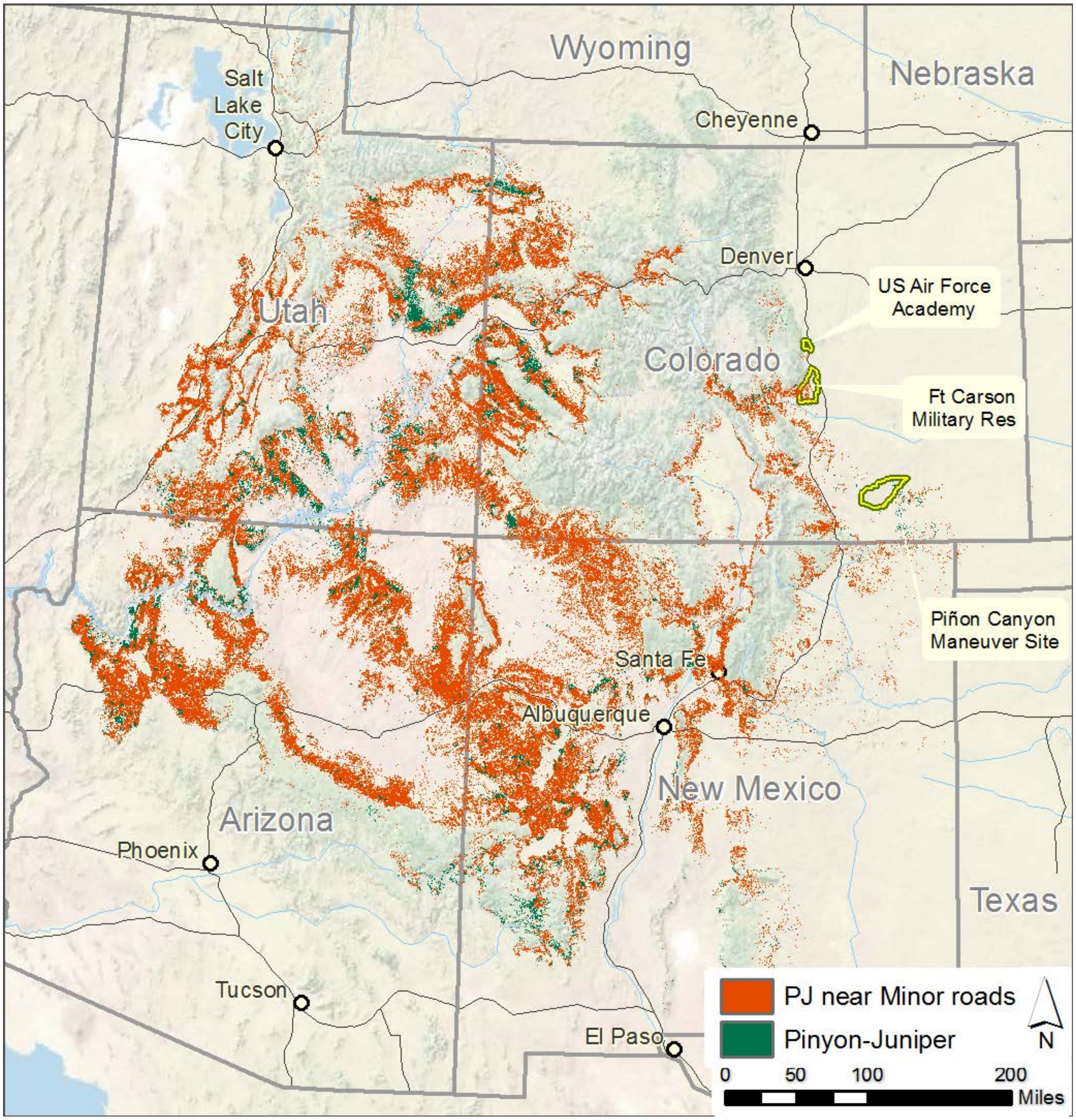



**Figure 27. Distribution of pinyon-juniper within one mile of minor roads.**

### 5.5.5 Biological Resource Use

Harvesting of trees and collecting of pinyon nuts are the primary consumptive uses of biological resources in these woodlands. Though pinyon-juniper is not a good source of commercial lumber, these woodlands have historically received extensive use for fuelwood and fence posts. Likewise, the harvesting of pinyon nuts has been, and continues to be, important for many human communities. Pinyon trees only produce large seed crops every ~5-7 years on average. Seeds are required for recruitment of young pinyon into pinyon-juniper woodlands since these trees only reproduce by seed. Pinyon seeds are also the mainstay of the pinyon jay's diet. Thus, sustained over-collecting of pinyon nuts could have have noticeable local impacts if it occurred.

***Installation Management for this Threat***

Sress on pinyon-juniper systems and dependent species from over-harvest is a potential threat over the range of this system, but is not applicable to Colorado's DoD installations. To the extent that DoD installations in Colorado or elsewhere may collaborate on future multi-partner conservation efforts across boundaries, abatement of harvest-related threats could be addressed at larger scales.

### 5.5.6 Human Intrusions and Disturbance

Pinyon-juniper is often subject to impacts from recreational use, particularly motorized recreation, across its range. Because these lower elevation woodlands are typically accessible year-round, they are utilized for horseback riding, hiking, ATV's, bicycling and other recreational activities. Increased recreational use may degrade habitat and disturb wildlife during vulnerable periods. Pinyon-juniper often provides good habitat for large game animals, so hunting is a seasonal source of human disturbance.

At Fort Carson and PCMS, military training and range activities are a source of disturbance to pinyon-juniper at Fort Carson and PCMS. With the exception of canyon and hogback areas on the southern edge of PCMS, woodland and savanna habitats are generally included in mechanized training areas. Pinyon and juniper trees can be damaged by vehicle passage during mechanized training. However, trees provide cover during training, and training policies are intended to minimize damage to existing trees during exercises. See Section 2.4 for additional information on impacts from training activities.

***Installation Management for this Threat***

Fort Carson and PCMS have numerous management programs related to military training impacts. These programs include: off-limit areas, non-vehicular use areas, rest/rotation/deferment program, maneuver damage assessment, and rare species restrictions on use. Information on these and other programs used at Fort Carson and PCMS can be found in Chapter 4 of this document.

- The Directorate of Family, Morale, Welfare, and Recreation is in charge of regulating various consumptive and non-consumptive recreational activities, including off-road use and hiking/equestrian trails.
- At the Air Force Academy, Academy Security Forces monitor illegal or unnecessary off-road and military training activity.
- All installations have wildland fire management programs to reduce the likelihood of large, uncontrolled fires from escaping training lands.

On the ground military training at the Air Force Academy is generally infrequent and of low impact. Programs and policies pertaining to the attenuation of military use impacts include the Environmental Restoration Program, several watershed plans administered in cooperation with local agencies, and threatened and endangered species management.

### 5.5.7 Natural System Modifications

Past fire suppression may have contributed to alteration of the natural fire regime within pinyon-juniper, leading to changes in structure and species composition, though there is some debate about the degree to which this has occurred (e.g., Brockway et al. 2002, Baker and Shinneman 2004, Floyd et al. 2004 cited in Huffman et al. 2009, Romme et al. 2009). Increased growth of woody species, including pinyon and juniper, has been observed in some areas, and may in some instances be a result of the legacy of grazing and fire suppression (Brunelle et al. 2014). See Section 5.2.1 for additional discussion of fire in pinyon-juniper systems.

Efforts to improve or restore conditions in pinyon-juniper (e.g., to reduce fuel loads for wildfire management, encroachment) can adversely impact species who inhabit these woodlands, depending on individual species needs and how treatments are conducted. Management approaches such as mechanical thinning and prescribed fire may be ineffective or detrimental when they are based on incompatible methods (e.g., developed for fire-adapted systems such as ponderosa pine). Researchers are investigating the effectiveness and species response of some widely used treatments, with some interesting results. Huffman et al. (2009) found that prescribed fire by hand crews did not reduce hazardous fuel loads in pinyon-juniper. They suggested that more extreme weather and fire behavior would be needed to achieve fuels reduction, but also acknowledged that such conditions would increase the risk of fire escape (ergo, potentially useful in remote areas but not in the WUI). Huffman et al. (2009) also found that treatments in their study did not affect densities of either pinyon or juniper seedlings. Redmond et al. (2013) found that past (1963-1988) chaining and seeding treatments resulted in reduced tree cover that persisted over multiple decades, but also significantly increased grass cover and therefore surface fuel loads. They also documented that treated areas had significantly fewer pinyon pine seedlings and saplings compared to non-treated areas, but no difference in juniper recruitment, suggesting that these stands may become more juniper-dominated in the future. A recent study in Colorado on responses of pinyon-juniper birds to mastication and hand thinning treatments found that pinyon-juniper obligate birds declined in treated areas (Magee and Coop in prep) at both local and landscape scales. Interestingly, for pinyon jay they found a positive effect at the landscape scale, but a negative effect at the local scale.

At PCMS, large burns in 2008 (Bridger fire) and 2011 (Bear Springs complex and Callie Marie fire) have restored fire to woodlands on the northern portion of the installation, resulting in a more heterogeneous patchwork of stand types. Smaller fires have occurred in pinyon-juniper woodlands at Fort Carson, where live fire exercises during training are a relatively common source of ignition for wildfires. Tree mortality from these fires has been limited. Prescriptive burning in the past has been sporadic, but is intended to be a regular management tool with a goal of restoring the historic fire regime (Jason Zayatz, Installation Forester, personal communication).

#### *Installation Management for this Threat*

All installations have wildland fire management programs to reduce the likelihood of large, uncontrolled fires from escaping training lands, protect life and property and comply with DoD and

Service Branch requirements. For a detailed discussion of the use of prescribed fire at front-range installations, see section 2.4.6.

### 5.5.8 Invasive and Other Problematic Species and Genes

In some areas, understory vegetation has been altered by the presence of invasive annual grasses, especially cheatgrass (*Bromus tectorum*), which can have an impact on the frequency and intensity of fire. Cheatgrass is highly flammable and very invasive, and thus has the potential to greatly increase continuity of fuels and subsequent spread of fire in pinyon-juniper and other semi-arid ecosystems (Whisenant 1990, Knapp 1996, Romme et al. 2009). This cool season grass begins growth earlier in the year than native western grasses, giving it a competitive advantage in terms of access to moisture and nutrients prior to native grasses breaking dormancy. Consequently, however, it dries out earlier in the summer, when climatic conditions are at their hottest and driest. Especially in years with winter precipitation, cheatgrass is able to grow and spread quickly, thus greatly increasing fuel to support wildfire (Billings 1992).

Outbreaks of the pinyon ips bark beetle (*Ips confusus*) have caused extensive mortality in pinyon-juniper woodlands (Kearns and Jacobi 2005). Extended droughts have increases the frequency and intensity of bark beetle outbreaks. See Section 5.2.2 for additional discussion on drought and the Ips beetle.

Betters and Reich (2002) reported widespread infestation of the pinyon "pitch mass" borer (a moth larva, *Dioryctria* spp.) at PCMS. Although the effects of burrowing larvae cause noticeable damage, mortality of otherwise healthy individual trees is not likely from this insect pest. Pinyon are susceptible to the fungal pathogen *Leptographium wageneri* var. *wageneri*, which causes black stain root disease, however, mortality from this pathogen is thus far confined to stands on the western side of the Continental Divide. Juniper are also susceptible to several species of wood-boring beetles and fungal diseases, which may cause localized mortality or reduced vigor of affected trees. Some limited bark beetle mitigation work involving stand thinning or clear cutting has occurred on both Fort Carson and PCMS, but better stand data are needed to guide future mitigation efforts (Jason Zayatz, Installation Forester, personal communication). As previously noted, some of the information in Betters & Reich is no longer accurate. Current field investigations are expected to yield updated information over the coming year.

***Installation Management for this Threat***

The Federal Noxious Weed Act (§2814 of 7 USC 360), part of the Plant Protection Act of 2000, mandates federal agencies to (DECAM 2015):

- have an office or person trained to coordinate an undesirable plant management program
- adequately fund the program
- implement cooperative agreements with state agencies, and
- conduct integrated pest management techniques for managing undesirable plant species.

Fort Carson, PCMS, the Air Force Academy, and several other Front Range military installations participate in the Noxious Weed Biological Control Program (DPW 2015). The program is an integrated control program that uses chemical, cultural, and mechanical methods of weed control.

Due to the size of PCMS, the widespread application of pesticides is difficult, and prescribed burns have been used in the past to control invasive weeds. An updated invasive species plan is currently in production for Fort Carson and PCMS.

### 5.5.9 Pollution

Throughout the region, many areas are exposed to deposition of atmospheric pollutants from both point and nonpoint sources. Affected areas are generally either downwind of large urban source areas, sites near large point sources such as coal-fired power plants, or regions with mixed sources including urban, mobile, agricultural and industrial sources (Fenn et al. 2003). Urban source areas and large point sources within the region are largely concentrated along the mountain front. The effects of increasing availability of nitrogen from air pollution may induce growth responses in pinyon and juniper in these areas, but in general the effects of air pollution in these woodlands are unknown.

Although the region is sparsely populated on the whole, human presence does introduce artificial light and noise pollution into the environment, especially around population centers. These disturbances can affect the behavior and physiology of many types of wildlife that use these areas, including mammals, birds, insects, fish, reptiles, and amphibians (Rich and Longcore 2006, Francis et al. 2009, Hölker et al. 2010, Barber et al. 2010).

***Installation Management for this Threat***

Water quality monitoring programs at all installations could be used to detect chemicals that are the product of non-point sources that are affecting the water supply. Air and water quality are tied to federal, state, and DOD standards and each installation is responsible for meeting these standards. Noise and artificial light are generally not addressed unless needed.

### 5.5.10 Climate Change and Severe Weather

Since the end of the last major glacial maximum, the distribution and relative abundance of pinyon and juniper has fluctuated in response to changing climatic conditions. Variability in disturbance history and site conditions across the distribution of pinyon and juniper woodlands have produced a dynamic mosaic of interconnected communities and successional stages that can be naturally resilient. Warming conditions during the past two centuries, together with fire suppression, livestock grazing, and atmospheric pollution, increased the ability of this ecosystem to expand into neighboring communities, at both higher and lower elevations (Tausch 1999). However, future precipitation and temperature patterns are projected to be less favorable for pinyon, enabling juniper to become more dominant. The future association of pinyon and juniper is likely to look much different than it has in the recent past.

There is general agreement that temperatures throughout the pinyon-juniper range are likely to increase, and in some places this increase may be extreme. For example, in Arizona, mean annual temperature has already increased by 1.8°F, and the rate of warming is predicted to accelerate, reaching a rise of 4-5°F by mid-century and 7-12°F by the end of this century (Sprigg et al. 2000, Arizona Game and Fish 2012). Likely impacts from higher temperatures include increasing duration and severity of heat waves and droughts, increasing variability in precipitation, increasing evapotranspiration rates, and increasing frequency and intensity of insect outbreaks and wildfires (Easterling et al. 2000, Fields et al. 2007, Garfin and Lenart 2007, New Mexico Game and Fish 2016). Though projections for precipitation are more variable, precipitation is projected to decrease overall across most of the American Southwest, not only exacerbating the impacts of higher temperatures, but also resulting in reduced snowpack and spring and summer flows (New Mexico Game and Fish 2016).

For Colorado, on average models tend to show increasing precipitation for most of the state (Decker and Fink 2014, Colorado Natural Heritage Program 2015). However, hydrologic modeling for the Colorado River and other basins (e.g., Nash and Gleick 1991, 1993) has indicated that, as a generalized rule-of-thumb, for each 1.8°F (1°C) of warming, an approximate 5% increase in precipitation would be required for runoff levels to remain unchanged. With projected mid-century temperatures increasing 4°F or more, no areas in Colorado are projected to receive sufficient compensatory precipitation (Decker and Fink 2014). Year-to-year variability in precipitation patterns could have an effect on pinyon pine persistence that is not always apparent from model averages. Even under somewhat warmer conditions than recent norms, and increased precipitation, there are likely to be occasional multi-year droughts over a period of several decades that would be detrimental to the persistence of pinyon pine.

Pinyon-juniper woodlands are projected to experience summer temperatures warmer than the current temperature range in more than one third of its current distribution in Colorado. Projected winter precipitation levels are generally within the current range, but spring and summer precipitation for 9-16% of the current distribution are projected to be lower than the driest end of the current range. The pinyon-juniper system has large ecological amplitude so warmer conditions may allow expansion, as has already occurred in the past centuries, as long as there are periodic cooler, wetter years for recruitment. The availability of canopy microsites to promote establishment and survival of seedlings may become increasingly important as conditions become drier (Redmond and Barger 2013). However, increased drought may drive fires and insect outbreaks, from which these woodlands would be slow to recover.

Under hotter and drier conditions, the ability of landscapes at Fort Carson and PCMS to support pinyon pine are predicted to be decreasing. At the same time, much of Fort Carson is predicted to become more suitable for one-seed juniper, while to the southeast, much of the area that currently supports juniper would no longer be suitable for that species. This agrees with other regional projections that suggest that some areas of southeast Colorado may eventually convert to a semi-desert grassland (Rehfeldt et al. 2012). Under the warm and wet scenario, suitability for pinyon pine is still decreasing at both installations, but conditions for juniper are more stable (Figures 28 – 30).

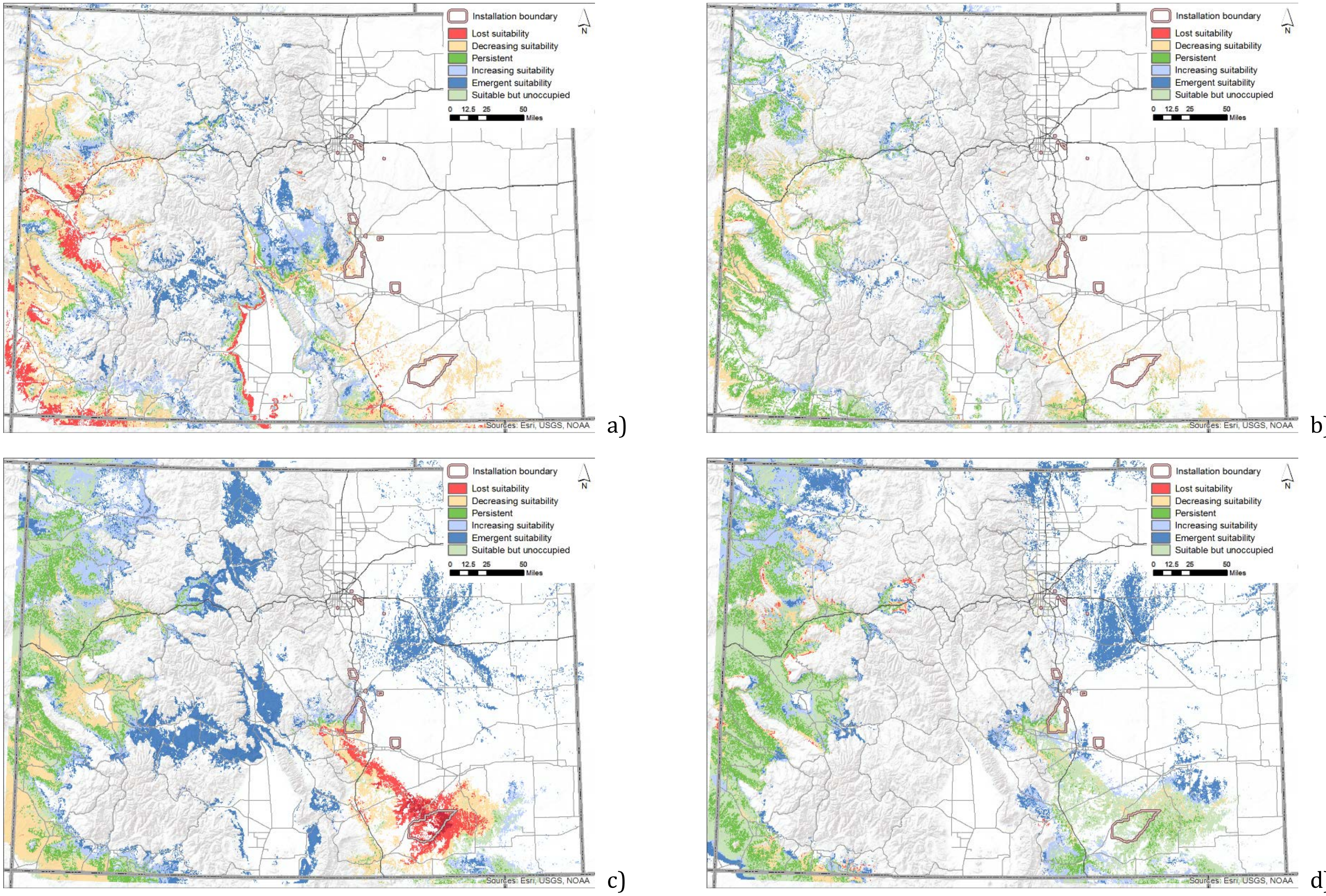



**Figure 28. Projected habitat suitability changes across Colorado for pinyon pine (top) and one-seed juniper (bottom) under two climate scenarios at mid-century:** a) pinyon pine under much hotter and drier conditions; b) pinyon pine under warmer, wetter conditions; c) juniper under much hotter and drier conditions; d) juniper under warmer, wetter conditions (CNHP 2017 in prep).

**Pinyon Pine** **Juniper**

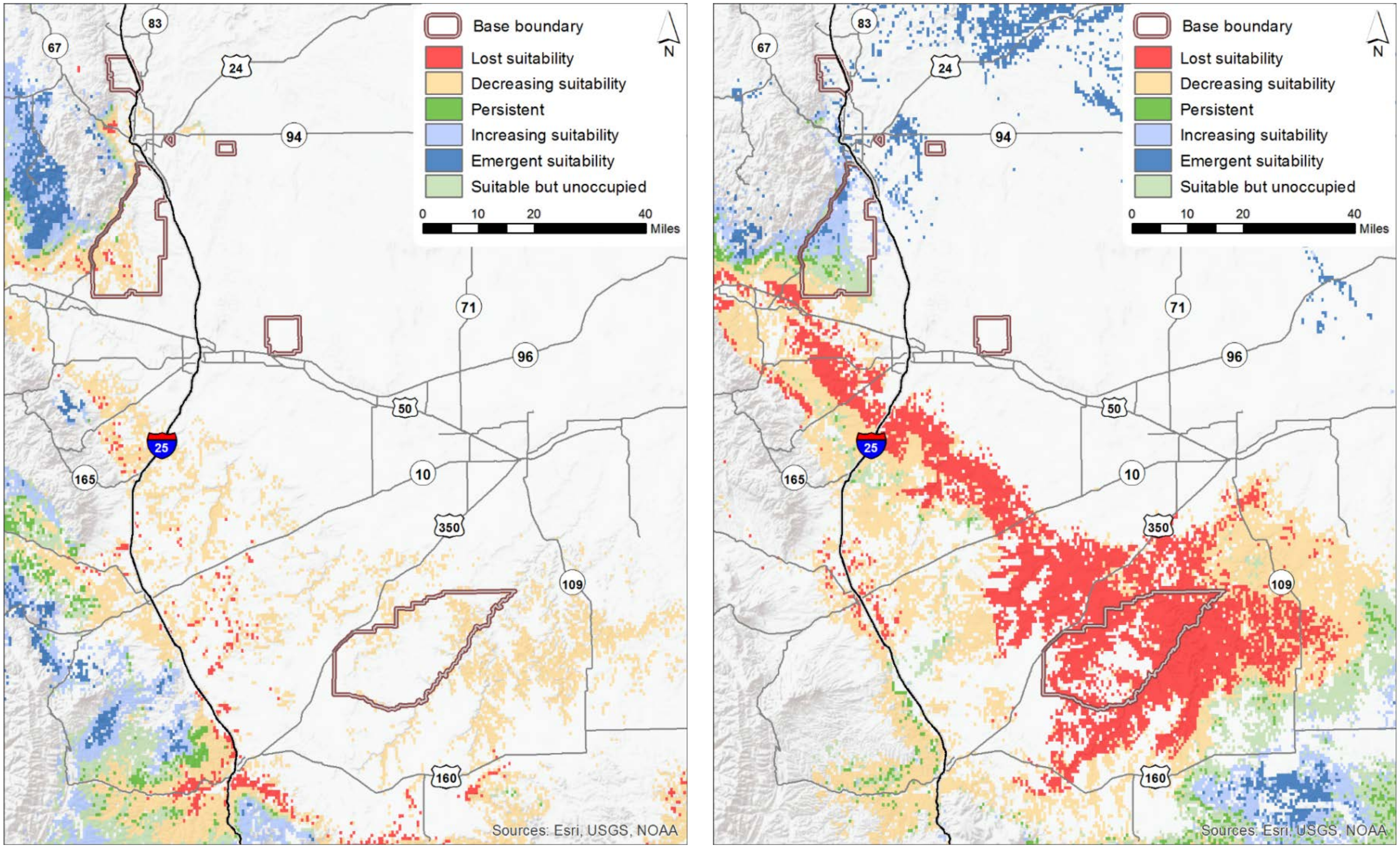



**Figure 29. Projected habitat suitability changes for pinyon pine (left) and one-seed juniper (right) at mid-century under a future climate projection of much hotter and drier conditions** (HADGEM2-ES.1.RCP85) (CNHP 2017 in prep).

**Pinyon Pine** **Juniper**

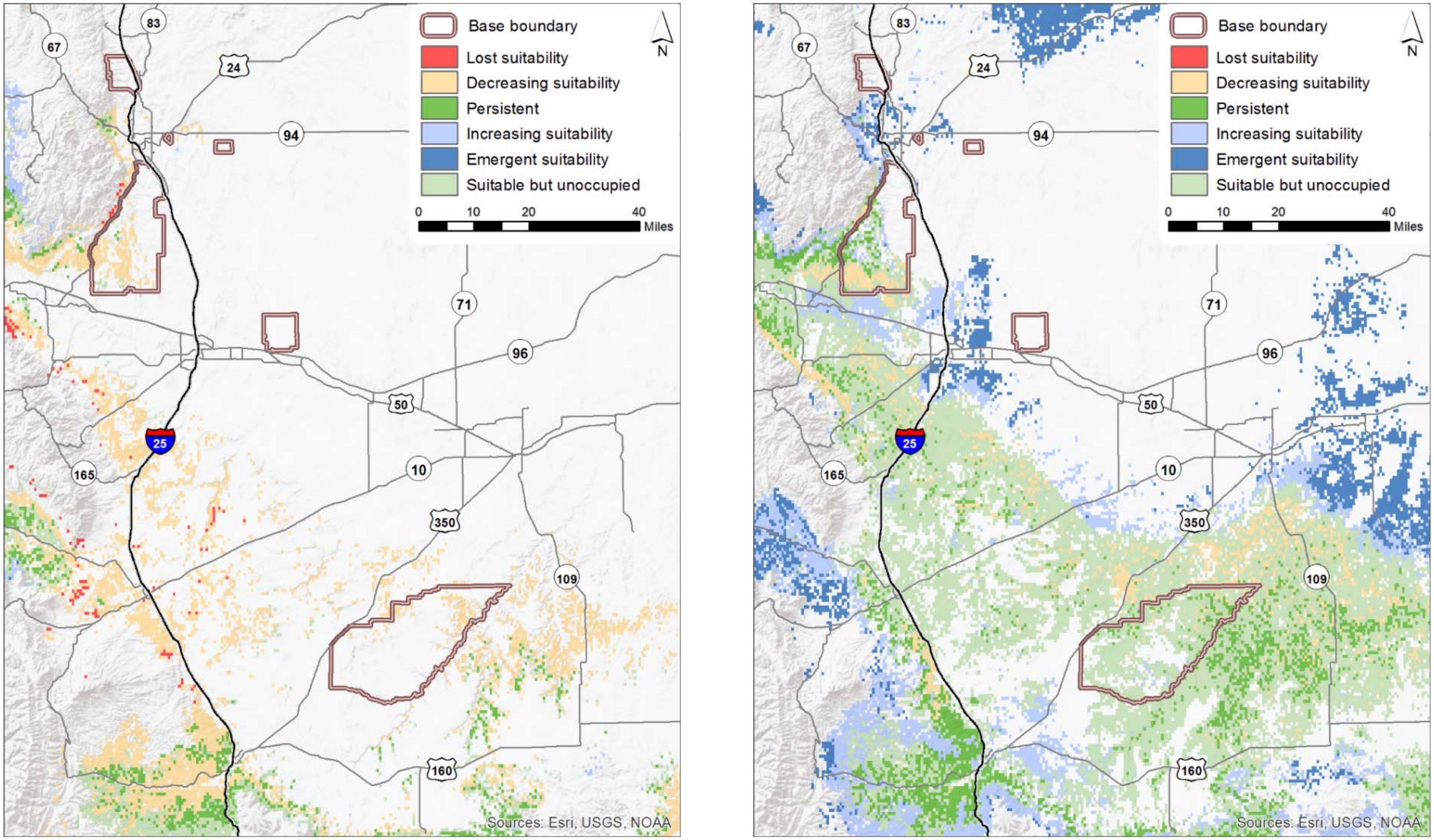



**Figure 30. Projected habitat suitability changes for pinyon pine (left) and one-seed juniper (right) at mid-century under a future climate projection of warmer and wetter conditions** (CNRM-CM5.1.RCP45) (CNHP 2017 in prep).

## 5.6 Historical and Current Management

Forest and woodland areas at PCMS are generally highly valued components of the landscape, especially with respect to wildlife habitat for game and non-game species, cultural value where associated with cultural features and other prehistoric and historic resources. They add aesthetic value to canyon landscapes, especially where very old trees are found. Lastly, forests and woodlands provide important training resources for the military in the form of landscape diversity and tactical concealment. In general, open woodlands supporting a mixed herbaceous and shrub understories are very desirable, have a higher watershed stability than more closed forests, and are less prone to high-severity fires compared to more open woodlands.

Following acquisition, there was some concern that military training might cause excessive tree damage and mortality. This view was supported by the tendency of mounted units to seek shade and tactical concealment when possible. For this reason, a campaign by the ITAM and Environmental Offices was undertaken in the 1980s to protect trees using a combination of education and penalties (i.e., monetary fines). This tree protection program was modified in the 1990s after anecdotal information and RTLA data suggested that training-related mortality and tree regeneration was not a significant problem (Jeff Linn, personal comm. July 2008). In general, the approach to forest management was mostly hands-off up through the 1990s. Sporadic insect infestations (e.g., *Ips* beetles) representing natural cycles were occurring and continue to the present. Despite the total acreage of forested areas on PCMS, the commercial value of the forest resources is relatively low, the primary products from these pinyon and juniper stands being fencepost material and firewood. Following the forest inventory in 2001, managers began considering forest management actions to address the primary concerns of fire risk and forest health, and a forest management plan was developed in 2006. Recommendations in the 2006 Plan include thinning (only slopes <30%) of some overstocked stands to reduce fire risk to neighboring areas, controlling insect infestations, promote understory grasses through destocking actions, and improving tactical vehicle mobility in select training areas.

The most recent information regarding forest composition and management on Fort Carson and PCMS is the 2011-2016 Forest Management Plan (DPW 2011). Using forest inventory data from the early 2001, it identified and outlined pinyon-juniper management concerns, desired conditions and objectives, management approaches, locations and priorities for specific treatment projects, and a plan for monitoring and evaluating the effectiveness of forest treatments.

*<u>Desired Conditions for Pinyon-Juniper Communities (DPW 2011):</u>*

- Habitat is comprised of native tree species and native herbaceous understory species.
- Stands are structurally diverse, containing old, mid-age and young trees, snags, downed logs, and downed woody debris.
- Invasive and exotic plants are absent or occur at low levels.
- Pinyon-juniper woodlands exist as a mosaic across the landscape with a natural uneven age structure among trees.

- Some areas have higher tree densities and canopy closures and serve as wildlife habitat patches.
- There are openings between trees and clumps of trees to facilitate wildlife movement and military maneuvers.
- Plant cover is present to stabilize soils, prevent erosion and promote nutrient cycling.
- Native insects and diseases occur at endemic levels.
- Persistent pinyon-juniper forest occurs in the same areal extent and with the same vegetation composition as it did historically.
- Native grasslands occur as in the same areal extent and with the same vegetation composition they did historically
- The pinyon-juniper savannas contain uneven- aged trees and open in appearance. Trees generally occur as isolated individuals, but occasionally occur in small groups. Scattered shrubs are present and understory grass and forbs are abundant.
- The persistent pinyon-juniper woodlands are highly variable in tree age, structure and density. Shrubs are sparse to moderate, and herbaceous cover is limited and discontinuous because of poor soils and other site conditions. Snags, downed logs, and downed woody debris are present.

*Objectives for Pinyon-Juniper Communities (DPW 2011):*

- Thin 40-200 acres annually to within the general range of 30-50 trees per acre in piñon - juniper savannas.
- Thin 10-40 acres annually for fuel mitigation projects in persistent piñon -juniper woodlands.
- Prescribed burn 100-500 acres or more annually in piñon-juniper savannas.

All forest management activities are non-commercial,  focuses on forest health, wildlife habitat, fuels management, and support for military training missions. Fundamentally, they will continue to use prescribed thinning and prescribed fire to transform the forest structure. They also accommodate/include special situations and needs for species protections (Jason Zayats, pers. comm.). Good examples of specific projects include the protection of Mexican Spotted Owl roost trees at Fort Carson and management of encroachment of Juniper encroachment into prairie areas. Development of shrublands or dense woodlands in grasslands is generally undesirable from a manuever training standpoint. Mechanical thinning through cutting and grinding, and fire are the primary tools used to manage pinyon-juniper systems. Restoration treatments will be emphasized in the pinyon-juniper savannas.  Treatments will be designed to attain low tree densities that increase understory grasses and forbs that are needed to maintain the natural fire regime. Vegetation management activities in this community will focus on areas with known wildlife corridors, historic openings, beetle infestation, and special management concerns. Wildlife patches (<5 acres) with dense trees and closed canopy should be incorporated into silviculture prescriptions because they provide protection from predators, thermal cover and, and are known parturition sites for deer and elk.

Fuel mitigation treatments will be emphasized in the persistent pinyon-juniper woodlands to protect the forest and areas surrounding it. Treatment areas will be concentrated along firebreaks and around special management areas. For the most part, persistent pinyon-juniper woodlands will not be subjected to extensive treatments.

A variety of metrics to monitor forested areas and evaluate management effectiveness are outlined in the *Forest Management Plan* (DPW 2011). They include basal area, trees per acre, exotics/invasive plants, grasses, tree snags, coarse woody debris and downed logs, insects disease, and type of forest treatment/prescription carried out. The Management Plan proposes monitoring pre and post treatment for most components or up to every 5 years depending on the indicator (DPW 2011). However, in practice there appears to be little regular monitoring of forest resources. RTLA data from woodland and forest samples has been examined in the context of tree densities, damage, mortality, and regeneration, and contributed to the decision to suspend tree damage billing (Jeff Linn personal comm.). Prescribed fire is being increasingly used to help reduce fuel loads in some forested areas. While tree mortality is extremely high (up to 100%) in burned areas, there is no information regarding the longer-term effects of fire on these forests and woodlands. In some cases, woodland conversion to grasslands may be taking place due to the prevalence of high-severity fires in the pinyon-juniper type. Most forested areas, including the canyon complexes, are not actively managed due to habitat and soil erosion concerns. This appears to reflect the high value placed on these areas for wildlife habitat. Changes in the RTLA program in the early 2000s resulted in forests being excluded from sampling. This decision is part of a larger trend to focus RTLA efforts in areas most highly-used by the military. For this reason, at PCMS there is no continuity in the long-term monitoring record for forest/woodland condition since 2000. Photographic monitoring has been proposed to document conditions pre- and post-thinning (U.S. Army 2006).

A common stand exam (i.e. forest stand inventory) for Fort Carson/PCMS is in progress and will be delivered this spring. This will allow the forester to prepare an updated forest management plan and initiate its implementation.

The Army also has also developed an administrative framework to help manage forest resources for conservation and training sustainability. The landscape is managed by the program using the following framework (DPW 2011).

**Land Management Areas (LMA)** are land units within Fort Carson and PCMS that are favorable for active forest management. LMAs were created by subtracting NMA and SMA areas from a GIS layer of all forested acres. Actual LMA acreages may be less than those depicted because the mapped areas include forests that are not in need of forest management, persistent piñon-juniper forests, and inaccessible areas that cannot feasibly receive treatments.

**Special Management Areas (SMA)** are land units that are given higher priority for treatments because of special characteristics or uses. Units within this classification include ranges and safety fans, wildlife habitat areas, resource protection areas (i.e utility corridors and firebreaks), and areas within the wildland urban interface (WUI). Ranges and safety fans are included in this classification because of access constraints; however, treatments should occur in these areas and will focus on the peripheries to provide defensible space around live-fire areas. Interior sections of ranges and safety fans may have very limited treatments because of access constraints. Actual SMA acreages may be higher than those depicted because the mapped areas may not include wildlife habitat and resource protection areas not currently identified.

**No Management Areas (NMA)** are land units that are not suitable for active forest management or may have limited forest management. These include previously thinned units, areas with steep slopes, inaccessible off-limit military use areas, heavily burned areas, and units with rich wildlife habitat such as riparian areas, shrubland areas, and winter roost sites for the Mexican spotted owl. These areas are represented in gray and should not require active forest management. Total acreage was obtained by adding wildland fire areas, forests on steep slopes, previously thinned areas and riparian and shrubland communities. Additional NMAs may exist within parts of LMAs and SMAs that are found to be adequately stocked and do not require treatments, or are located within areas with inaccessible terrain. Burned areas within NMAs are not excluded from forest rehabilitation, forest salvage or hazard tree removal projects.

## 5.7 Management Recommendations

The primary threats to the pinyon-juniper system within the region are residential and commercial development, energy production, fire exclusion/altered fire regimes, and climate change. On Fort Carson/PCMS, physical disturbance to trees and hydrologic/soil stability from vehicle training training may cause direct mortality or stress trees. There are policies and procedures in place to minimize damage to trees during vehicle maneuvers. Larger and more intense wildland fires have impacted pinyon-juniper habitat on the installation in recent years. Drought stress and climate change further stress the trees, reduce tree regeneration, and make trees more vulnerable to insects. Higher than desired tree densities make fires larger, more severe, and more difficult to control. Increases in the abundance nonnative annual vegetation such as cheatgrass may further alter the fire regime and result in undesireable type conversions from pinyon-juniper woodlands to shrublands or grasslands. The hotter/drier climate projections for the regions are predicted to reduce the amount of habitat suitable for juniper at PCMS, and significantly reduce habitat suitability for pinyon pine at Fort Carson and PCMS. In response to these system level threats, we recommend that the installations pursue the following recommendations:

- Expedite the development of updated/revised forest management plans. Within the context of multiple stressors such as insects, drought and climate change, a clean and well-prioritized management plan is critical.
- Continue to implement a combination of thinning and burning prescriptions to reach desired conservation, safety and mission support objectives. However, great care must be taken in managing these types. Fuels reduction treatments in pinyon-juniper forest types have potential to degrade ecological conditions by creating novel stand structures and altering natural disturbance regimes. Consider the needs of pinyon-juniper obligate bird species when planning treatments.

- Initiate or continue to implement monitoring for adaptive management of pinyon-juniper systems. Linking monitoring attributes with management prescriptions will help improve the effectiveness and fine-tune best management practices over time.
- Develop and use a state and transition framework to facilitate management decisions, monitoring, and adaptive management with respect to prescriptions. Include a management objective for development and maintenance of a given percentage of the pinyon-juniper acreage in each of the different pinyon-juniper community types.
- Examine and incorporate considerations related to climate change scenarios into forest management planning. Examples might include stand replacement considerations, site-specific considerations for forest treatments or planting, anticipated fire behavior under climate change, and identification of refugia (e.g., cooler, moister sites) where species might persist or experience less ecological stress.

These actions could potentially be followed by the Air Force Academy as well. However, the amount of pinyon-juniper woodland at the AFA is nominal (35 acres), and management of this system is of low priority.

# 6 Pinyon Jay (*Gymnorhinus cyanocephalus*)

There is a dearth of primary research on pinyon jays in Colorado, so much of the information in this account has been derived from a few key sources: the Birds of North America (Balda 2002), the U.S. Forest Service Region 2 Technical Conservation Assessment (Wiggins 2005), and recent field studies of pinyon jays on DoD and BLM lands in New Mexico (Johnson et al. 2014 and 2015, respectively). There has also been recent (2013) work done in Nevada (home to roughly half of the global pinyon jay population) by the Great Basin Bird Observatory, which adds useful insight into the rangewide ecology of this species. Wiggins noted that much of the information in his assessment came from a long-term study of a population in a suburban setting in Arizona (also the source of much of the information in Balda 2002), and therefore may not be representative of the species' wider range. The Johnson et al. studies are more recent, and are geographically closer and in habitat that is more similar to our area of interest.

## 6.1 Range, Distribution, and Abundance

The pinyon jay is a permanent resident in 11 states in the western U.S., as well as northern Baja in Mexico (Figure 31). Its range extends from central Oregon and eastern California across the Great Basin into central Montana and Wyoming, and south through Arizona, Colorado and New Mexico, as well as in disjunct pockets of habitat in western South Dakota and Nebraska, southern California, and Baja California. As a permanent resident, summer and winter ranges are essentially the same, though birds may be found outside their year-round range when pine crops fail (Balda 2002). The pinyon jay population is currently estimated at ~690,000 birds across the U.S. and Canada (Rosenberg et al. 2016). The greatest abundances during breeding season occur in Nevada, which supports roughly half of the global population of pinyon jays (GBBO website), as well as Utah, Colorado, Arizona, and New Mexico (Figure 32).

In Colorado, the pinyon jay is primarily found in the southern, western, and central portions of the state (Figures 33 and 34; Kingery 1998, Wiggins 2005, Wickersham 2016). During periods of low seed crops, pinyon jay may expand their eastern range further into southeast Colorado, as they did during the winter of 2002-2003 (Wiggins 2005). When this happens, this species may be found in atypical habitats such as riparian woodlands (Cable et al. 1996 in Wiggins 2005).

On DoD installations in Colorado, pinyon jays occur in the pinyon-juniper woodlands at Fort Carson and PCMS. Other Colorado installations either do not contain pinyon jay habitat, or only contain potential habitat in very small patches (e.g., 35 acres of pinyon-juniper on the Air Force Academy) with no recorded occurrences of pinyon jays. Within Fort Carson, pinyon jays have been reported from 16 locations: the Bird Farm and Training Areas 20, 28, 30, 31, 35, 40, 43, 45, 48, 49, 50, 51, 52, 55, and 56. Biologists there have often encountered lone individuals, small flocks, and a single observation of a flock of 50 individuals (Clawges, pers. comm 2016). These reports were not a result of formalized surveys for pinyon jays, but rather incidental observations by resource management staff. Specific locations for pinyon jay observations on PCMS were not available. Legacy-funded research by Bird Conservancy of the Rockies counted 7 pinyon jays on Fort Carson in May, 2015, with an estimated density of 0.18 birds/sq.km., and a population size of 73 (BCR unpublished data). That same study counted 15 pinyon jays at PCMS, and estimated density at 0.09 birds/sq.km., and a population size of 53.

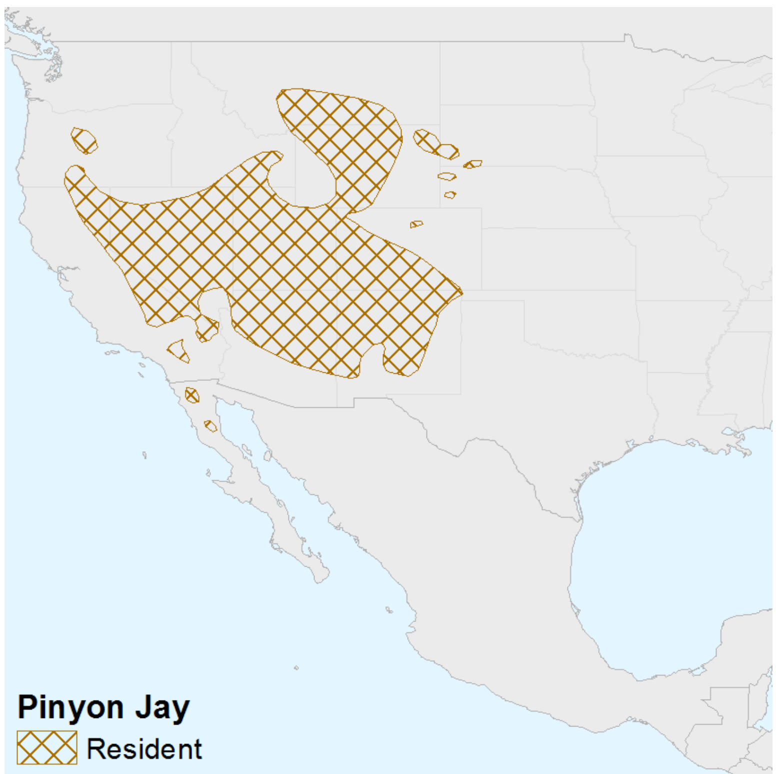



**Figure 31. Range of the Pinyon Jay in North America** (Birdlife International and NatureServe 2015, birdlife.org).

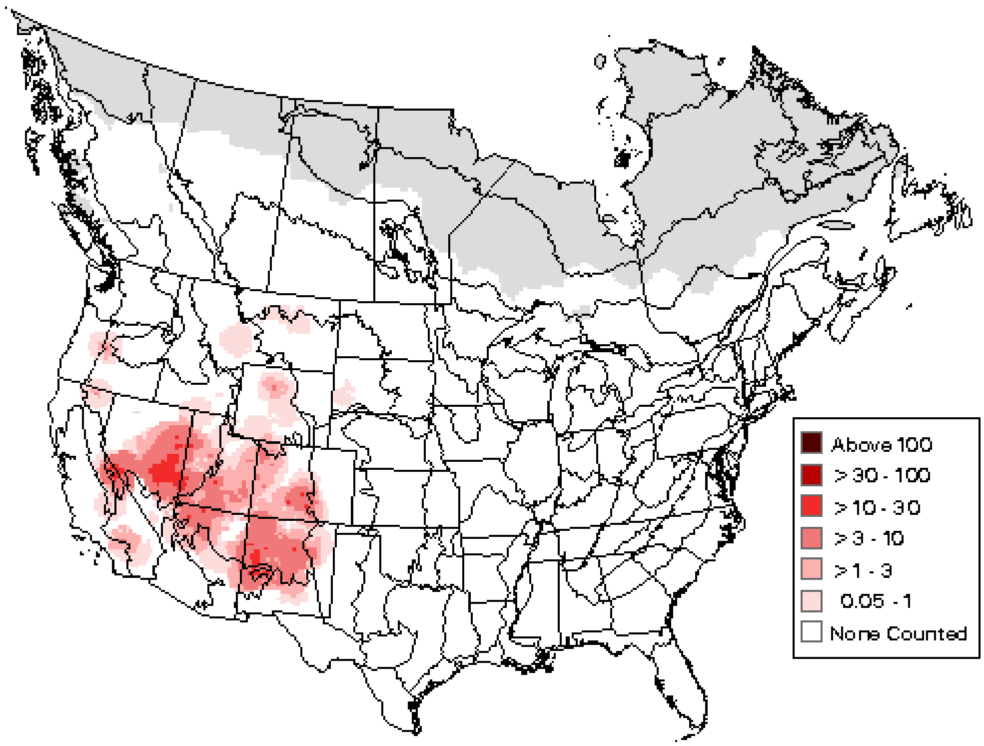



**Figure 32. BBS summer distribution 2007 - 2013.** This map is a simple summary of relative abundance based on raw BBS data, using average counts of pinyon jays observed on each route over the time interval (http://www.mbr-pwrc.usgs.gov/bbs/ra2013/ra04920.htm).

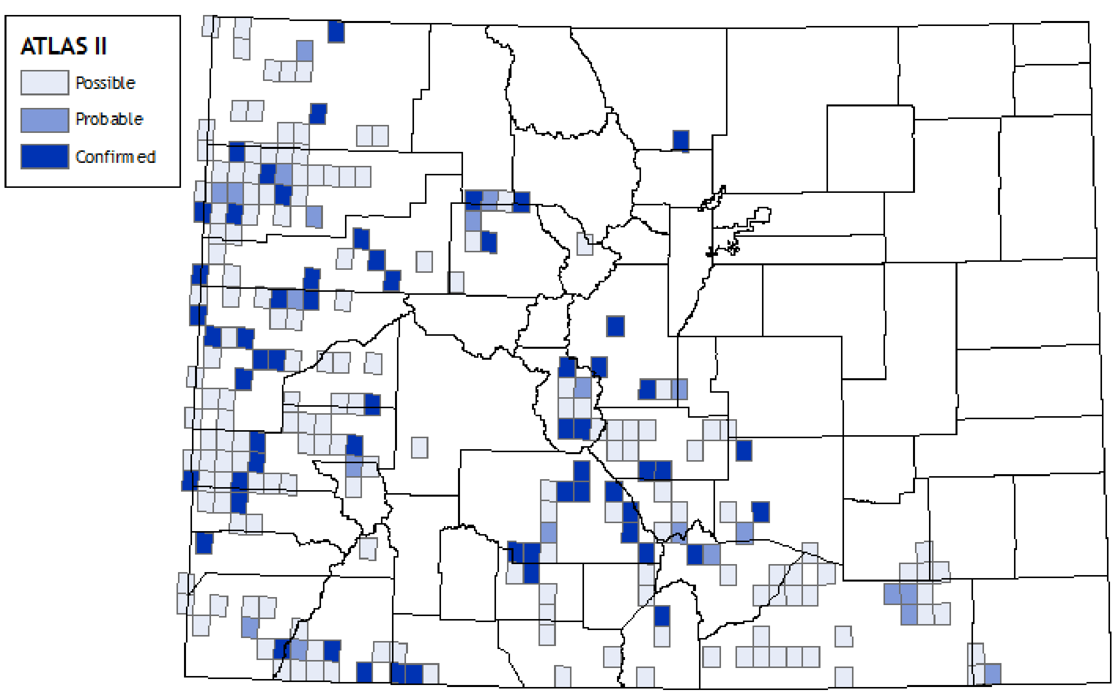



**Figure 33. Pinyon Jay breeding distribution in Colorado** (Colorado Breeding Bird Atlas II, Wickersham 2016).

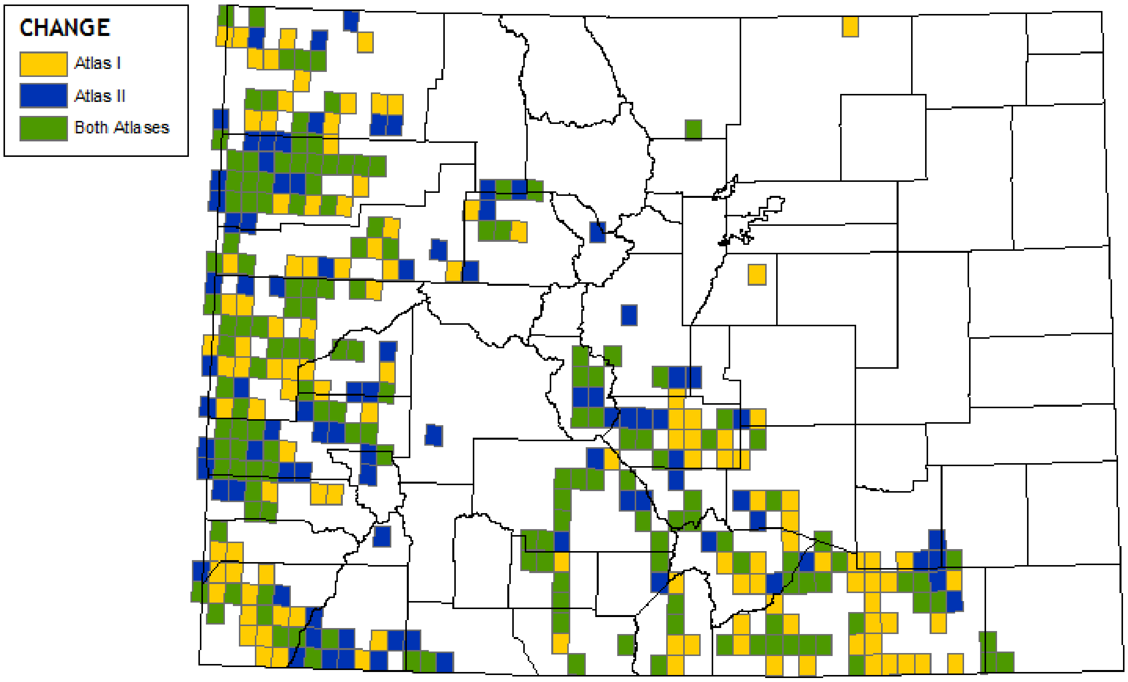



**Figure 34. Change in pinyon jay breeding distribution in Colorado from Breeding Bird Atlas I to Breeding Bird Atlas II** (Colorado Breeding Bird Atlas II, Wickersham 2016).

## 6.2 Conservation Status

According to the 2016 Partners in Flight Landbird Conservation Plan, Breeding Bird Survey (BBS) data show that the continental population of the pinyon jay has suffered an 84% loss from 1970 – 2014. The plan further estimates that an additional 50% of the remaining population could be lost within 19 years if trends experienced over the past 10 years continue. Vulnerability factors include population trend, threats in breeding areas, population size, and threats in non-breeding areas (Rosenberg et al. 2016).

Wiggins (2006) demonstrated that Christmas Bird Count (CBC) data show significant long-term decline within the U.S. Forest Service Region 2 states of Colorado, South Dakota, and Wyoming. He also notes, though, that neither BBS nor CBC are especially good at sampling this species, due in part to their secretive nature and their early breeding phenology, suggesting some degree of uncertainty associated with trend information. On the other hand, regardless of past trends, he predicted that future declines would likely be very high due to effects of current widespread pinyon die-off. He went on to speculate that the jays might move into ponderosa pine (*Pinus ponderosa*) habitats, but their ability to switch breeding habitats is unknown. Balda (2002) also noted that conventional census methods are inadequate for pinyon jays because they have very large home ranges, travel widely throughout these areas, and are always in a flock. This makes interpretation of data tricky, but the current assessment of BBS data by the U.S. Geological Survey indicates widespread declines across much of the range (Sauer et al. 2014, Figure 35).

This species is included on the following conservation status lists:

***International***

- International Union for Conservation of Nature (IUCN) 2016 Red List – Threatened
- Partners in Flight Watchlist – Yellow (threatened and declining)
    - 2016 State of the Birds watchlist (at risk of becoming threatened or endangered without conservation action) (also based on PIF data)
    - American Bird Conservancy and North American Bird Conservation Initiative Watchlist (Yellow), Species of Continental Importance for Bird Conservation Regions 9, 10, 16, and 34

***National***

- U.S. Fish and Wildlife Service Birds of Conservation Concern
- DoD PIF Mission-Sensitive Priority Bird Species (i.e., determined to have greatest potential impact on military mission if listed)
- Bureau of Land Management Sensitive Species in Arizona, Nevada, and New Mexico

***State***

- Species of Greatest Conservation Need in Arizona, Colorado (Tier 2), Nebraska, Nevada, and New Mexico (Immediate Priority)
- Natural Heritage Program conservation status ranked Vulnerable in Montana, Nebraska, Nevada, and New Mexico.

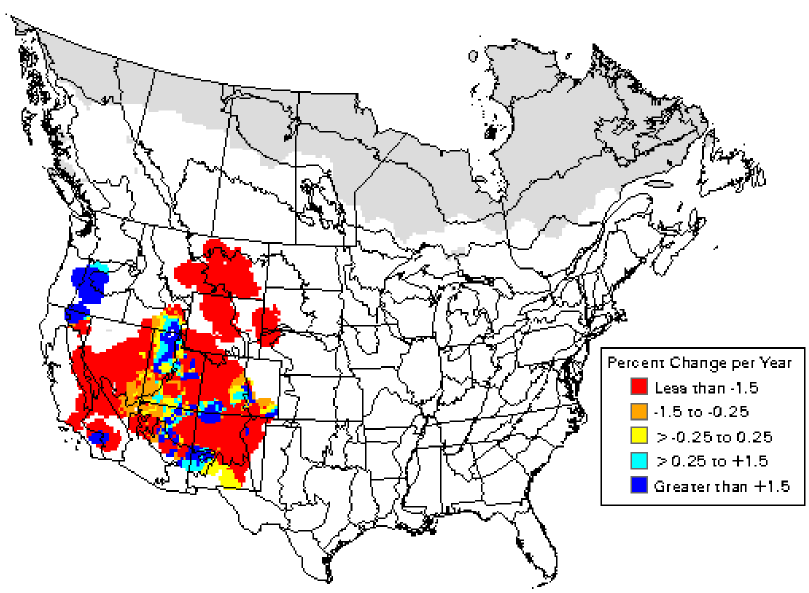



**Figure 35. Pinyon jay trend based on BBS data from 1966-2013 (Sauer et al. 2014).**

## 6.3 Species Requirements

### 6.3.1 Habitat

Pinyon jays are usually found in pinyon-juniper woodlands or low elevation ponderosa pine forests, with some populations occurring in foothill woodland and shrub communities in the southwestern United States (Balda 1987). The pinyon jay is often considered a mutualist with pinyon pines, where the pines provide jays with the seeds that are their primary food source, nesting sites, and protection from predators, while jays act as dispersal agents for the pinyon seeds (Wiggins 2005). Although pinyon jays typically cache pinyon seeds, some caches are not recovered, allowing the pinyon seeds to germinate. Johnson et al. (2014) note that the pinyon jay is the only seed disperser capable of replanting entire woodland after loss from fire, insects, or intentional destruction.

While the core breeding range for pinyon jay is dominated by pinyon-juniper woodlands, habitat choice varies throughout the species' range. In some areas, pinyon jays also occupy (and nest in) sagebrush (*Artemisia* spp.) shrublands, scrub oak (*Quercus* spp.), and ponderosa pine forests (Wiggins 2005). For example, Jays primarily use pinyon-juniper in Colorado, but shift to ponderosa pine and juniper woodlands in Wyoming and South Dakota (Wiggins 2005). In Arizona, they are permanent residents in lower elevation ponderosa pine as well as pinyon-juniper (Balda and Bateman 1971, Latta et al. 1999). In general, though, mature pinyon-juniper, juniper, and ponderosa pine, and their associated cone crops, are thought to be the most important factor in the stability of pinyon jay populations (Wiggins 2005).

The Great Basin Bird Observatory has documented a "strong edge association" in the northwestern part of pinyon jay range. Their telemetry work in Nevada and Idaho documented more use of pinyon-juniper/sagebrush transitional landscapes and sagebrush understory than expected (Ammon and Boone 2015). Their results revealed that most foraging occurred within 400 meters of the edge transition between pinyon-juniper and sagebrush, caching was often in pure sagebrush up to 4 miles from the habitat edge, most roosting and nesting was in denser stands of pinyon-juniper but usually within 800m of the edge, use of dense, older stands more than 800m from edge was rare, and birds made "long" [not defined] movements between habitat patches daily to harvest pinyon nuts.

In Colorado, pinyon-juniper woodlands provide the core habitat (96% in Kingery 1998, nearly 90% in Wickersham 2016), with some use of ponderosa pine along the foothills east of the Continental Divide (though not in southwestern Colorado), as well as use of juniper woodlands and savannas in southeastern Colorado (Kingery 1998, Wickersham 2016). Adults feeding fledglings and fledged young have also been found in riparian forests, scrub oak, and sagebrush (Wickersham 2016). The highest densities of pinyon jay in Colorado are found at elevations between 5,000 and 8,000 feet (Kingery 1998).

***Nesting Habitat***

Pinyon jays are colonial nesters who use the same general nesting area from year to year, and who require large stands of mature of pinyon-juniper woodlands (Wiggins 2005). Johnson (2014) documented repeated use of traditional colony sites over seven years, but noted that birds move around within the same general area (e.g., <1km) if tree vigor declines in part of the pinyon-juniper stand. They went on to suggest that, as colonial nesters, pinyon jays' choice of colony sites may be related to identifying places with enough trees "of appropriate size and canopy thickness" for multiple nests, and that nest sites are based on characteristics not only of the nest tree, but also of the trees nearby (e.g., density, size, vigor).

In multiple study sites on DoD and BLM lands in New Mexico, Johnson et al. (2014 and 2015, respectively) found that pinyon jays require a variety of age classes of pinyon pine and juniper. They found approximately equal use of pinyon v. juniper trees for nesting. Their data suggested that pinyon jays "are not fussy about colony-scale attributes" (e.g., slope, aspect, elevation) other than vegetation. Plots that contained pinyon jay nests had pinyon pine trees with higher canopy cover, larger root-crown diameter, and higher litter cover than those in random non-used plots. At their 2014 study sites, mean density of nest plots was 960 trees/ha (range 25-2725). At 2015 study sites, mean nest plot density was 436 trees/ha compared to random plot density mean of 423/ha.

At the nest scale, Johnson et al. (2014, 2015) found mean diameter of nest trees was 34cm (range 12-69), compared to mean diameter of 22cm (~1-70) for non-nest trees. Mean nest tree height was 6m (range 2.5-10), compared to a mean height of 4.35m (1.2-11) for non-nest trees. Overall, jays chose the tall, but not the tallest, trees for nesting. Nest trees in their studies were larger than random trees but not the "huge, emergent trees present in small numbers within colony sites;" they suggested that this may be because emergent trees provide better perches for predators and less cover for nests. This preference for taller trees and higher foliage density is consistent with findings of previous work in Arizona (Gabaldon 1979, Latta et al. 1999). Johnson et al. (2015) also indicated that nesting pinyon jays also require access to water (e.g., in their study, tagged birds flew ~3600m from the colony site to use a wildlife guzzler).

Though the Johnson et al. studies did not find aspect to be a significant factor at the colony scale in New Mexico, nest sites in Arizona have been found more commonly on the south, southeast, and southwest facing sides of nest trees (Gabaldon 1979, Balda and Bateman 1972, Marzluff and Balda 1992, Latta et al. 1999), potentially because these aspects offer more solar gain for early spring nesting (Balda 2002). South-facing nests receive up to 40% more solar energy compared to north-facing nests (Cannon 1973, Balda 2002).

***Foraging Habitat and Caching Sites***

Foraging habitats are generally the same as nesting habitats. The seeds of the pinyon pine are the pinyon jay's primary food source (Wiggins 2005). Pinyon pine is a masting species that produces seed crops every 4 – 7 years. Pinyon pine trees do not begin bearing cones until around 25 years old, with the highest production occurring in older trees (75-100 years old) (Gottfried 1992). Larger, healthier pinyon produce more seeds; seed production declines in extremely old trees (>300 years). Thus pinyon pine and pinyon-juniper woodlands with healthy, mature pinyon pine trees provide crucial foraging habitat. Johnson et al. (2015), citing Dighton and Mason (2011), suggested that large, old trees not only produce more seed cones but also may be "more important than smaller trees in maintaining underground mycorrhizal fungi networks, which provide nutrients to surrounding trees." Johnson and Smith (2006, 2007) found seed production comparatively lower where trees are more dense, so thinning may improve health of most productive trees where densities are high (e.g., >2000 trees/ha).

Though pinyon jays rely primarily on pine seeds, they also eat juniper berries, fruits, agricultural grains, small mammals, insects, lizards, and snakes (Balda 2002). When pine seeds are scarce, pinyon jays will search widely for such foods (Wiggins 2005) in habitats that include grasslands and meadows, ponderosa pine, and mixed coniferous forests (including burned areas) (Balda 2002). Pinyon jays are also known to visit suburban bird feeders in Arizona (Balda 2002) and Colorado (Wiggins 2005). In addition to pine seeds, the diet of nestlings in Arizona and New Mexico include a wide variety of arthropods (including grasshoppers, spiders, butterflies, and beetles, many of which are restricted to ground or herbaceous layers of terrestrial habitats (Balda and Bateman 1972, Ligon 1978 in Balda 2002). Therefore, availability of habitats with sufficient understory structure and composition to support these food sources is important.

Caching sites tend to be in open areas with scattered trees, sometimes up to 11km from colony sites (Ligon 1978, Marzluff and Balda 1992, Balda 2002, Wiggins 2005). Johnson et al. (2014) also found main caching areas had sparse vegetation. A main caching area in their study was described as about 18 ha in size, with gentle topography, mostly grasses and shrubs with only scattered junipers lower on the hill, and more juniper/shrub open woodland higher up and in drainages. They noted that this area stayed free of snow in January and February, when other places had deep snow cover. Caching sites reported by Marzluff and Balda (1992) were also often snow-free in winter.

***Wintering Habitat***

The pinyon jay is a year-round resident, so wintering habitat is very similar to breeding habitat. However, in fall and winter, birds may also use nearby habitats such as higher elevation mixed-conifer (Dawson 1923, Balda 2002, Wiggins 2005), caching sites outside their traditional home range, and occasionally lower elevation riparian areas. This seems to be especially true when pine seed crops are poor (e.g., Jays were "unusually common" on eastern limits of range, including southeastern Colorado during the 2002-2003 winter) (Wiggins 2005). In fall and winter, jays may also forage in neighboring limber (*Pinus flexilis*) and bristlecone (*P. aristata*) pine forests (Dawson 1923, Balda 2002 in Wiggins 2005). Johnson et al. (2014) suspected that birds in their study area winter in low elevation juniper savanna and wander widely outside of breeding season. Johnson et al. (2015) suggested that larger wintering sites with plenty of food are probably at least as important for long-term viability as high-quality nesting sites.

***Habitat on DoD Installations***

At Fort Carson, pinyon jays have been observed primarily in the western and southern areas of the installation in pinyon-juniper woodlands, but they have also been observed in grassland habitats (Rick Clawges, pers. communication 2016). The U.S. Air Force Academy does not possess significant pinyon jay habitat, and the species has not been observed on that installation. However, pinyon-juniper does occur along the western edge of the U.S. Air Force Academy, so the possibility of pinyon jays occupying nearby habitat, and occasionally wandering onto the Academy cannot be discounted. See Section 5 for additional information on pinyon-juniper at Fort Carson and PCMS.

### 6.3.2 Spacing and Movement

Researchers have estimated a wide range of home range sizes, from an average of 800 to a potential maximum of over 4,000 ha (8-40 sq. km.). A northern Arizona study reported that home range size varies from 1,600-6,400 ha (16-64 sq. km.), with flock members nesting in a relatively even distribution across approximately 100 ha (1 sq. km.) (Marzluff and Balda 1992, Wiggins 2005). Flock sizes in that study varied from 150 to about 300 individuals over the course of 12 years. Previous work in Arizona documented a flock of ~250 birds occupying a home range of about 2,100 ha, with a nesting area of approximately 95 ha (Balda and Bateman 1971, Latta et al. 1999). Wiggins (2005) noted that average home range in Arizona was approximately 8 sq. km. when food was abundant, but that birds foraged over areas up to 30 km. during years when food was less abundant (citing Balda 2002). The Great Basin Bird Observatory documented flock home ranges of approximately 1,000-1,500 ha (10-15 sq. km.) in Nevada and Idaho. In 2013, they documented five colonies, each with between 30-60 nests and an estimated 200-300 individuals. Johnson et al. (2014 and 2015) suggested that a "medium-sized" flock needs ~3,500-4,000 ha. of productive pinyon trees. Their studies in New Mexico reported home ranges of approximately 3,100-3,500 ha (31-35 sq. km.), with non-breeding home ranges 12-33% larger than breeding ranges. They estimated ~3,100 ha as a minimum flock home range in summer, but possibly up to 4,200ha if calculations include all sampling blocks where jays were detected *and* all the blocks between those detections. They summarized their findings by indicating that "pinyon jay summer and fall home ranges in pinyon-juniper habitat cover at least 3,500 ha, and considerably larger areas are likely needed in winter." They further noted that the areas documented in their studies were larger than most home ranges reported in previous literature (Johnson 2015).

As previously noted, pinyon jays move outside their normal range when seed crops fail, and may travel "hundreds, even thousands of kilometers during these movements" (Balda 2002). These irruptions normally begin late August to early September, and last into January. Pinyon jays may travel up to 11 km to cache seeds, and up to 30 km to forage (Wiggins 2005). Though the vast majority of young remain with their natal flock, birds who do disperse tend to move to an adjacent flock, generally 3-30 kilometers away (Marzluff and Balda 1989, Balda 2002).

### 6.3.3 Phenology

Pinyon jays are considered very early breeders. Courtship begins in November (Balda 2002). Reports of nest building in Arizona range from early/mid-February to late April, depending on availability of food resources and weather, and may be stimulated by the presence of green cones on pinyon pines (Lignon 1974, Wiggins 2005). Nesting is delayed until April or May when cone crops are small and/or snow cover is heavy (Ligon 1971, Balda 2002, Latta et al. 1999). In other parts of the species' range, commencement of breeding has been reported as late as early May (Bendire 1895, Dawson 1923, Bent 1946a in Balda 2002). Peterson (1995) documented incubation and nests with eggs April 29 – May 18 in South Dakota. Dexter (1998) documented nests with eggs between March 23 and May 19 in Colorado. Young generally leave the nest at approximately 21-22 days old, and are no longer dependent on parents for food by 6-8 weeks (Balda 2002). Pinyon jays are non-migratory, so these birds tend to remain in the same general vicinity year-round, unless wandering during years with poor seed crops as previously noted.

## 6.4 Threats

### 6.4.1 Rangewide Threats and Current Habitat Condition

Pinyon jays have not been well-studied with specific regard to threats. In their ranking assessment for IUCN, Birdlife International considered destruction of pinyon-juniper woodlands to be the major threat to pinyon jays (BirdLife International 2012). According to PIF's 2016 Landbird Conservation Plan, the most significant threats to the pinyon jay are changing forest conditions and changing rangeland conditions. The pinyon jay's primary habitat has been impacted throughout the interior western U.S. by a complex web of potential threats, including weakened condition of trees due to drought, resulting in increased mortality from insect outbreaks and increased risk of wildfire (which is further exacerbated by fuel buildup related to fire suppression, especially in the wildland-urban interface). Loss, degradation, and fragmentation of habitat have resulted from these disturbances, as well as from energy production, urban development, forest management, and incompatible grazing. The cumulative effects of these impacts are likely to be exacerbated by climate change in at least some components of the pinyon jay's habitat.

In states within the core range of the pinyon jay where the jay is listed as a Species of Greatest Conservation Need, state wildlife action plans and other documents present a mixed picture of current habitat condition and relative level of threat. They summarize as follows:

- **Arizona State Wildlife Action Plan** – "Great Basin conifer woodlands [pinyon-juniper] have been significantly affected by changes in fire regime, livestock grazing, and mechanical or chemical treatments (Monsen and Stevens 1999, Stevens and Monson 2004). Due to increased density of tree canopies and of invasive grass species, widespread crown fires are predicted and the area of these woodlands may decline, to be replaced by shrublands or grasslands (Gruell 1999, Tausch 1999). Only about 11% of the Great Basin conifer woodlands have fire regimes which are severely altered from their historical range, but another 70% are moderately altered, creating a moderate risk of losing key ecosystem components (USFS data; Schmidt et al. 2002). Pinyon pines have recently experienced widespread mortality due to drought and insects, affecting 1.2 million acres (9% of total distribution in Arizona) during 2002-2004 (Breshears et al. 2005; USFS 2003, 2004, 2005)."

- **Arizona Partners in Flight Landbird Conservation Plan** – "Three major factors, which vary annually, affect the long-term success of Pinyon Jay populations: size of pinyon pine crops, amount of nest predation, and harshness of the physical environment, particularly the amount of snow during the nesting season (Marzluff and Balda 1992)…Primary management concerns related to these include: 1) habitat loss due to urbanization, as documented in the Flagstaff vicinity (Marzluff and Balda 1992), as well as to management of pinyon-juniper woodlands (e.g. chaining, burning) and potential habitat loss from Ips beetle invasion of stressed pinyon trees, 2) abundance of mature pinyon pine trees which provide the primary source of food for breeding pinyon jays and which can also be affected by land management practices, and 3) increasing numbers of American Crows and Common Ravens (important nest predators) in Pinyon Jay breeding areas near urban areas (also documented in the Flagstaff area) (Marzluff and Balda 1992)."

- **Colorado State Wildlife Action Plan** – "Pinyon-juniper habitat quality has declined compared to historic norms, as significant acreage has been chained and burned in an effort to increase forage for livestock and big game on productive sites. Other threats include urban development, recreation (especially motorized recreation), invasive species (most notably an increase in cheatgrass (*Bromus tectorum*) in the understory, which has led to increasing fire ignitions), and energy development. Pinyon-juniper habitats across Colorado are in generally fair to good condition, and are excellent in more remote, untreated or administratively protected areas. Some patches can be in poor condition in areas where incompatible grazing has reduced native bunch grasses and invasive species such as cheatgrass have become established…Oil and gas development, and chaining to improve livestock forage, have degraded the condition of some stands. Climate change may result in additional degradation of this habitat type, especially via an increase in frequency and/or severity of wildfire."

- **Nevada Bird Conservation Plan** (2010) – Pinyon jay declines may be related to reduced habitat quality – i.e., "increases in the acreage of closed-canopy, mature (or senescent) woodland with a poor shrub understory, coupled with corresponding loss of mixed-age woodland mosaics with openings and a complex shrubland edge." This plan attributed changes primarily to altered fire regime, but acknowledged grazing and weeds as possible contributing factors.

- **Nevada State Wildlife Action Plan** (2012) – "Pinyon-juniper woodlands, generally being found on steep and unproductive soils, are usually in good condition because access is difficult and water is limited for livestock. Many woodlands in proximity of mines (<5 miles) may have been thinned or cutover during the historic mining era, but younger trees are found today growing among the remnant old trees. The greatest threats to pinyon-juniper woodlands are invasion by non-native cheatgrass and conversion to non-native annual grassland after fire, uncharacteristic fires either fueled by cheatgrass ignition or originating from tree-encroached shrublands surrounding woodlands, and infilling of young trees between older trees (stand densification; Weisberg et al., 2007)."

- **New Mexico State Wildlife Action Plan** (2016) – "Piñon-juniper woodlands (*Pinus edulis* and *Juniperus monosperma*) have recently spread into ponderosa pine woodlands in north central New Mexico (Allen and Breshears 1998). Juniper species (*Juniperus* spp.) have also expanded into grasslands in southwestern New Mexico (Romme et al. 2009). However, woodland species, especially piñon pine trees, are highly susceptible to attack by bark beetles (*Ips confusus*) and twig beetle (*Pityophthorus opaculus*). Warmer temperatures increase bark beetle survival and developmental rates leading to more severe outbreaks

(Bentz et al. 2010). Drought conditions and delayed onset of monsoons have increased mortality in infested piñon pine (Gustafson et al. 2015). Although juniper is somewhat more drought-tolerant, it also experiences increased mortality rates during persistent droughts (Breshears et al. 2005, Gaylord et al. 2013). It is likely that these widespread mortality events will become more frequent as the climate changes. Wildfires are expected to increase in woodland habitats (Moritz et al. 2012) and may lead to a shift to grassland or shrubland habitats at woodland ecotones."

- **New Mexico Partners In Flight 2007 Bird Conservation Plan** – "The main threats to Pinyon Jays breeding in New Mexico are conversion of pinyon-juniper woodland habitat to rangeland and overall decline of this habitat due to drought and bark beetle infestation. In the past, large areas of pinyon-juniper woodland have been eradicated to encourage livestock grazing on both public and private lands. Removal of woodland by chaining has dramatic effects on breeding bird populations (Sedgwick and Ryder 1987). Habitat may also be degraded by poorly planned woodland thinning and tree removal efforts. Habitat loss due to development and urban encroachment is a problem in some areas."

***Natural Systems Modifications: Disturbance Processes***

Drought is a natural and common process in the semi-arid regions inhabited by pinyon jays. However, frequent, prolonged, and/or intense droughts can kill pinyon pines outright, and result in an imbalance in other disturbance regimes, particularly those related to insect and disease outbreaks and wildfire. The southwest experienced a severe drought during 2002-2003, which resulted in an explosion in the population of the native Ips beetle (also known as pinyon engraver beetle, *Ips confusus*). Greater than 90% of pinyon pine trees died within 15 months in northern New Mexico (Francis et al. 2011 citing Breshears et al. 2005), and 32% of pinyon pines died over one year in northern Arizona,[15] (Mueller et al. 2005), reducing Arizona's pinyon-juniper canopy cover by 55% (Johnson 2015 citing Clifford et al. 2011). In Colorado, an estimated one million trees were killed, with up to 90% loss of mature pinyon in some parts of the state, including both southwestern and southeastern Colorado, and the southern Front Range (Colorado State Forest Service 2003, 2004). Pinyon death associated with this beetle outbreak may have long-term (>25 years) consequences for pinyon jays in southern and western Colorado (Wiggins 2005).

Wildfire can be another significant factor in pinyon-juniper habitats. Given the combined impacts of past fire suppression (e.g., dense canopies, fuel buildup in the understory), increasing temperature, and prolonged drought, many low elevation pine forests are at risk for severe wildfire. Pinyon pines are slow to recolonize after fire, if they recolonize at all. For example, roughly 50% of Mesa Verde National Park, in Colorado, burned in the early 1990s. At this time, there is still no sign of pinyon-juniper regeneration. Instead, burned areas have been invaded by cheatgrass and smooth brome (*Bromus inermis*). Wiggings (2005) noted that slow recolonization, combined with the length of time required for maximum cone production (~75 years), could result in abandonment by pinyon jays after a large fire. Wiggins went on to speculate that pinyon jays may shift their habitat

[15] Only 5% juniper mortality was documentd in the same locations.

association in Colorado from pinyon-juniper to ponderosa pine or possibly even move into suburban areas.

***Biological Resource Use and Incompatible Agriculture: Forest and Rangeland Management***

During the first half of the 20th Century, the policy of the U.S. Forest Service regarding pinyon-juniper management was essentially eradication based on a non-commercial (i.e., no value) classification (Balda 2002). Pinyon-juniper woodlands were removed for wood products (e.g., firewood, fenceposts) and increased grazing opportunities for cattle. From the 1860s to the 1960s, pinyon-juniper stands were completely cleared in portions of AZ, NM, NV, CO, and UT (Balda 2002). During the middle of the last century (1950-1964), 1.2 million acres of pinyon-juniper woodland were converted to rangeland (Arnold et al. 1964, Balda 2002). This had significant impact on pinyon-juniper, and thus likely on pinyon jays as well (Johnson 1962, Johnson 1975a in Balda 2002). Though wholesale destruction of pinyon-juniper is no longer the norm, managers do continue to eliminate pinyon-juniper to increase pasture for cattle grazing. In addition, thinning to reduce fuel loads has been emphasized as part of the National Fire Plan (Wiggins 2005). In many places, management priorities are directed against pinyon-juniper in preference for reducing the "invasion" of trees (particularly juniper) into grassland and shrubland habitats. This is especially true in places such as the sagebrush steppe, where much focus has been centered around the needs of sage-grouse.

Wiggins (2005) noted that there had been no studies specifically on effects from forest management on pinyon jay ecology to date. He recommended investigating how jays respond to thinning treatments (e.g., percent, age, and species of trees removed).

***Residential and Commercial Development***

Urban development destroys native habitat, and fragments remaining habitat patches. In many areas, especially those near urban and suburban centers, pinyon-juniper habitats are highly desirable for exurban development as well. Breeding success of pinyon jays may be decreased in home ranges near urban development due to elevated abundance of predators (e.g., crows, ravens) (Wiggins 2005). On the other hand, Wiggins (2005) also suggested that access to extra food (e.g., bird feeders) common in suburban areas may be helpful, especially during snowy winters. Probably most conservation biologists would agree such a scenario would be far from ideal.

***Energy Production***

Oil and natural gas development often results in a dense network of roads and wellpads over large areas, fragmenting landscape scale habitats into smaller patches. Vehicle traffic may alter behavior patterns of some species, and fragmentation can increase vulnerability to predators, though this has not been intensively studied in pinyon jays.

Johnson et al. (2015) found pinyon jays to be tolerant of some gas well noise as long as it remained below ~40 dBA, as well as limited vehicle traffic. They documented the presence of a colony in the midst of four gas wells, where five of the six nests closest to wells had noise levels of ~39 dBA, but found that jays consistently failed to nest in areas with dBA higher than 40. Though they found in their DoD study that jays tolerated occasional loud noises (e.g., rifle firing, sonic booms), they determined that the constant noise produced by gas wells was probably more detrimental than louder but intermittent sounds. Their rationale was that, because pinyon Jays are highly social, interactive, and vocal, constant noise such as that produced by gas wells would likely impact communications such as alarm, begging, contact, and courtship calls.

### 6.4.2 Threats on DoD Installations

At Fort Carson and PCMS, potential threats to pinyon jays include: 1) fragmentation and degradation of habitat from training activities, 2) drought and climate change, 3) noise and disturbance from human activities, and 4) tree damage from insects.

***Fragmentation and Degradation of Habitat from Training Activities***

Nearly all of the land at Fort Carson and PCMS is used for military training activities (92% and 95%, respectively) (Table 1). Training activities can damage pinyon and juniper trees, resulting in the loss or degradation of nesting and foraging habitat for pinyon jays. Native shrubs, grasses and forbs in the woodland understory provide critical cover that helps pinyon jays avoid predators (Johnson et al. 2015), so damage to the vegetation in the woodland understory could lead to increased predation on pinyon jays. Soil compaction and loss from training activities could result in the inability of a site to sustain native plant communities, and could potentially cause dominance of non-native species like cheatgrass (*Bromus tectorum*). Field data from vegetation monitoring plots collected in 2012 indicate a reduction in ground cover, total cover, and a decline in composition of native perennial species at PCMS (Schulte 2012). However, the conditions reported by Schulte (2012) are still within acceptable limits of DoD management plans, and drought conditions during sampling likely contributed to lower amounts of vegetation cover across PCMS.

***Fort Carson***

The best available data on the location and magnitude of training activities at Fort Carson is from data obtained from the installations regarding training occurring from 2004 to 2008. Table 10 shows the average number of training days per year over this time period within the vicinity of pinyon-juniper habitat at Fort Carson. Table 10 also shows training days for the breeding and nesting season for the Pinyon Jay, commonly regarded to be from November through May.

**Table 10. Average training days per year (and average training days per year from November to May) for training areas of interest for Pinyon Jay.**

| Training Area | Average Training Days / Year | Average Training Days / Year (Nov-May) |
|---|---|---|
| 25 | 4.6 | 4.4 |
| 28 | 4.8 | 4.4 |
| 30 | 1.6 | 1.6 |
| 31 | 2.2 | 2.2 |
| 39 | 0.6 | 0.6 |

Most military maneuvers within pinyon-juniper habitat were concentrated in Training Areas 25 and 28, and to a lesser extent 30, 31, and 39. The majority of use came from the 3rd Battalion, 29th Field Artillery unit of the 3rd Armored Brigade Combat Team discussed in Chapter 2. This training occurred mostly during April, 2005 in preparation for their deployment to Operation Iraqi Freedom in November, 2005. This unit consists of three firing batteries of M109 Howitzer tanks, as well as numerous support vehicles and personnel. The training impact was likely highly intense, but short lived. As previously stated, the heaviest use was in Training Areas 25 and 28, which are on the periphery of the pinyon-juniper habitat, while Training Areas 41 and 45, where the core of this habitat occurs on Fort Carson, remained untouched. Training in this habitat is sporadic in both time and space, however, it is highly impactful when training does occur in these areas. Due to these factors, the Pinyon jay is moderately vulnerable to potential military training activities at Fort Carson.

***PCMS***

The majority of pinyon-juniper habitat at the PCMS is along the northern boundary. There are also isolated patches of pinyon-juniper along the southeast boundary of the installation, but nearly all of it is in canyonlands, where mechanized training is virtually impossible due to terrain, and training is restricted by the installation to dismounted maneuvers only. Due to these limitations the vulnerability of Pinyon Jay to military training in these areas is negligible.

As described in section 2.3.4, the majority of military training is conducted in the corridor formed by Training Areas 7 & 10. The core pinyon-juniper habitat at the PCMS is found in Training Areas 1, 2, and 16. The majority of the combined area of these units is composed of dismounted training only areas and Soil Protection Areas with limited vehicular access. The safety fan of Range 9 does extend into Training Areas 2 and 16, however, these safety fans are meant purely for personnel safety and there is no threat of habitat damage beyond the actual range boundaries due to the small arms projectiles being used at this training area. Due to these factors, the Pinyon jay has low vulnerability to military training activities at the PCMS.

***Noise and Disturbance from Human Activities***

Pinyon jays at DoD installations in New Mexico did not show a strong avoidance of roads, buildings or occasional loud noises when choosing their nesting sites. One breeding colony tracked since 2007 had some nests situated within 10-15m from unimproved roads, and several nests situated within 50-100m from regularly occupied buildings (Johnson et al. 2014). They noted that their sample size was not large enough to evaluate impacts from infrastructure at the colony scale, but nests were farther from buildings and other infrastructure than from roads. However, jays, especially those with fledglings, were very sensitive to humans approaching on foot (Johnson et al. 2015).

Johnson et al. (2014) documented one colony within 850m of a firing range. They suggested that loud noises of short duration (e.g., vehicles, aircraft, explosions, gunfire) did not prevent habitat use by jays, but that constant noise might interfere with flock communications, as previously noted.

***Tree Damage from Insects***

Overall forest health at Fort Carson and PCMS is generally considered good, with the exception of pinyon pine at PCMS. Evidence of infestation by pinyon pitch mass borer (*Dioryctria* spp.) was found on virturally every pinyon pine tree at PCMS during a forest inventory study in 2001 (Betters and Reich 2002). The borer is unlikely to kill pinyon pine trees, but can negatively affect overall health and growth, especially when combined with other stressors like drought (Betters and Reich 2002). The same forest inventory found evidence of twig and Ips beetle infestations, but to a much lesser extent than the borer (Betters and Reich 2002).

### 6.4.3 Climate Change

Observed and projected climate trends for Colorado generally point to decreased suitability for the pinyon-juniper woodlands that provide the primary habitat for pinyon jays. Colorado's statewide annual average temperatures have increased by 2°F over the past 30 years, and addition warming is expected in the future (Lukas et al. 2014). Projections for precipitation are more variable and less reliable, but even if precipitation increases somewhat, the greater degree of warming will likely still mean less moisture available for vegetation (see Section 5.5.10 for additional discussion of predicted climate impacts on pinyon-juniper). This is expected to have adverse impacts on pinyon pine trees, including increased drought stress and reduced recruitment. For example, Redmond et al. (2012) found a 40% decline in pinyon pine cone production associated with an average 2.3°F increase in summer temperatures in New Mexico and Oklahoma. In addition, drought can cause direct and widespread mortality in pinyon pine (Breshears et al. 2008, Adams et al. 2009). Juniper species are typically more drought-tolerant, and they may persist under drought conditions, becoming more abundant in pinyon-juniper stands. Though pinyon jays are known to use juniper trees for both nesting and cover, juniper seeds may not be enough of a substitute for pinyon seeds in the jay's diet.

Climate change vulnerability assessments for the pinyon jay have produced somewhat variable results. Tomasevic (2010) assigned the pinyon jay a "medium" score for climate sensitivity. Siegel et al. (2014) reported "Presumed Stable" status for pinyon jay climate vulnerability in California's Sierra Nevada. Gradali et al. (2012) determined that this species should not be affected by climate change in California. Conversely, this species is considered "climate threatened" by the Audubon Society (http://climate.audubon.org/birds/pinjay/pinyon-jay), and "Highly Vulnerable" according to the rapid assessment we produced for this report. To help us better understand relative vulnerability of the pinyon jay to climate change, we evaluated 21 direct and indirect factors related to species distribution, habitat connectivity, and life history using NatureServe's Climate Change Vulnerability Index tool (CCVI) (see Appendices B and C, respectively for CCVI results and for details on the CCVI tool). We considered the pinyon jay's distribution across the western U.S. as well as its distribution in Colorado, and found that the species ranked "Highly Vulnerable" at both scales, which is consistent with distribution modeling discussed below. The primary factors driving vulnerability in our assessment were:

1. Projected temperature increase of over five degrees across the state, which could result in pinyon die off, decline in pinyon seed production, and increase in frequency / intensity of drought, wildfire, and insect outbreaks.
2. Specialized diet (i.e., they rely on a primary food source, and that food source is likely to be adversely impacted by climate change), and
3. Projected loss of up to 31% of the entire breeding range of pinyon jays by the end of the century.

The pinyon jay had previously been evaluated using the CCVI for its distribution in Nevada and in the Sierra Nevada of California, by the Nevada Natural Heritage Program (2012) and Siegel et al. (2014), respectively. Each of these evaluations resulted in a rank of "Presumed Stable," compared to our "Highly Vulnerable" score. Results aren't directly comparable since the CCVI tool has been modified somewhat since the Nevada and California assessments. However, we note that projected departure from recent past for both temperature and precipitation is greater in Colorado compared to NV or CA, and models of future range and distribution showing significant potential effects on pinyon jays have been produced since the Nevada and California scores were developed. Our highly vulnerable score is comparable to New Mexico's vulnerability assessment for pinyon jay in their state, which was very highly vulnerable (New Mexico Game and Fish 2016).

A variety of models estimating climate-related changes within the pinyon jay's range include:

- Range contraction in Arizona, southern New Mexico, and Utah (Thompson et al. 1998, Cole et al. 2007) and range expansion in Colorado and northern New Mexico (Cole et al. 2007).
- A range reduction of 10-25% across the western U.S. by roughly mid-century and 13-31% by end century, depending on whether or not distribution data for plants were included in the model. Failure of plant migration rates to keep up with shifting climate envelopes resulted in increased range contraction for species that rely closely on specific plant species (van Riper et al. 2014).
- Future contractions of both summer and winter range compared to the 2000 range; summer range is predicted to decrease by 24% by 2080, with only 7% of current range stable (i.e., the remaining range is expected to shift); winter range is predicted to decrease 37% by 2080, with 34% of the range stable and the remainder shifting (Figure 36) (National Auduon Society 2013).
- As much as 19% of Nevada's current population of pinyon jays could be displaced as a result of 50 years of modeled climate change; possible outcomes include adapting to change within current home ranges, increasing density in unaffected habitat, leaving the state, or reduction in population size (GBBO 2010, GBBO 2011).
- Significant range contractions are also predicted for ponderosa pine by next century (Van Riper et al. (2014), citing Notaro et al. 2012 and Williams et al. 2012).
- Pinyon-juniper transition from earlier to later successional stages projected within 50 years, which based on Great Basin Bird Observatory work suggesting that jays require open early-mid successional stages, would be detrimental for pinyon jays (Provencher and Anderson 2011). Including changes in disturbance regimes in addition to changes in temperature and precipitation in pinyon-juniper models highlighted some impacts to birds, such as:
    - $CO_2$ feritilization during wetter years resulting in increased non-native vegetation and also increased dispersal of pinyon and juniper into shrublands;
    - Longer growing season droughts resulting in higher tree mortality;
    - Larger and more frequent fires in forest systems.

Audubon's modeled projections for future pinyon jay habitat suitability (Figure 36) suggest that in the nearer term (2020), suitability could increase somewhat in the southern Front Range and southeastern Colorado regions around Fort Carson, PCMS, and the Air Force Academy compared to present. Longer time frames show decreasing habitat suitability overall, with the "best" (i.e., darkest blue on the maps) shifting from the current core range of Nevada, Arizona, and New Mexico northward into Colorado and Wyoming. Modeled projections by van Riper et al. (Figure 37) generally support this prediction.

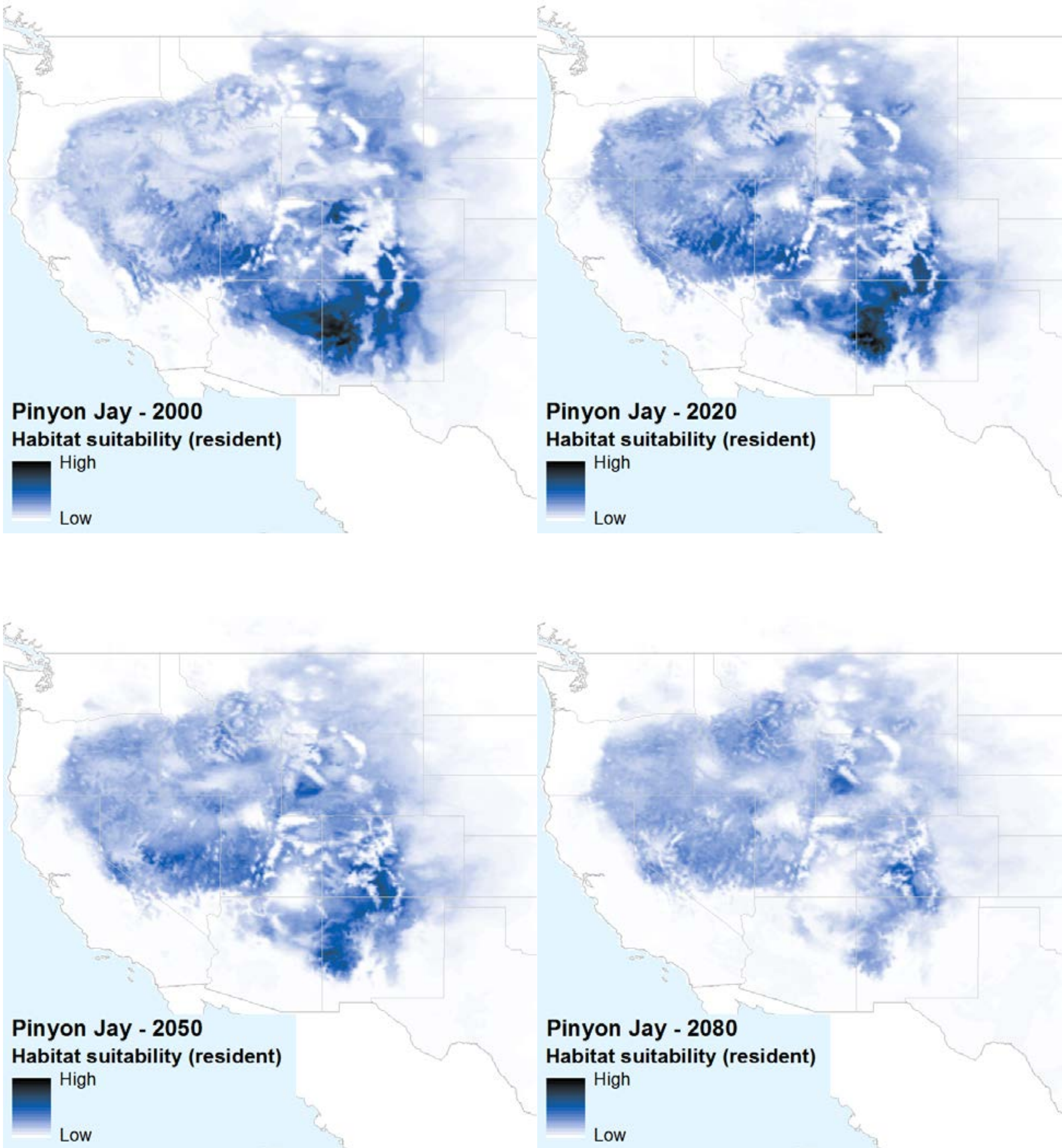



**Figure 36. Predicted current (2000) and future (2020, 2050, and 2080) habitat suitability (National Audubon Society 2013).** This species is a resident in the Western U.S. and does not have separate breeding and winter ranges. Therefore, breeding and winter models were averaged for each time period, and the average value displayed as "Resident" range. Underlying models for summer and winter distribution can be found at http://climate.audubon.org/birds/pinjay/pinyon-jay.

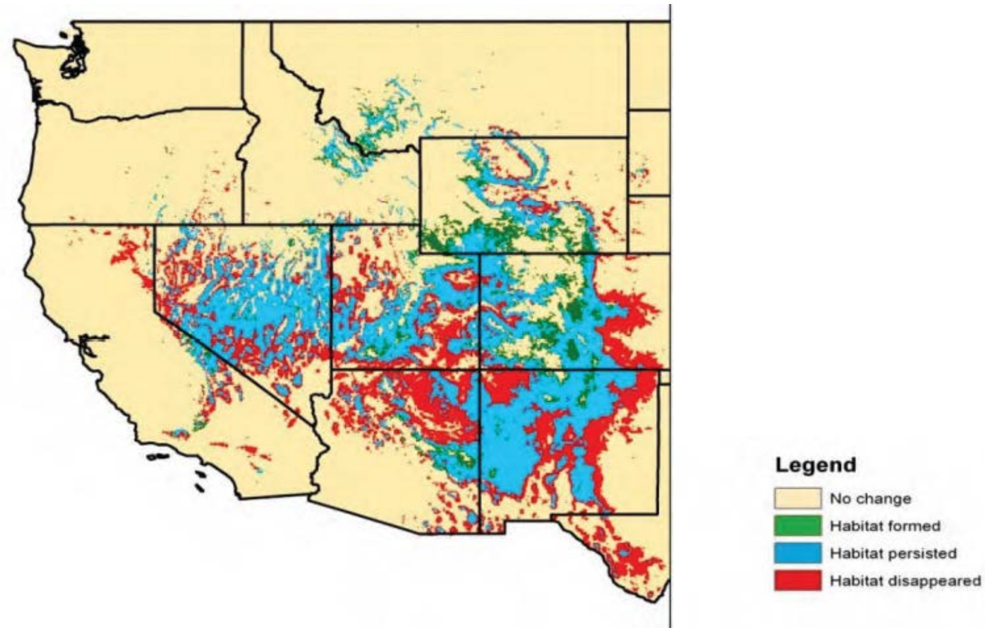



**Figure 37. Predicted pinyon jay range in 2099 compared to range in 2000 from van Riper et al. 2014.**

## 6.5 Management Recommendations

Objectives for the pinyon jay in the 2016 Landbird Conservation Plan call for reducing the rate of decline within 10 years, and then stabilizing and increasing the rangewide population by 5-15% within 30 years. The single most effective means of supporting stable pinyon jay populations is to manage for healthy, mature pinyon-juniper (and ponderosa pine) woodlands (Wiggins 2005). Landscape-scale management that provides both pinyon pine woodland (for nesting and food source) as well as lower elevation juniper woodland and savanna (for wintering, caching, and potential early spring breeding) in proximity to pinyon-juniper woodlands is important (Johnson et al. 2014). Because of the variability of masting in pinyon pine, jays need thousands of hectares of pinyon or pinyon-juniper (Johnson et al. 2014) to support birds who may need to move hundreds or thousands of kilometers for food during non-masting years (Balda 2002).

A variety of sources provide recommendations for habitat management to benefit pinyon jays, and these present generally consistent messages:

1. **Maintain extensive stands of pinyon-juniper or pinyon woodlands at the landscape scale, with emphasis on retaining mature, cone-producing trees** (Latta et al. 1999, Pierce 2007, Wiggins 2005, Johnson et al. 2014).
    a. Avoid cutting or clearing of healthy, mature pinyon-juniper habitat (Wiggins 2005, New Mexico Partners in Flight 2007, Johnson et al. 2014, 2015)
    b. Maintain patches in a *minimum* of 7 sq.mi. (18 ha, an estimated minimum flock home range) (Latta et al. 1999 citing Balda & Bateman 1971, Gillihan 2006, Wiggins 2005). Johnson et al. (2015) recommended managing for larger areas – at least 50ha with a 50m buffer of suitable habitat for flocks of 20 nesting pairs.

c. Maintain tree densities of approximately 400-900 trees/ha, with pinyon dominant in most areas (Johnson et al. 2014, 2015). Seed production has been found to be comparatively lower where trees are more dense, so thinning may improve the health of the most productive trees where densities are high (e.g., >2,000 trees/ha) (Johnson and Smith 2006, 2007).
d. Maintain woodlands with large (12 in. diameter at root collar) trees scattered approximately 30/acre with 35% canopy closure, standing dead trees (10 in. diameter at root collar) 1/acre, and large downed trees (2/ac, 10 in. at root collar and 10 ft. long) (Gillihan 2006 citing Miller et al. 1999).
e. Where feasible, initiate long-term restoration efforts in areas where large-scale pinyon die-offs have occurred (New Mexico Partners in Flight 2007).

2. **Identify and maintain occupied home ranges** (Latta et al. 1999, Wiggins 2005)
    a. Develop a reliable method for censusing pinyon jay populations and search potential habitat for nest sites (Wiggins 2005).
    b. Where nesting is known to occur, install permanent transects and survey 3-4 times per year, ideally in April and May. Band and radio-collar some individuals in known flocks to improve understanding of flock movements, dispersal, habitat use, and breeding site identification (Wiggins 2005).

3. **Maintain structural diversity in pinyon-juniper woodlands** (Latta et al. 1999, Wiggins 2005, Gillihan 2006, New Mexico Partners in Flight 2007). This is consistent with the desired condition and management objectives described in the current (2011-2016) Forest Plan for Fort Carson/PCMS.
    a. Maintain undisturbed woodland habitat with a mixed size and age distribution of trees (New Mexico Partners in Flight 2007).
    b. Maintain or create small-scale (<20 acres) openings to reduce soil erosion in dense stands (Latta et al. 1999), and reduce fuel loads (Wiggins 2005).
    c. In dense stands of young trees, create openings $\leq$ 60 ft. wide with irregular outlines to improve shrub and grass components (Gillihan 2006 citing Sedgwick 1987).
    d. When thinning, avoid cone-producing trees[16] (Wiggins 2005).
    e. Maintain grass and herbaceous understory (e.g., via appropriate livestock and/or wild ungulate densities, Latta et al. 1999).

4. **Manage human use and disturbance to protect nesting colonies and cone-producing trees**
    a. Limit collection of mature trees for fuelwood (Latta et al. 1999) and limit any tree harvesting to times outside nesting season (Gillihan 2006).
    b. Avoid introduction of new infrastructure any closer to known nesting colonies than existing infrastructure (Johnson et al. 2014).

[16] Over-thinning juniper may adversely impact other bird species (Wiggins 2005). E.g., Francis et al. (2011) documented 35 species nesting in New Mexico pinyon-juniper; 86% of nests were in juniper compared to 14% of nests in pinyon [though note timing of study was too early to detect pinyon jays].

   c. Maintain a 1km buffer for roads and other infrastructure around known nesting sites (Wiggins 2005).
5. **Fire is *not* recommended as a management tool in pinyon-juniper habitat** (New Mexico Partners in Flight 2007, Romme et al. 2009, Johnson et al. 2014, 2015)

Additional recommendations specific to Fort Carson and PCMS are based on recommendations for military installations in New Mexico (Johnson et al. 2014). In the absence of targeted field research on pinyon jays on Colorado installations, these offer the best information currently available.

1. Avoid introduction of new infrastructure any closer to known nesting colonies than existing infrastructure (Johnson et al. 2014).
2. Avoid ground training within 2km of traditional or active colony sites March-July. In masting years, avoid ground training within 2km of foraging areas August-October.
3. Avoid habitat destruction and loud noises (e.g., bombing), especially consistent noise over 40 decibels, within 2km of nesting colonies.
4. Avoid activities with high potential for sparking wildfires within known flocks' breeding home range.
5. The USFWS Memorandum of Understanding recommends collaboration with willing landowners and use of DoD Readiness and Environmental Protection Integration program and Land and Water Conservation Fund program to improve habitat adjacent to or near DoD boundaries to help minimize potential conflicts between species conservation and military readiness.

## 6.6 Information Needs

1. Specific information on pinyon jay occurrence and habitat use at Fort Carson, PCMS, and potentially other Colorado installations is needed.
2. Investigations of pinyon jay habitat use during and after high cone crop years is needed to test apparent preferences for young classes and invasion zones that have been documented in Nevada (Nevada Wildlife Action Plan Team 2012).
3. Research into the ability of pinyon jay flocks to breed in shifted home ranges (e.g., in response to habitat loss from fire, insect, other disturbance) is needed (Wiggins 2005).
4. Pinyon jay response to thinning and other forest management treatments in Colorado is needed (Wiggins 2005).

# 7 Gray Vireo (*Vireo vicinior*)

**Gray vireo in Utah juniper.**
Photo by Roger Staples (birds.netai.net)

There is a dearth of primary research on gray vireos in Colorado, so much of the information in this account has been derived from a few key sources: the Birds of North America (Barlow et al. 1999), and recent field studies of pinyon jays on DoD and Bureau of Land Management (BLM) lands in New Mexico (Johnson et al. 2014 and 2015, respectively). The Johnson et al. studies are more recent, geographically closer, and in habitat that is more similar to our area of interest.

## 7.1 Range, Distribution, and Abundance

The gray vireo breeds in Arizona, California, Colorado, Utah, Nevada, New Mexico, Texas, and Baja California. It is a short distance migrant that winters in southwestern Arizona, southwestern Texas, and the Mexican states of Baja California, Baja California Sur (Mexico), and Sonora (Figure 38). With the exception of southwestern Texas, breeding and winter ranges do not overlap. Migration routes are unknown, but Barlow et al. (1999) suggested that birds breeding on the eastern slope of Colorado may winter in Big Bend, Texas. The 2016 Partners in Flight Landbird Conservation Plan estimates the U.S./Canada population at 460,000 birds (Rosenberg et al. 2016), with the greatest abundances in southwestern Utah and northwestern Arizona (Figure 39).

In Colorado, this species primarily occurs on the western border with Utah, but probable breeding occurrences have been observed in southeastern Colorado (Wickersham 2016). Breeding Bird Atlas II data suggest that gray vireos have expanded along Colorado's western border compared to the original Colorado Breeding Bird Atlas (Figures 40 and 41).

On DoD installations in Colorado, gray vireo have been observed in juniper and pinyon-juniper woodlands at Fort Carson and PCMS. Pinyon-juniper woodlands are present in very low acreages on the Air Force Academy (35 acres), and the gray vireo has not been documented there (Siemers et al. 2012). Within Fort Carson, gray vireos have been observed at Training Area 41. Two observations of singing males, the first in July 2013 and the second in May 2014. The May 2014 observation was from a grassland with scattered junipers on an old burn scar (Clawges and Day 2013, Clawges 2014). Though gray vireos have been documented on PCMS (DPW 2015), specific locations were not reported. Legacy-funded research by Bird Conservancy of the Rockies did document gray vireos on either installation in 2015 (BCR unpublished data).

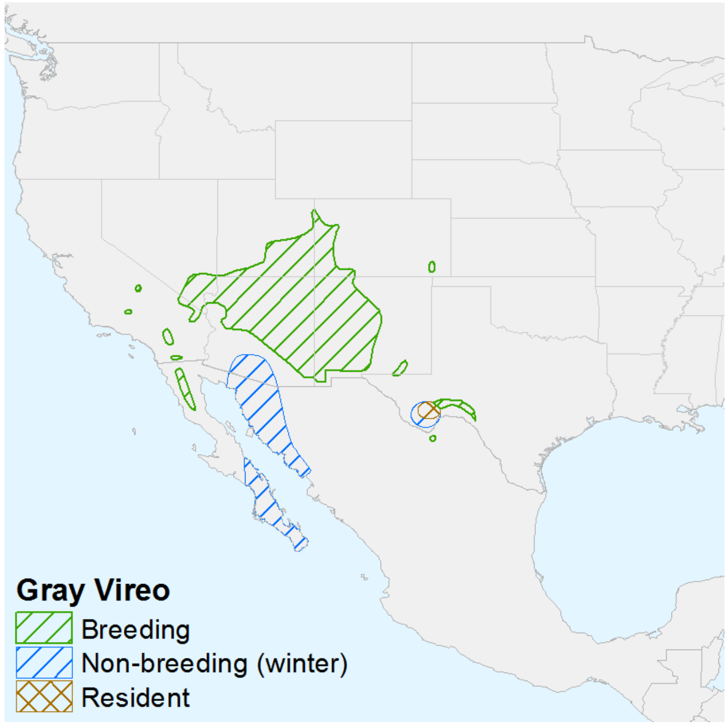



**Figure 38. Gray vireo global distribution.** Source: Birdlife International and NatureServe 2015.

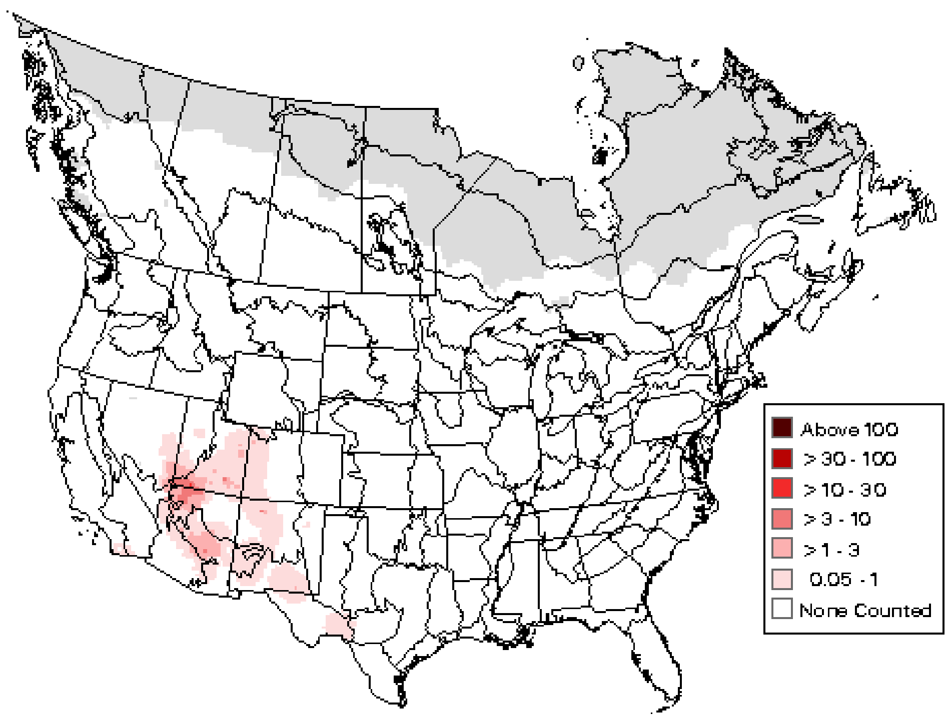



**Figure 39. BBS summer distribution 2007 - 2013.** This map is a simple summary of relative abundance based on raw BBS data, using average counts of gray vireos observed on each route over the time interval (https://www.mbr-pwrc.usgs.gov/bbs/ra2013/ra06340.htm).

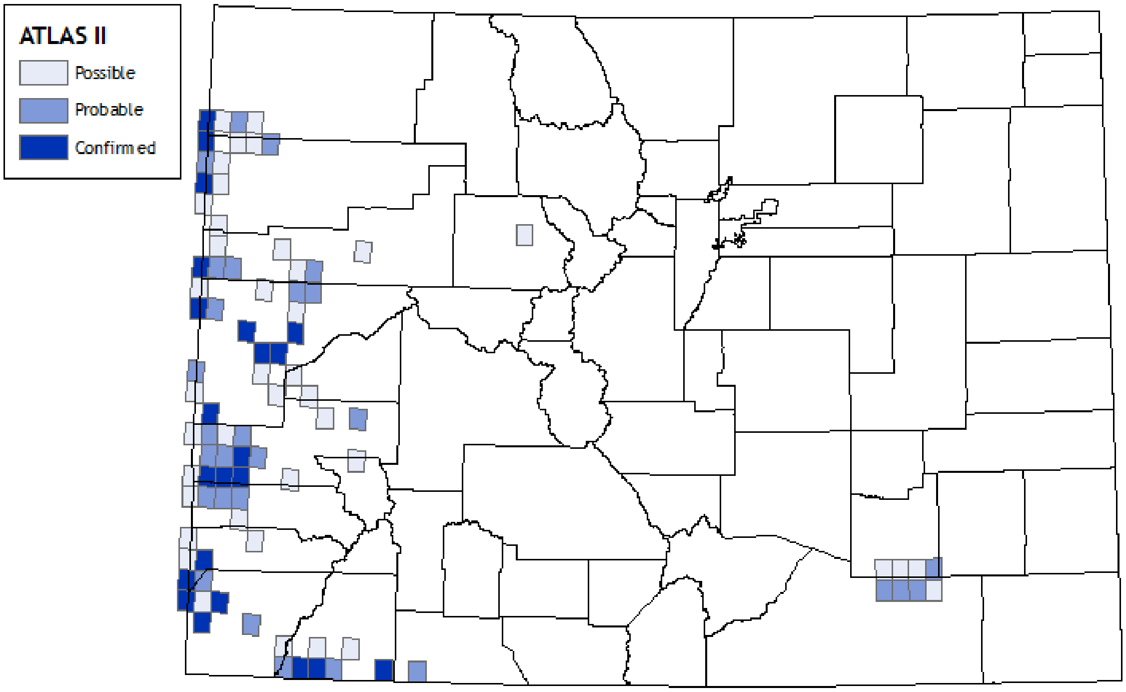



**Figure 40. Gray vireo distribution in Colorado.** Source: Wickersham 2016.

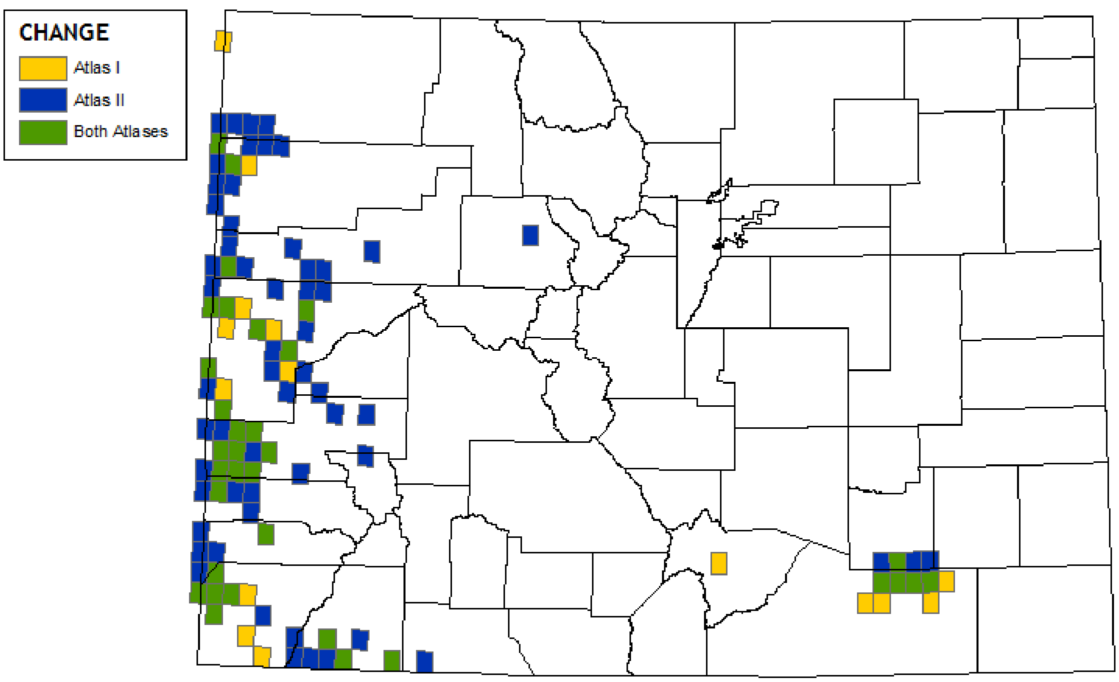



**Figure 41. Change in gray vireo breeding distribution in Colorado from Breeding Bird Atlas I to Breeding Bird Atlas II.** Source: Wickersham 2016.

## 7.2 Conservation Status

Breeding Bird Survey data show a significantly increasing trend for gray vireo across their range (Figure 42). Rosenberg et al. (2016) estimate a 75% increase rangewide during the 1970-2014 timeframe, with long-term population increases estimated at 41% and >50% in pinyon-juniper woodlands in the Intermountain West (BCRs 9, 16, 34, 35) and Sonoran (BCRs 32, 34) respectively. However, they also estimate a long-term decline of 84% in the desert scrub habitat of the Rio Grande (BCR 35). Latta et al. (1999) notes a population decrease in California (citing Small 1994). Some authors consider BBS efforts inadequate to monitor the species because of its patchy distribution, cryptic nature, and occurrence in remote areas (Barlow et al. 1999, Shuford and Gardali 2008, Butler et al. 2013), and some reported increases may be attributable in part to increased survey effort. According to New Mexico's recovery plan for gray vireo (Pierce 2007), trend information should be viewed with extreme caution since only 12 of over 80 BBS routes in in the state detect the species (citing DeLong and Williams 2006) and national BBS routes are considered too imprecise to draw proper trend inferences (citing Rich et al. 2004). In any case, despite reports of increasing population numbers, the gray vireo population is still small, and thus this species is included on the following conservation status lists:

***International***

- Partners in Flight Watchlist (Yellow – Species not declining but vulnerable due to small range or population and moderate threats)
  - 2016 State of the Birds watchlist (at risk of becoming threatened or endangered without conservation action) (also based on PIF data)
  - American Bird Conservancy and North American Bird Conservation Initiative Watchlist (Yellow), Species of Continental Importance for Bird Conservation Regions 9, 16, 34, and 35

***National***

- U.S. Fish and Wildlife Service Birds of Conservation Concern
- DoD PIF Mission-Sensitive Priority Bird Species (i.e., determined to have greatest potential impact on military mission if listed)
- Bureau of Land Management Sensitive Species in California
- U.S. Forest Service Regions 3 (Arizona, New Mexico) and 5 (California)

***State***

- Species of Greatest Conservation Need in Arizona, California, Colorado (Tier 2), and New Mexico (Immediate Priority)
- Natural Heritage Program conservation status ranked Imperiled in California and Colorado, Vulnerable in Nevada and Utah.

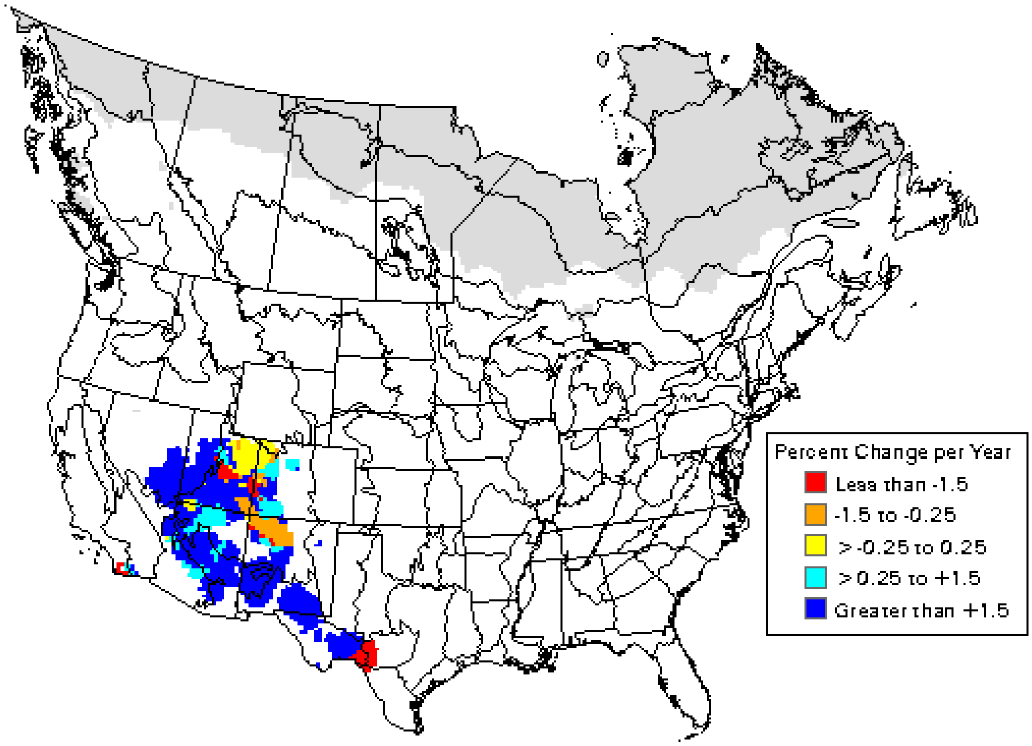



**Figure 42. Gray vireo trend based on BBS data from 1966-2013.** Source: Sauer et al. 2014 (https://www.mbr-pwrc.usgs.gov/bbs/tr2013/tr06340.htm).

## 7.3 Species Requirements

### 7.3.1 Habitat

The gray vireo is found primarily in pinyon-juniper woodlands, juniper woodlands, oak shrublands, desert shrublands, and chaparral (Barlow et al. 1999) during breeding season. Some authors consider the gray vireo an obligate of mature, relatively weed-free and open pinyon-juniper, juniper, or oak woodlands with a shrubby under story (Balda 1980; Parrish et al. 2002). Woodlands with moderate to steep slopes appear to be a critical factor, but elevation does not as long as the preferred habitat type is present. Proximity to water is apparently not essential (Parrish et al. 2002, GBBO 2010), though GBBO (2010) notes that proximity of "water-dependent habitat" increases value to birds generally. In the extreme southwestern U.S., oak (*Quercus* spp.) woodlands replace pinyon-juniper habitats (Tanner and Hardy 1958, Hubbard 1978, Parrish et al. 2002). During winter, gray vireos inhabit desert scrub and similar habitats.

In Colorado, the gray vireo occurs at elevations ranging from 4,400 to 7,990 feet, almost exclusively in juniper or pinyon-juniper woodlands (Wickersham 2016). Kingery et al. (1998) described these sites as having relatively open canopies interspersed with patches of sagebrush, grasses, and shrubs (Kingery et al. 1998). A few breeding birds have also been documented in low-elevation shrubland and tall desert shrublands (Wickersham 2016). In Colorado's western counties, gray vireos often select small patches of pinyon or pinyon-juniper woodland with steep slopes and avoid tall, dense stands of trees (Andrews and Righter 1992, Kingery 1998).

***Nesting Habitat***

Gray vireos nest predominantly in juniper trees, and gray vireo density appears to increase as proportion of juniper to pinyon pine increases (Schlossberg 2006, Francis et al. 2011). Johnson et al. (2015) determined that juniper woodland and savanna was strongly preferred for nesting, but that vireos will also occupy shrublands when juniper availability is limited. Of 65 nests documented at their study sites in New Mexico, they found that 82% of vireo nests were in juniper, compared to 15% in pinyon pine and 3% in sagebrush (*Artemisia tridentata*), though they noted that sagebrush without trees should not be considered breeding habitat. Vireos were found in juniper woodlands and savannas with no significant pinyon pine component, but not in pinyon-juniper habitat occupied by pinyon jays. Britt and Lundblad (2009) described nesting habitat in southern New Mexico as dry canyons with varying amounts of pinyon-juniper and desert scrub, and open juniper savanna at the base of slopes. In their study, more nests were in juniper trees than other substrates, but nests were also found in pinyon pine, mountain mahogany (*Cercocarpus montanus*), ash (*Fraxinus cuspidate*), evergreen sumac (*Rhus virens*), and Wright's silktassel (*Garrya wrightii*). Stake and Garber (2009) documented almost exclusive use of juniper (91%) as the nesting substrate in northwestern New Mexico, but almost split use of oak and juniper (41% and 53%, respectively) in southeastern New Mexico. Parrish et al. (2002) describes nesting habitat there as open, steeply sloped pinyon-juniper or juniper woodlands at elevations between 4400 and 6400 ft. Woodlands may have open understories of grass, sagebrush (*Artemisia* spp.), saltbush (*Atriplex* spp.) or other desert scrub species, where understories are 6-8 feet in height. Breeding habitat in Arizona is consistent with descriptions from New Mexico and Utah: open mature pinyon-juniper woodlands on canyon and mesa slopes from 975-2075 m (3200-6800 ft) in elevation, with a broadleaf shrub component (e.g., Utah serviceberry, single-leaf ash) or chaparral (T. Corman, Arizona Game and Fish, pers. observ., cited Latta et al. 1999). Descriptions of habitat in Nevada are similarly consistent: Multi-aged stands of pinyon-juniper with well-developed shrub understory 1.6-6.6 ft. high, and canopy density approximately 5-15%, and a higher proportion of juniper to pinyon pine than unoccupied sites (Barlow et al. 1999, Schlossberg 2006, Walker and Doster 2009 cited in GBBO 2010). Nests are attached to twigs of shrubs or trees approximately 2-6 ft. above ground (Latta et al. 1999 citing Ehrlich et al. 1988, Parrish et al. 2002, Britt and Lundblad 2009).

Results from Johnson et al. (2015) revealed that vireos preferred nest sites with slightly more and taller trees compared to available trees within their territories. They suggested that this may be to balance the risk of increased predation in taller trees and the benefit of better vantage points for mating songs and territory defense. At documented nest sites, mean nest tree height was ~3m (~2-8), with mean nest tree canopy ~3m wide (~1-7). Britt and Lundblad (2009) also documented nest tree height ranging from 2-8m (mean 2.4m). Frei and Finley (2009) also calculated mean nest tree height at approximately 3m.

Johnson et al.'s 2015 study on BLM land in New Mexico found mean tree density on nest plots to be 316/ha, which was three times higher than their similar 2014 work on DoD installations (also in New Mexico), where mean juniper densities in gray vireo territories were 113 trees/ha (within a range of 25-425 trees/ha). They suggested that vireos may prefer juniper savanna to woodlands, and proposed that vireos may prefer densities high enough to allow for territory defense, nesting, predator/cowbird avoidance, and abundant food sources, but not so high as to make foraging difficult. Frei and Finley (2009) found that juniper savannas with a mean tree density of 56 trees/ha (range 31-90) and mean canopy cover of 8.5% (range 5-15) were most commonly used. Barlow et al. (1970) suggested that relatively more trees would present more foraging opportunities closer to nests since vireos forage from leaves, branches, trunks (Barlow et al. 1970). LaRue (1994) reported that gray vireos avoided dense woodlands (>280 trees/ha) in northeastern Arizona (Latta et al. 1999).

Johnson et al. (2014, 2015) found preference for elevation and aspect to be variable depending on topography. Elevation reported from Arizona, New Mexico, and Utah range from approximately 4900-7300 ft. (1500m – 2228m) (Schlossberg 2006, Wickersham and Wickersham 2007). Vireos in the Johnson et al. (2014, 2015) studies preferred a south-facing aspect. Britt and Lundblad (2009) documented a preference for placing nests on the downhill side of the nest tree. Delong and Cox (2005) reported a preference for west-facing, but either south or west would be the warmest sites and may therefore be important for egg viability, especially during May and early June (laying & incubation periods) (Johnson et al. 2014, 2015). Preference for aspect has not been documented in Utah (Parrish et al. 2002).

Fidelity to breeding sites have been documented in Texas, where 20 of 22 banded birds returned to the same site the following year, and in Colorado, where one banded male returned to the same territory for three consecutive years (Barlow et al. 1999). Johnson et al. (2014) also found "relatively high" site fidelity in New Mexico. GBBO (2010) considers site fidelity in Nevada to be "probably high" (citing Shuford and Gardali 2008).

In Colorado, nests have been documented in Utah juniper (*Juniperus osteosperma*), Rocky Mountain juniper (*Juniperus scopulorum*), and pinyon pine (*Pinus edulis*) (Hutching and Leukering unpublished data referenced in Barlow et al. 1999). No specific information is available on nesting habitat at Fort Carson or PCMS, but the most likely nesting tree species is oneseed juniper (*Juniperus monosperma*).

***Foraging Habitat***

The diet of the gray vireo in summer is comprised primarily of insects, including a wide variety of moths, large caterpillars, and grasshoppers, as well as flies, beetles, butterflies, wasps, and other insects (Barlow et al. 1999). Vireos forage for prey in foliage, leaves, and bark of tree and shrub thickets, with most foraging occurring from approximately 3-13 ft. above ground (Oberholser 1974, Griffin 1986, Barlow et al. 1999).

***Wintering and Migration Habitat***

Wintering populations in southwestern Arizona and northwest Mexico inhabit lowland Sonoran desert scrublands with little or no rainfall or other fresh water source (Bates 1992), but also patches of desert scrub adjacent to mangrove (*Avicennia nitida*) swamps in Mexico (Russell and Monson 1998). In southern Arizona, the gray vireo lives in the rocky canyons of desert mountains dominated by elephant tree (*Bursera microphylla*) (Bates 1992). Wintering populations in the Big Bend area of southwestern Texas occur in Chihuahuan desert scrub with Texas persimmon

(*Diospyros texana*), as well as desert riparian scrub with desert-willow (*Chilopsis linearis*) and Rio Grande cottonwood (*Populus fremontii* var. *wislizenii*) close to springs or intermittent streams (Griffin 1986). Little information is available on gray vireo wintering habitat in Baja California and Baja California Sur, Mexico. Winter diet is comprised of fruits of the elephant tree along the Sonoran coast and southwestern Arizona, and possibly other fruits (e.g., sumac or guayacan – *Porilaria* spp.) in Texas (Bates 1992, Barlow et al. 1999, Latta et al. 1999). Dietary habits are variable across the species's winter range – birds wintering in Texas are insectivorous year-round, while birds wintering in western Mexico feed on fruit (Barlow et al. 1999). This species may sometimes be found in riparian corridors and at lower elevations during migration (Parrish et al. 2002).

***Habitat on DoD Installations***

There have only been a few sightings of gray vireo on Fort Carson and PCMS, so habitat use there is not well known. See Section 5 for additional information on pinyon-juniper on these installations.

### 7.3.2 Spacing and Movement

The gray vireo is a territorial species, reported as occurring in low densities (Latta et al. 1999, Parrish et al. 2002,), with territory sizes ranging from a low of 0.3 ha (Bates 1992) to a high of 16 ha (Parrish et al. 2002). Data from Texas suggest that size of breeding territories varies with population density, ranging from 2-4 ha (for adjacent territories) to 4-10 ha for isolated territories (Barlow et al. 1999). Larger territories have been documented in New Mexico – up to 11.3 ha (Britt and Lundblad 2009) and 12.4 ha (Johnson et al. 2014, 2015). Mean territory sizes reported for New Mexico include 2.8-3.2 ha (Johnson et al. 2014), 4.0-4.1ha (Britt and Lundblad 2009), and 8ha (DeLong and Cox 2005). In Utah, territory size has been estimated at 4-16 ha (Parrish et al. 2002) based on density estimates of 1.6 to 2.4 individuals/40 ha (Grinnell and Swarth 1913, Weathers 1983), but these estimates were considered speculative. Estimates for territory size in Nevada are 2-10 ha, but confidence in this estimate is low (GBBO 2010). Territory size in California has been roughly estimated at 3-8 ha (Winter and Hargrove 2004). Density estimates for California range from 1.6 to 4.9 birds/40 ha (Grinnel and Swarth 1913, Johnson et al. 1948, Winter and Hargrove 2004).

The only Colorado-specific information available (a single territory estimated at ~7 ha) is consistent with territory sizes in other parts of the species range (Barlow et al. 1999 citing unpublished data from Hutchings and Leukering). No information is available for movement distances of individuals, or for home range size (though Barlow et al. 1999 suggested that home range size is probably very similar to territory size).

### 7.3.3 Phenology

The Gray vireo arrives in southern Arizona in early April and northern Arizona in late April, and return to wintering ground in September (Latta et al. 1999). Young fledge at 13-14 days (Latta et al. 1999). In Colorado, breeding birds begin to arrive in early May, and depart by mid-August (Barlow et al. 1999). Pair formation and nest building occurs within about a week of arrival. Reports of clutches range from late April to early July across the breeding range, early June in Colorado. Fledged young have been reported from late May to mid-August; Colorado-specific information is not available. In the southern portions of the species' range, two broods per year are probable (Barlow et al. 1999).

## 7.4 Threats

### 7.4.1 Rangewide Threats and Current Habitat Condition

The gray vireo has not been well-studied with specific regard to threats. The specific life history information that is available is insufficient to support clear determination of human and land-use related impacts to this species (Parrish et al. 2002).

According to the Partners in Flight 2016 Landbird Conservation Plan, vulnerability factors for the gray vireo include small population size, restricted distribution, and threats in both non-breeding and breeding areas. Primary threats are reported as deforestation and changing forest conditions. Previously discussed impacts to pinyon-juniper habitats (sections 5 and 6 of this report) are also relevant to gray vireo. Latta et al. (1999) and Winter and Hargrove (2004) note that gray vireos may be less susceptible to some habitat-related population declines due to their tendency to occupy steep terrain in remote areas, which is less likely to be disturbed. In some parts of this species' range, extensive areas of apparently suitable habitat are unoccupied (Winter and Hargrove 2004).

A number of authors suggest that the greatest threats to gray vireos are likely to be clearing, thinning, and/or other degradation of habitat for exurban development, energy development (biofuels, oil, and gas), and to improve forage or reduce expansion into grasslands and shrublands, as well as large-scale loss of pinyon pine and juniper from drought and insect outbreaks (Gilliahn 2006, Walker and Doster 2009, Barlow et al. 1999, Butler et al. 2013, Johnson et al. 2014, 2015). Crow and van Riper (2010) found that relative abundance of pinyon-juniper birds was significantly reduced after mechanical thinning, and that vireos disappeared altogether. Much of the southwestern U.S. experienced significant mortality in pinyon-juniper woodlands after the 2002 drought, with associated increases in insect and wildfire activity. Temperatures and drought are increasing across the gray vireo's range, and impacts to habitat from these stresses are expected to worsen. Juniper trees are better able to withstand drought than pinyon pines, so impacts to gray vireos may be less severe.

In states within the core range of the gray vireo, state wildlife action plans and other documents present a mixed picture of current habitat condition and relative level of threat to habitats and/or gray vireos. They summarize as follows:

- **Arizona State Wildlife Action Plan** – "Great Basin conifer woodlands [pinyon-juniper] have been significantly affected by changes in fire regime, livestock grazing, and mechanical or chemical treatments (Monsen and Stevens 1999, Stevens and Monson 2004). Due to increased density of tree canopies and of invasive grass species, widespread crown fires are predicted and the area of these woodlands may decline, to be replaced by shrublands or grasslands (Gruell 1999, Tausch 1999). Only about 11% of the Great Basin conifer woodlands have fire regimes which are severely altered from their historical range, but another 70% are moderately altered, creating a moderate risk of losing key ecosystem components (USFS data; Schmidt et al. 2002). Pinyon pines have recently experienced widespread mortality due to drought and insects, affecting 1.2 million acres (9% of total distribution in Arizona) during 2002-2004 (Breshears et al. 2005; USFS 2003, 2004, 2005)."

- **California State Wildlife Action Plan (2015)** – Stresses on gray vireo habitat include changes in sediment erosion-deposition and flood regimes, groundwater levels, and soil moisture; changes in spatial distribution of habitat types, community structure / composition / dynamics, succession processes, and ecosystem development; and habitat fragmentation. These pressures are attributed to housing and urban areas, roads and railroads, renewable energy, commercial and industrial areas, utility and service lines, invasive plants/animals, cropland, recreational activities, airborne pollutants, military activities, and industrial or military effluents.

- **Colorado State Wildlife Action Plan** – "Pinyon-juniper habitat quality has declined compared to historic norms, as significant acreage has been chained and burned in an effort to increase forage for livestock and big game on productive sites. Other threats include urban development, recreation (especially motorized recreation), invasive species (most notably an increase in cheatgrass (*Bromus tectorum*) in the understory, which has led to increasing fire ignitions), and energy development. Pinyon-juniper habitats across Colorado are in generally fair to good condition, and are excellent in more remote, untreated or administratively protected areas. Some patches can be in poor condition in areas where incompatible grazing has reduced native bunch grasses and invasive species such as cheatgrass have become established…Oil and gas development, and chaining to improve livestock forage, have degraded the condition of some stands. Climate change may result in additional degradation of this habitat type, especially via an increase in frequency and/or severity of wildfire."

- **New Mexico State Wildlife Action Plan** – "The gray vireo (*Vireo vicinior*) is…listed as Threatened by the Department. Populations have declined in northern New Mexico and are characterized by relatively low densities (DeLong and Williams 2006). This species' patchy distribution makes populations especially vulnerable to further isolation through fragmentation of juniper woodlands from energy development, firewood harvest, and clearing of land for grazing. Additionally, nest parasitism by cowbirds can greatly decrease recruitment."

- **New Mexico Gray Vireo Recovery Plan** – "The primary threat to the Gray Vireo is habitat alteration, through such activities as juniper control, firewood collection, use of trees for energy production, and removal of trees to facilitate oil and gas production, as the species will not use areas lacking trees…A secondary threat is brood parasites, such as cowbirds…Lastly, juniper has been implicated in soil erosion in some parts of its distribution through exclusion of native grasses that help retain the soil (Davenport et al.

1998, Miller et al. 2000); although in the majority of the Gray Vireo's range in New Mexico juniper is the species of tree in which the bird nests, such soil erosion or desertification might negatively impact other aspects of the Gray Vireo's natural history, such as through loss of prey base."

- **Nevada Comprehensive Bird Conservation Plan** – Pinyon juniper habitats are threatened by changes in fire intensity and frequency, insect outbreaks, livestock grazing, climate change (changes in precipitation), urban/suburban/industrial development, motorized recreation, and invasive weeds (Great Basin Bird Observatory 2010).

- **Utah Partners in Flight Avian Conservation Strategy** – "Pinyon-Juniper habitats have traditionally been viewed as little more than wastelands, and any value attributed for wildlife has traditionally focused on game birds and big game (Balda 1980). Since the advent of European settlers, whether through direct or indirect actions, these habitats have been heavily impacted through a variety of land-use practices, including overgrazing, recreational vehicle use, fuel wood harvest, alteration for development of livestock or big game forage-browse, cultivation, urbanization, soil erosion, and the introduction of exotic annual weeds. Of these, the most significant impact on these woodlands has been exotic annual weeds that have increased the frequency and intensity of wildfires in these habitats...In an ecosystem that did not evolve with fire, the introduction of exotic weeds and associated increase in wildfires has changed the vegetation structure and fragmented the historically large expanses of Pinyon- Juniper and juniper woodlands, and shrub steppe communities."

***Invasive and Other Problematic Species: Brown-headed Cowbird Parasitism***

Parasitism of gray vireo nests by brown-headed cowbirds (*Molothrus ater*) has been reported across the gray vireo's range (Latta et al. 1999, Parrish et al. 2002, Winter and Hargrove 2004, Tweit 2005, Pierce 2007), but the extent and impact of parasitism is unknown (Latta et al. 1999, Parrish et al. 2002). Where pinyon-juniper habitat is fragmented and in proximity to cattle, brood parasitism may be increased (Parrish et al. 2002), as cowbirds are often associated with disturbed landscapes and/or cattle (Lowther 1993, Tewksbury et al. 2006, Pierce 2007). Gray vireos have been observed chasing cowbirds away from nests, and often abandon nests when cowbird eggs are laid (Harrison 1979, Barlow et al. 1999, Tweit 2005). Delong and Williams' (2006) study in New Mexico reported high rates of parasitism (24-71% of nests), and abandonment of 75% of the parasitized nests. Hawks Aloft (2006) reported 71% of nests (12 of 17) parasitized, with one cowbird fledged. Frei and Finley (2009) found that, of 35 nests documented, brood parasitism was the cause of up to 62% (17-62% variable across study years) of failed nesting attempts, where the majority of parasitized nests were abandoned. Stake and Garber (2009) found differing rates of cowbird parasitism at separate study sites – 62% (16 out of 26 nests) in southeastern New Mexico and 11% (1 out of 9 nests) in northwestern New Mexico. Pierce (2007) suggested that cowbird parasitism may be a major limiting factor of gray vireos in New Mexico. Parrish et al. (2002) reported two cowbird young and two dead downy vireo chicks in a nest tended by adult gray vireos. However, data sufficient to demonstrate population level effects of brood parasitism is lacking.

***Energy Production***

Much of the western U.S. has undergone an explosion of oil and gas development in recent decades, and this is expected to continue. The impact of oil and gas development and associated infrastructure (e.g., roads, pipelines) on gray vireos is unclear and may vary regionally, but it is considered a potential threat in New Mexico. Stake and Garber (2009) found gray vireos nesting within 120-636 m of gas well pads in New Mexico (mean 338m, n=11), suggesting that wells did not deter breeding. They went on to note, however, that continued development could reduce and fragment remaining habitat, with potential adverse impact on territory selection. Wickersham and Wickersham (2007) likewise found that neither density of natural gas wells nor proximity of wells and roads appeared to influence gray vireo distribution in New Mexico. They cautioned that there may have been few options for relatively undisturbed territories given the density of wells in their study areas (39 wells/2km and 244 wells/5km), and that whatever effect there was may have already been realized. These questions could not be answered in the absence of pre-development baseline data. Francis et al. (2009) determined that gray vireos nested significantly farther away from well pads that had compressors (which produce constant noise, running around-the-clock and year-round) compared to well pads without compressors. This finding supports Johnson et al.'s (2015) suggestion than constant noise may have more of an impact than periodic, short-duration noises. Johnson et al. (2015) documented a mean distance of 304 m (65-1,449m) between gray vireo nests and nearest well pads, and mean distance of 97m (10-319) to the nearest road.

Development of large-scale solar farms in desert winter habitat may pose future threats to gray vireo (Butler et al. 2013). See Section 5.5.3 for additional information on impacts of energy production to pinyon-juniper habitats.

***Human Intrusions and Disturbance***

Gray vireos may abandon nests during nest building and egg laying if disturbed by humans (Barlow et al. 1999). Johnson et al. (2014, 2015) found gray vireos to be were relatively tolerant of humans on foot on the rare instances when this occurred during their study. They found that loud but short-term noises (e.g., vehicles, firing ranges) did not appear to affect territory selection.

### 7.4.2 Climate Change

The potential vulnerability of the gray vireo to climate change is uncertain. Gardali et al. (2012) found the gray vireo to be a lower priority compared to some other species, but still of concern for potential climate impacts in California. Molinari et al. (2016) determined that the gray vireo is vulnerable to climate change (also in California). Pierce (2007) considers climate change a potential threat to gray vireo habitat in New Mexico, where increasing temperatures may lead to effectively drier conditions, reducing the health of pinyon-juniper woodlands and subjecting them to increased pressure from drought, fire, and pests.

To help us better understand relative vulnerability of the gray vireo to climate change, we evaluated 21 direct and indirect factors related to species distribution, habitat connectivity, and life history using NatureServe's Climate Change Vulnerability Index tool (CCVI) (see Appendices B and C, respectively, for CCVI results and for details on the CCVI tool). We considered the gray vireo's distribution across the western U.S. as well as its distribution in Colorado, and found that the species ranked "Less Vulnerable" at both scales. The primary factors driving these results were the fact that this species tolerates extreme heat and aridity, as does its most significant habitat component (juniper trees). Our current thinking is that both gray vireos and juniper woodlands may increase their range in future years as conditions become hotter and drier (see section 5.5.10 of this report). Obviously we can't be certain of this, and other factors may come into play, but for now this species seems to be *less* vulnerable to climate change than other species.

Spatial models projecting future distribution also present conflicting information. The National Audubon Society considers the gray vireo "Climate Threatened." Though their climate model projects greatly increased overall "climate space," they predict an almost complete shift in the location of suitable breeding areas for the gray vireo (Figure 43), with only 3% of the current breeding range remaining suitable by 2080 (National Audubon Society 2013). In contrast, van Riper et al. (2014) projects an overall range increase from 58 –71% between 2010 and 2099 across the southwestern U.S., but with much of the current breeding range remaining persistent in its present location (Figure 44). Hatten et al.'s 2016 analysis, which built on the van Riper et al. study, projected a range contraction for gray vireo at mid-century, but an overall 58% increase by end century, with predicted current range persistence comparable to van Riper's. See Section 5.5.10 for additional information on the potential effects on climate change on pinyon-juniper habitats.

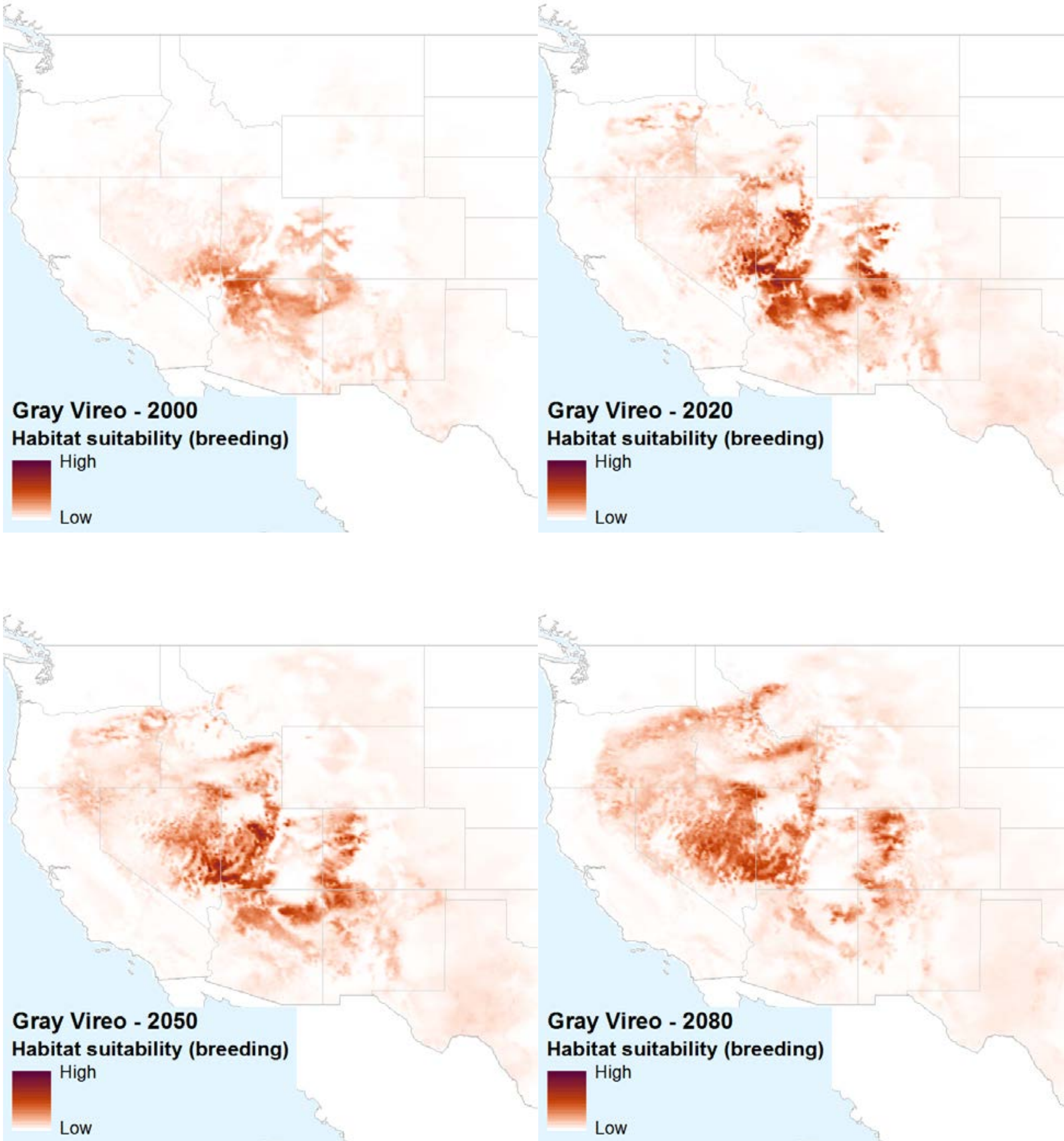



**Figure 43. Predicted current (2000) and future (2020, 2050, and 2080) habitat suitability.** Source: National Audubon Society 2013. Underlying models for summer and winter distribution can be found at http://climate.audubon.org/birds/gryvir/gray-vireo.

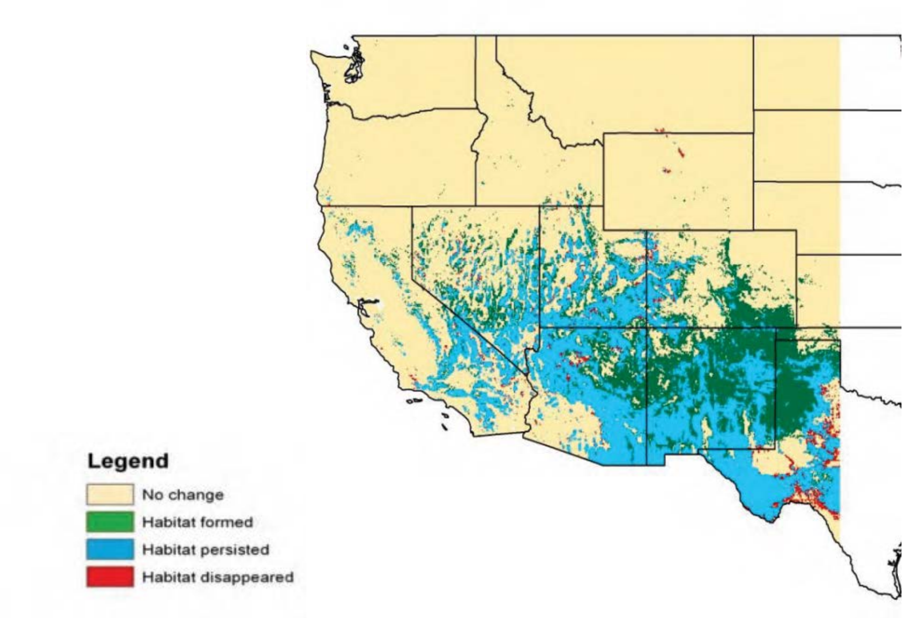



**Figure 44. Predicted gray vireo range in 2099 compared to range in 2000.** Source: van Riper et al. 2014.

## 7.4.3 Threats on DoD Installations

At Fort Carson and PCMS, habitat loss and degradation has occurred due to development and training activities. Wildfires and prescribed fires are also somewhat common on Fort Carson and PCMS. These events have changed the composition and structure of woodland habitats at these installations, but how these changes may have affected the gray vireo is unknown. Between January 1st and April 15th, 2016, four human-caused fires burned over 9,000 acres at Fort Carson. Other large fires have occurred at Fort Carson in recent years, including a 9,000 acre fire in 2008, and a 6,500 acre fire in 2009. At PCMS, the Bridger Fire burned 45,839 acres in 2008 and the Bear Springs Callie Marie Fire burned 36,043 acres in 2011.

Gray vireos have been observed at the edge of pinyon juniper woodlands at Fort Carson using open grasslands, and it is possible that more open habitats from fires could create improved habitat conditions for gray vireo. However, open and disturbed landscapes such as burned areas used for training could lead to increased numbers of brown-headed cowbirds, which are known to parasitize gray vireo nests. The brown-headed cowbird has been documented at both Fort Carson and PCMS (Bird Conservancy of the Rockies 2016). The potential effects of fire and training activities on habitat quality and brown-headed cowbird parasitism is unexplored, and warrants further investigation.

***Fort Carson***

The best available data on the location and magnitude of training activities at Fort Carson is from data obtained from the installations regarding training occurring from 2004 to 2008. Table 11 shows the average number of training days per year over this time period within the vicinity of pinyon-juniper habitat at Fort Carson. Table 11 also shows training days for the breeding and nesting season for the gray vireo, commonly regarded to be from May through August.

**Table 11. Average training days per year (and average training days per year from May to August) for training areas of interest for gray vireo.**

| Training Area | Average Training Days / Year | Average Training Days / Year (May-August) |
|---|---|---|
| 25 | 4.6 | 0.6 |
| 28 | 4.8 | 0.6 |
| 30 | 1.6 | 0.0 |
| 31 | 2.2 | 0.6 |
| 39 | 0.6 | 0.6 |

Most military maneuvers within pinyon-juniper habitat were concentrated in Training Areas 25 and 28, and to a lesser extent 30, 31, and 39. The majority of use came from the 3rd Battalion, 29th Field Artillery unit of the 3rd Armored Brigade Combat Team discussed in Chapter 2. This training occurred mostly during April, 2005 in preparation for their deployment to Operation Iraqi Freedom in November, 2005. This unit consists of three firing batteries of M109 Howitzer tanks, as well as numerous support vehicles and personnel. The training impact was likely highly intense, but short lived. As previously stated, the heaviest use was in Training Areas 25 and 28, which are on the periphery of the pinyon-juniper habitat, while Training Areas 41 (where most sightings have occurred) and 45, where the core of this habitat occurs on Fort Carson, remained untouched. Military training of this type is highly impactful when it does occur, however, it is sporadic in time and location, and has historically occurred outside of the gray vireo's breeding season. Due to these factors, the gray vireo has low vulnerability to potential military training activities at Fort Carson at the present time (though note that the potential for high intensity training could change in the future depending on geopolitical events).

***PCMS***

The majority of pinyon-juniper habitat at the PCMS is along the northern boundary. There are also isolated patches of pinyon-juniper along the southeast boundary of the installation, but nearly all of it is in canyonlands, where mechanized training is virtually impossible due to terrain, and training is restricted by the installation to dismounted maneuvers only. Due to these limitations the vulnerability of gray vireo to military training in these areas is negligible.

As described in section 2.3.4, the majority of military training is conducted in the corridor formed by Training Areas 7 & 10. The core pinyon-juniper habitat at the PCMS is found in Training Areas 1, 2, and 16. The majority of the combined area of these units is composed of dismounted training only areas and Soil Protection Areas with limited vehicular access. The safety fan of Range 9 does extend into Training Areas 2 and 16, however, these safety fans are meant purely for personnel safety and there is no threat of habitat damage beyond the actual range boundaries due to the small arms projectiles being used at this training area. Due to these factors, the pinyon jay has low vulnerability to military training activities at the PCMS.

## 7.5 Management Recommendations

A variety of sources provide recommendations for habitat management to benefit gray vireos, and these present generally consistent messages:

1. **Maintain extensive stands of pinyon-juniper and pinyon woodlands at the landscape scale** (Latta et al. 1999, Pierce 2007, Johnson et al. 2014, 2015)
    a. It is important to distinguish between pinyon-juniper woodland and juniper woodland, and to maintain healthy juniper woodlands and savannas on hill and toe slopes (Johnson et al. 2014, 2015).
    b. Refrain from removing large junipers in gray vireo nesting habitat (Johnson et al. 2014, 2015), and from removing cover needed for successful reproduction (Stake and Garber 2009, New Mexico Game and Fish 2016).
    c. Where feasible, initiate long-term restoration efforts in areas where large-scale pinyon die-offs have occurred (Pierce 2007)

2. **Identify and maintain occupied home ranges** (Latta et al. 1999, Winter and Hargrove 2004, Pierce 2007, GBBO 2010)
    a. Much more information is needed on the distribution and density of gray vireos, both within known centers of occupation, and across suitable habitats throughout the range of the species (Parrish et al. 2002).

3. **Maintain structural diversity in pinyon-juniper woodlands** (Latta et al. 1999, Gillihan 2006, GBBO 2010)
    a. Maintain undisturbed woodland habitat with a mixed size and age distribution of trees (Pierce 2007).
    b. In dense stands of young trees, create openings ≤ 60 ft. wide with irregular outlines to improve shrub and grass components (Gillihan 2006 citing Sedgwick 1987).
    a. Avoid over-thinning of juniper trees.[17] Pinyon-juniper thinning / removal projects would be most beneficial to gray vireos in areas where pinyon-juniper canopy closure exceeds 35%, potential for development of a desirable shrub understory is high, and potential for invasive weeds is low or manageable (GBBO 2010)
    b. Maintain a shrubby understory, especially in open woodlands on moderate rocky slopes (Latta et al. 1999, GBBO 2010).
    c. Maintain woodlands with large (12 in. diameter at root collar) trees scattered approximately 30/acre with 35% canopy closure, standing dead trees (10 in. diameter at root collar) 1/acre, and large downed trees (2/ac, 10 in. at root collar and 10 ft. long) (Gillihan 2006 citing Miller et al. 1999).

[17] Over-emphasis on juniper when thinning pinyon-juniper woodlands may adversely impact other bird species besides gray vireo (Wiggins 2005). E.g., Francis et al. (2011) documented 35 species nesting in New Mexico pinyon-juniper; 86% of nests were in juniper compared to 14% of nests in pinyon.

4. **Manage human use and disturbance**
    a. Limit collection of mature trees for fuelwood, and limit any tree harvesting to times outside nesting season (Latta et al. 1999, Gillihan 2006, New Mexico Game and Fish 2016).
    b. Avoid introduction of new infrastructure any closer to known nesting sites than existing infrastructure (Johnson et al. 2014).
    c. Discourage disturbances that may increase the presence of cowbirds (Latta et al. 1999).
    d. Invest in efforts to promote understanding of, and appreciation for, the variety of forms that healthy pinyon-juniper stands may take, and their importance to the native bird community (GBBO 2010).

5. **Fire is *not* recommended as a management tool in pinyon-juniper habitat** (Pierce 2007, Romme et al. 2009, Johnson et al. 2014, 2015).

## 7.6 Information Needs

1. Basic life history information, including breeding phenology, population dynamics (e.g., clutch size, fledging success, effects of brood parasitism, survivorship and recruitment, population trends), and migration routes is needed (Latta et al. 1999, Parrish et al. 2002, GBBO 2010).
2. Research on gray vireo habitat selection is needed, especially with regard to percent canopy closure, preferred density and species composition of the shrub layer (Latta et al. 1999, GBBO 2010).
3. Improved understanding of population trends and habitat threats (GBBO 2010).
4. Potential effects of fire and training activities on habitat quality and brown-headed cowbird parasitism.

# Shortgrass Prairie Ecosystem and Western Burrowing Owl

# 8 Shortgrass Prairie

## 8.1 Origins, Distribution, and Composition

### 8.1.1 Origins

Shortgrass prairie forms one component of the original expansive central North American grassland biome, with a composition and distribution that reflects its complex climatic and biogeographic history. The elevation of the Rocky Mountains and globally increasing aridity during the Miocene-Pliocene transition (7-5 million years ago) contributed greatly to the development of the east-west moisture gradient where, to the west of the 100$^{th}$ meridian, precipitation is limited by the rain shadow of the mountains, and prolonged drought is more frequent. This aridity probably led to the initial development of extensive grasslands, and consequent loss of forests in the Great Plains (Axelrod 1985, Engle et al. 2008).

After the initial development of Great Plains grasslands, climate fluctuations between cold glacial advances and warmer interglacials during the Pleistocene allowed the dominance of conifer and oak forests and woodlands throughout the region. The Great Plains were largely unglaciated, and grassland ecosystems persisted in reduced extent. Soils of unglaciated areas indicate the effects of these climatic cycles, with increased soil development during cool, wetter periods, and deposition of wind-blown sandy soil during warm dry periods (Muhs and Holliday 1995, Lauenroth et al. 2008). The treeless prairies that characterized the central plains regions before settlement are thus comparatively recent in origin, beginning to expand at about 10,000 years ago, and reaching maximum extent about 3000 years ago (Hart 2008). Grasslands generally occur in areas where there is at least one annual dry season and soil water availability is lower than that required for tree growth (Sims and Risser 2000). However, the widespread presence of small woodland stands of ponderosa, juniper, pinyon and oak on escarpments throughout the Great Plains implies that in most of the shortgrass prairie region climatic conditions remain adequate for tree growth (Wells 1965, Axelrod 1985).

### 8.1.2 Distribution

The Great Plains extends from the coastal plain of Texas north to Canada, forming the westernmost portion of the extensive lower mid-continental area between the Appalachians and the Rocky Mountains (Trimble 1980). Grasslands of the Great Plains range across a precipitation gradient from east to west, and a temperature gradient from north to south. Shortgrass prairie[18] is

[18]Some authorities in more recent work (e.g., Lauenroth and Burke 2008) use the term *steppe* instead of *prairie* to describe the shortgrass region, restricting the definition of prairie to those areas where conditions are sufficient to

characteristic of the warm, dry southwestern portion of the Great Plains, lying to the east of the Rocky Mountains, and ranging from the Nebraska Panhandle south into Texas and New Mexico (Figure 14). The high plains of the *Llano estacado* define the southern extent of the shortgrass prairie, bounded by escarpments formed in the Ogalalla Caprock (called the Mescalero escarpment to the west and the Caprock escarpment on the east). The eastern boundary of the shortgrass prairie is a fluctuating ecotone on the east-west precipitation gradient between short and midgrass prairie, defined by a transition area where precipitation is often insufficient to provide soil moisture for the taller grasses (Carpenter 1940, Sims and Risser 2000). The northern boundary represents the transition to cooler, more mesic mixed-grass types, generally occuring in southeastern Wyoming and southwestern Nebraska, although occasional shortgrass stands may be found further north. Lauenroth et al. (2008) place the northern boundary at the High Plains escarpment near the Colorado-Wyoming border.

The shortgrass prairie region covers about 34 million hectares in the western central and southern Great Plains, accounting for 11% of this central grassland region (Lauenroth et al. 2008). The largest remaining intact tracts of shortgrass prairie vegetation are in southeastern Colorado and northeastern New Mexico.

DoD installations within the range of the shortgrass prairie (Table 12) primarily lie within the western portion of the biome. Of these, PCMS and Fort Carson have the most significant extent of shortgrass; Pueblo Chemical Depot in Colorado and Melrose Range in New Mexico also have considerable acreage.

**Table 12. Extent of shortgrass prairie on DoD installations within the western Great Plains.**

| Installation | Approximate acreage of Shortgrass Prairie |
|---|---|
| Fort Carson Military Reservation | 48,135 |
| Piñon Canyon Maneuver Site | 170,826 |
| U.S. Air Force Academy | 10 |

### 8.1.3 Composition – Soils and Vegetation

Shortgrass prairie occurs primarily on flat to rolling uplands with loamy, ustic (dry, but usually with adequate moisture during growing season) soils ranging from sandy to clayey, at elevations generally below 6,000 feet. Organic matter accumulation in shortgrass prairie soils is primarily confined to the upper 20 cm (Kelly et al. 2008). The action of a freeze-thaw cycle on these grassland soils increases their vulnerability to wind erosion in late winter and spring (Pielke and Doesken 2008).

support continuous plant cover and the growth of mid-height grasses. We have chosen to retain the term prairie, in order to maintain a sense of connectivity and integration with other Great Plains grasslands.

Prior to European settlement, the shortgrass prairie was a generally treeless landscape characterized by blue grama (*Bouteloua gracilis*) and buffalo grass (*Buchloe dactyloides*). In much of its range, shortgrass prairie forms the matrix vegetation with blue grama dominant. Other grasses include three-awn (*Aristida purpurea*), side-oats grama (*Bouteloua curtipendula*), hairy grama (*Bouteloua hirsuta*), needle-and-thread (*Hesperostipa comata*), June grass (*Koeleria macrantha*), western wheat grass (*Pascopyrum smithii*), James' galleta (*Pleuraphis jamesii*), alkali sacaton (*Sporobolus airoides*), and sand dropseed (*Sporobolus cryptandrus*). Local inclusions of mesic or sandy soils may support taller grass species, including sand bluestem (*Andropogon hallii*), little bluestem (*Schizachyrium scoparium),* Indiangrass *(Sorghastrum nutans),* and prairie sandreed *(Calamovilfa longifolia).* Scattered shrub species, including sand sagebrush (*Artemisia filifolia*), prairie sagewort (*Artemisia frigida*), fourwing saltbush (*Atriplex canescens*), tree cholla (*Cylindroputia imbricata*), spreading buckwheat (*Eriogonum effusum*), snakeweed (*Gutierrezia sarothrae*), pale wolfberry (*Lycium pallidum*), and soapweed yucca (*Yucca glauca*), may also be present. Relative species dominance is variable from north to south and from east to west (NatureServe 2015). One-seed juniper (*Juniperus monosperma*) and occasional pinyon pine (*Pinus edulis*) trees are often present on shaley breaks within the shortgrass prairie matrix.
Grasslands in areas where mean annual temperature is above 10°C are generally dominated by grasses using the $C_4$ photosynthetic pathway, which are tolerant of warmer temperatures and more efficient in water use (Sims and Risser 2000). Species with $C_4$ photosynthesis are favored in conditions of high light intensity, high temperature, and limited water availability (Ehleringer 1978). In comparison to $C_3$ grasses, the relative productivity of

Lauenroth (2008) identified three primary shortgrass vegetation communities: blue grama dominated, blue grama and western wheatgrass dominated, and a blue grama with buffalo grass, alkali sacaton and/or galleta grass type. The two characteristic shortgrass prairie grasses, blue grama and buffalo grass, are low growing, perennial, grazing-tolerant, and clump-forming (caespitose) species that are well adapted to the relatively warm and dry conditions of the shortgrass prairie. Buffalo grass can spread by above-ground stolons, forming matlike stands, while blue grama reproduces by short rhizomes (tillering), or rare seed recruitment events (Lauenroth et al. 2008).

Soil moisture level is a key determinant in the distribution of shortgrass prairie, and is affected by precipitation seasonality, amount, and pattern. Soil water availability acts on both plant water status and nutrient cycling (Sala et al. 1992). Lauenroth and Sala (1992) reported that shortgrass prairie “forage” production (due largely to blue grama) is primarily controlled by annual and seasonal precipitation patterns instead of temperature. Blue grama is able to respond quickly to very small rainfall events, although this ability is apparently reduced during extended drought periods (Sala and Lauenroth 1982, Cherwin and Knapp 2012). Although blue grama exhibited extensive spread during the drought of the Dustbowl years (Albertson and Weaver 1944), repeated drought can also decrease the dominance of this species (Rondeau et al. 2013).
Blue grama and buffalo grass are somewhat different in phenology and reproductive adaptations. Buffalo grass flowers slightly earlier than blue grama (Dickinson and Dodd 1976). Although both species spread primarily through vegetative reproduction, seed production is also a source of new

individuals. Buffalo grass is dioecious (male and female inflorescences are borne on different plants); burs produced by female plants contain seeds of both sexes that may germinate at different times. Quinn and Engle (1986) suggested that this type of dispersal mechanism is well adapted for the colonization of semi-arid habitats with irregular rainfall events.

Seed production in blue grama is closely tied to soil type, especially silt content (Lauenroth et al. 1994). On soils with higher clay content, lower infiltration rates and higher water-holding capacity in the surface layers increase loss by evaporation in comparison to more coarse-textured soils. In the absence of direct removal of biomass by grazing, seed production was highest on coarse-textured soils (Coffin and Lauenroth 1993). However, blue grama recruitment events are most common on silty soils. Predictive modeling indicated that recruitment events occurred several times a century on silty soil types, in contrast to less than once in 5,000 years on sandy soils (Lauenroth et al. 1994). Although blue grama clones are long lived (up to 450 years under heavy grazing conditions), the interaction between soil type and precipitation patterns within the top 20-30 cm of soil is key to the persistence of blue grama (Lauenroth et al. 1994).

## 8.2 Primary Ecological Processes

### 8.2.1 Drought

Drought is a recurrent local and regional event throughout North America, as demonstrated by both historical instrumental measurement, and by other evidence from previous centuries. Multi-year droughts have occurred once or twice in a century in the Great Plains (Woodhouse and Overpeck 1998). Annual weather and longer-term climate patterns are critical drivers of ecosystem status and dynamics within the shortgrass steppe, and greatly influence vegetation production and composition (which can influence fire frequency and severity), soil stability and movement, hydrologic response, and surface water quality and quantity. Moreover, annual and longer-term weather can greatly influence the resistance and resilience of vegetation communities as a compounding or synergistic stressor or moderator. Shortgrass prairie is extremely resilient to drought. Drought in this region generally results in reduced production and changes in species composition during the short-term. Dominant species such as blue grama and buffalo grass may have reduced production and less common grasses and forbs may have very low production. Droughts lasting three or more years may result in some mortality of dominant grasses and other species. However, when a drought period ends, the relative species composition typically resembles pre-drought conditions within one to two years. Wet year periods can encourage the growth of weedy, early-seral annuals and biennials. Although the “Dust Bowl” is often considered a historic standard of major drought, events lasting three to four times as long dating back to at least the middle Holocene have been inferred from tree ring data, sediments, archaeological sites, and other sources (Diaz 1983, Holliday 1989, Woodhouse and Overpeck 1998).

Drought in the shortgrass prairie region can occur during any season, but generally has its greatest impact during the growing season, when most annual precipitation occurs (Woodhouse and Overpeck 1998). Although severe droughts are often accompanied by high temperatures, paleoclimatic data indicate that severe drought has also occurred with cold temperatures, resulting in different types of stress on ecosystems (Woodhouse 2004). Although causes of widespread and lengthy drought are not compeletly understood, they are likely due in part to large-scale, low-frequency ocean and atmospheric circulation patterns (Woodhouse 2004). It is when drought acts as a compounding and unpredictable agent with other ecosystem stresses that land management and training mission planners may need to respond to avoid long-term damage to the resource base

The incidence of drought accompanied by higher temperatures is a key determinant of the extent of sand dune activation in the Great Plains (Muhs and Holliday 1995). The extensive eolian sand deposits of the Great Plains, although at present largely stabilized by vegetation, are a sensitive indicator of climate trends.

Weather data from PCMS illustrates the variability and cyclic nature of drought and wet conditions over time. In this region, weather in any individual year seldom resembles the long-term averages (Figures 45, 46). For example, since acquisition, years with significantly below-average rainfall include 1989 and 2000-2003. Years between these dry periods were generally average to wet. Drought severity for the period from 1950 to 2008, which is related to annual precipitation totals by precipitation year (October-September), is shown in Figure 45. 1989 Palmer drought severity indices (PSDIs)[19] for the three Colorado climatic regions that converge near PCMS show some similar and dissimilar patterns. The periods of wetter and drier years for Colorado Climate Region 4, the Arkansas drainage mesas, appears similar to the patterns described by PCMS natural resources managers, with drought conditions occurring in 1989-1990, 2000-2003, and 2005-2006. Periodic drought is not uncommon, but the previous 4-year drought in the region prior to the 2000-2003 drought took place in the 1961-1965 timeframe, approximately 40 years earlier (Figure 46). Examination of the precipitation data from Trinidad, CO reveals that since acquisition of PCMS in 1983, there have been five average moisture years (value is within 10% of the long-term average), eleven above average years, and nine below-average years. While drought is sometimes described as cyclic, these cycles are highly unpredictable in frequency and duration.

[19] The Palmer Drought Severity Index (PDSI) quantitatively compares the actual amount of precipitation received in an area during a specified time period with the normal or average amount expected during that same period. Long-term drought is cumulative, so the intensity of drought during a point in time is dependent on the current weather patterns plus the cumulative patterns of the previous period. The Index is used widely by the U.S. Department of Agriculture and other agencies. PSDI values range between -4.00 or less (extreme drought) and +4.00 or greater (extreme moisture). The index uses a value of 0 as "normal". The Palmer Index is most effective in determining long term drought (i.e., at least several months).

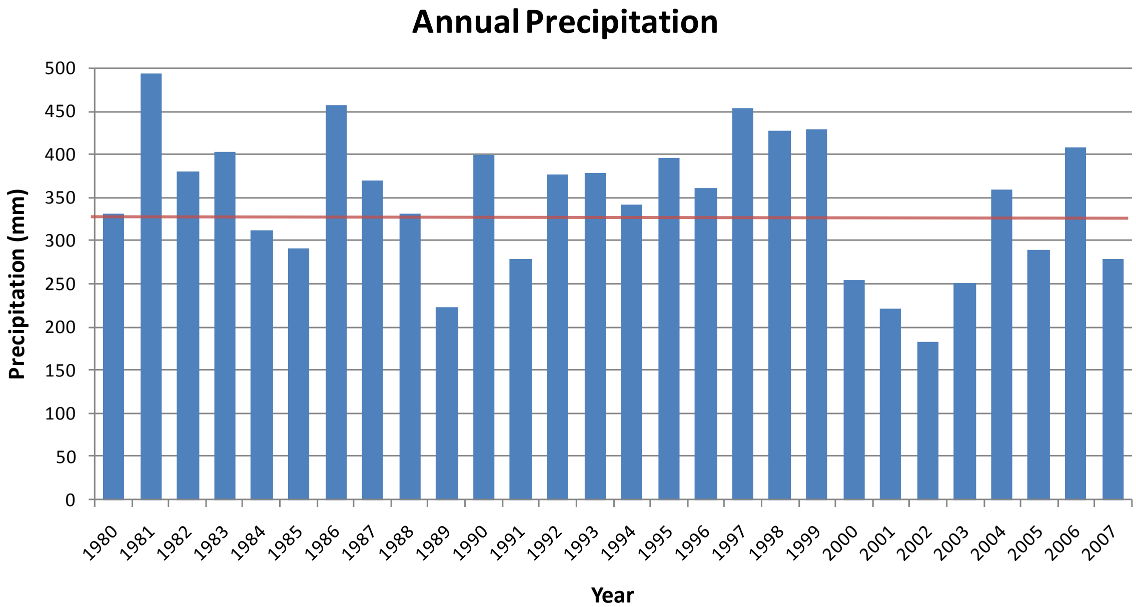



**Figure 45. Annual precipitation for the 1980-2007 period compared to the annual long-term average precipitation of 327 mm (1948-2005 period) shown by the horizontal red line.** Trinidad, CO data courtesy of NOAA).

## 8.2.2 Fire

The role of fire in maintaining herbaceous cover and suppressing woody vegetation is well demonstrated in most prairie types. Although fire is of somewhat lesser importance in shortgrass prairie compared to other prairie types, it is still a significant source of disturbance (Engle et al. 2008). Both flora and fauna of the shortgrass prairie are sensitive to the seasonality and frequency of fire (Ford and McPherson 1997). Large scale climatic conditions act to determine seasonality and frequency of wildfire on the shortgrass prairie, while extent and local fire effects are dependent on topographic and edaphic conditions. The xeric climate of the shortgrass reduces overall fuel loads, but also dries vegetation sufficiently for it to become flammable. The generally open, rolling plains and often windy conditions in the shortgrass prairie facilitate the spread of fire when fuel loads are sufficient (Axelrod 1985). Conversly, breaks and rocky areas that are protected from fire are able to support woody vegetation, even under the dry conditions typical of the region (Wells 1965). In burned areas, graminoids are better adapted than trees or shrubs to withstand the effects of fire. With growing points below or near the surface, grasses are well protected from the heat of most fires, and are able to resprout and regain dominance.

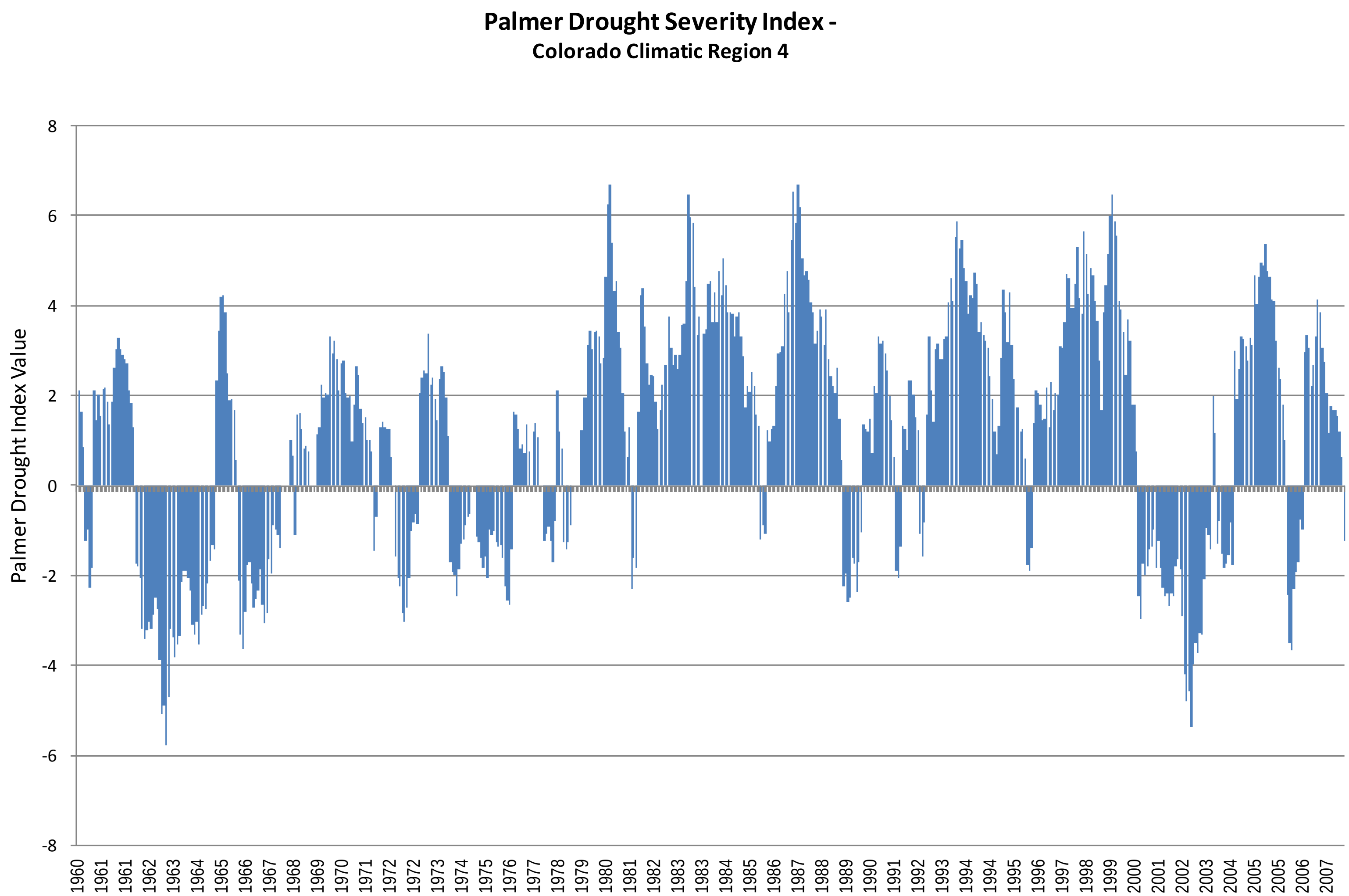



**Figure 46. Palmer Drought Severity Index from 1960 to mid-2008, based on a regional drought summary prepared for Colorado Climate Region 4 (Arkansas Drainage Mesas).** Data provided by Colorado Climate Center - http://ccc.atmos.colostate.edu/drought.php). Negative values represent drought conditions and positive values represent moist conditions.

The general lack of trees bearing fire scars has made it difficult to reconstruct the historical importance of fire in the shortgrass prairie (Wright and Bailey 1980, Ford and McPherson 1997). Annectodal accounts of historical fires were provided by early explorers and settlers, but these typically focus on especially large or destructive events (Ford and McPherson 1997). Large fires were often reported in drought years that followed several years of above average precipitation during which higher fuel loads accumulated (Wright and Bailey 1980). Some historic fires burned wide paths of 30-50 miles or more in length, scorching extensive tracts of shortgrass prairie (e.g., Ray 1906, West Texas Historical Association 2006). Under current conditions, most fires are stopped by roads. In addition, fire suppression and grazing patterns in the region have likely decreased the fire frequency even more (Brockway et al. 2002, Freilich et al. 2003), and it is unlikely that these processes could now occur at the previously natural scale.

Compared to mid- or tallgrass prairie, the fire ecology of shortgrass prairie is generally lacking longer term studies (Brockway et al. 2002). Furthermore, many studies are focused on the interaction of fire with forage production for domestic livestock. However, the response of shortgrass to burning is different than that of the more mesic prairie types, in that post-fire productivity of grasses is not generally increased, and forb cover may be enhanced (Scheintaub et al. 2009). The suceptibility of shortgrass prairie vegetation to fire, and its abilty to recover from burning, are closely tied to both inter-and intra-year variation in precipitation (Ford and Johnson 2006, Augustine and Milchunas 2009, Scheintaub et al. 2009). In wet years fuels build up, allowing fire to carry in subsequent dry years. Recovery of prairie species by regrowth or seeding depends on appropriate moisture conditions following fire, as well as a persistent seed bank or nearby source.

The natural fire regime of the shortgrass prairie has been altered by livestock grazing and fire suppression, leading to changes in structure and species composition (Brockway et al. 2002). Increased growth of woody species has been observed in some areas, and may be a result of the legacy of grazing and fire suppression (Brunelle et al. 2014).

Historical fire data from PCMS were examined to help understand drivers and effects of the current fire regime and implications for management. Several fire regimes predominate within PCMS. The grasslands were a replacement severity, moderately high frequency regime where fires generally remove all or most above ground biomass every 20 to 30 years. Because of the dearth of fire-scar records for the grassland and mixed shrubland communities, there is some disagreement regarding the presettlement fire regime. Upland sites where pinyon-juniper occurs are more complex, but generally experienced a low to moderate severity, moderate to low frequency fire regime where fires returned every 50 to 150 years. There were also pockets of low severity, high frequency fires in the southernmost portions of the installation, and significant low to moderate severity, low to moderate frequency regimes in the vegetation along the rivers and streams (LANDFIRE 2008). The vast majority of PCMS falls into fire regime condition class (FRCC) 1, meaning there has been little departure from the historic fire regime, though patches of high departure exist, usually in the pinyon-juniper vegetation type (LANDFIRE 2008). This reflects the fact that the vegetative communities have remained largely intact, despite a century of aggressive fire suppression. However, FRCC is based on vegetation metrics, rather than on the occurrence or absence of fire, and there are some indications that there has been a shift to a lower fire frequency. One indicator is the encroachment of woody species into areas previously dominated by grasslands. Pinyon-juniper woodlands and forests that are removed by fire are nearly impossible to re-establish naturally. Although the reasons for this phenomenon are not fully understood, contributing factors may include changes in microclimates and establishment sites, moisture availability, and seed sources. This vegetation type is important for tactical concealment and important habitat for many wildlife species, and is therefore a priority area for fire suppression.

Weather plays a major role in fire behavior and climate largely determines the fire regime. At PCMS, moisture availability and winds are the major drivers of both the fire regime and fire behavior. The semi-arid climate limits vegetation growth, with pulses of moisture in wet years producing large increases in production of annual and perennial biomass. This increased vegetation production can become a fuel management problem if a wet year is followed shortly by a dry one, or even during a short period of dry weather. Because fire development is largely governed by fine fuels (also known as 1 hour fuels), which are abundant at PCMS and absorb and release moisture rapidly, even relatively short periods of dry weather can result in high fire danger.

Drought is a major factor in the occurrence and severity of fire in all of the communities represented at PCMS. Drought conditions exacerbated the severity and size of the 2008 Bridger fire on PCMS. Foehn or Chinook winds (dry downslope winds which occur in the lee of a mountain range) are only occasionally experienced. Because of the heating experienced by the air during these events, these winds are not only strong, but hot and very dry. Fires starting during Foehn winds are likely to spread rapidly and produce severe fire behavior.

In some ways, fire and grazing pressure can have similar effects on graminoid cover and structure, as they both can, when accompanied by adequate precipitation, can promote vigorous stands of native perennial grasses, high basal cover, and vegetation diversity at community to landscape scales. However, fire that is too frequent or intense can stress native plant communities, lead to mortality, and alter community structure. For example, short fire return intervals in shrublands can lead to significant shrub mortality and result in a type conversion to grasslands.

***Installation Management for this Threat***

All installations have wildland fire management programs to reduce the likelihood of large, uncontrolled fires from escaping training lands, protect life and property and comply with DoD and Service Branch requirements. Prescribed fire is frequently used as a management tool by resource managers. The following discussion pertains to Fort Carson and PCMS. Areas targeted for prescribed burns include small arms ranges, other grassland habitats, and pinyon-juniper woodlands. Managers note that within small arms range fans, ignitions can still occur the year following prescribed burning, but the fires are more easily managed. In the few cases where a wildland fire burned into an area that had been prescribed burned, fire control may be easier. Burn plans are developed annually by resource managers and are approved by the Fort Carson Fire

Department. The annual plans include all required components and conform to National Wildland Coordinating Group standards. Smoke permits are obtained from the Colorado Department of Public Health and Environment. Because each plan covers many burns, prescription windows are relatively large. A prescribed fire management plan that will address ecological aspects of prescribed fire is currently in development.

The current target for fire-return interval on Fort Carson/PCMS grasslands is about 10 years, depending on drought conditions. In consecutive years of drought, the target for fire return interval may be closer to 15 years. On-the-ground prescriptions should be flexible and consider weather/climate cycles (drought conditions or a wet period), composition and current plant vigor (James Kulbeth, pers. comm.). Currently, prescribed burning at Fort Carson and PCMS focuses on the range SDZs where most fires ignite and burn and the installation perimeters. There is interest in more discussion and possible use of burning in other areas to promote ecological/conservation goals (James Kulbeth, pers. comm.), with the idea that ecological-based burning at larger landscape scales could reduce fuels and the risk of large and severe fires, while promoting native grass vigor. This could be part of a larger program to improve range condition and increase resilience, especially to buffer effects of extended/severe drought. State smoke regulations and permitting are a constraint to burning of grasslands and woodlands, making it harder to do more small burns vs. occasional larger burns (Jason Zayatz, pers. comm.).

Detailed fire history data was not available for Fort Carson. The following synopsis of wildfires on PCMS was provided by Mead Klavetter, and is excerpted here from Doe et al. (2008). There seems to be no formal documentation available for fire occurrence in the 1980s. Fires probably occurred regularly in the range of tens to hundreds of acres. No recollections of larger fires (thousands of acres) were made by Fort Carson/PCSM staff. Fires in the early 1990s were not uncommon and seemed smaller than those in the 1980s. Partly because the 1990s was a relatively wet period and there was often a troop rotation on site to provide firefighting support, fires were regular but fairly small (up to hundreds of acres). During the period from 2000 to the present, fires were still fairly common when conditions favored ignitions and a higher number of larger (2,000-3,000 acre) fires occurred. The larger fires on PCMS may be attributed to many factors, including drought, limited firefighting resources on site, high fuel loads, and ignitions occurring when burning conditions were ideal (red flag warning and high Haines index). Heavy fire seasons on PCMS often coincided with heavy fire activity in Colorado and in the west in general. Examples of larger fires that took place on PCMS during this period include the 2001 Four Corners fire (2500-3000 acres), the 2002 Bent Canyon Fire (2,500 acres), and the 2008 Dillingham fire (3,474 acres). The 2008 Bridger Fire (46,000 acres) was an order of magnitude larger than previous fires on PCMS since acquisition. As with many fires in arid western lands, the Bridger fire was driven largely by extreme weather and corresponding low fuel moistures, which contributed to numerous fires on lands surrounding PCMS (Mead Klavetter, personal comm. August 2008). In some areas that have burned repeatedly in recent history, relatively high fire frequency coupled with precipitation levels insufficient for vegetation regrowth has produced large areas of exposed soil, with subsequent erosion (James Kulbeth, Natural Resources Specialist, personal communication).

### 8.2.3 Grazing

Grazing is one of the predominant land uses in the region, and the quality of grazing management can vary hugely among ranches and pastures. Cattle and sheep grazing were the dominant land use at PCMS until acquisition in 1983, and cattle grazing also occurred at Fort Carson until 1972. Grazing was likely also present to some degree at AFA prior to acquisition. There is some grazing and browsing by elk, deer, pronghorn, and other animals, but at pressures well below those exerted by bison or livestock. Given that this system evolved with large ungulates, moderate grazing generally has positive ecosystem effects, including maintenance of vigorous bunchgrass communities and vegetation diversity. The distribution of grazing across the landscape was probably more uniform during presettlement times. Historic grazing was more concentrated near water sources, and often led to localized degradation of soils and vegetation, weed invasion, degradation of riparian vegetation, and impacts to water quality.

Shortgrass prairie developed in the presence of large grazers, especially bison, and grazing is still the primary land use for most remaining shortgrass tracts. A voluminous, ongoing, and sometimes contentious literature on the effects of domestic livestock grazing in grasslands has generally failed to settle the question of whether or not cattle mimic the effects of native herbivores in the functioning of grassland ecosystems (Ellison 1960, McNaughton 1983, Belsky 1986, Milchunas et al. 1999, Fleischner 1994). The question of grazing effects is further complicated by the several orthogonal perspectives represented by researchers, namely, management for livestock production, management for natural ecosystem biodiversity, or basic research on community ecology.
The overall species composition of shortgrass is influenced by grazing. Early range management principles were based on the recognition that livestock grazing pressure tended to lead to the replacement of one type of plant cover with another (Sampson 1919), and that the total amount of forage available to livestock (i.e., range condition) could also be influenced by grazing history (Humphrey 1947, Ellison 1960). The classification of plant species by their response to grazing (i.e., increasers vs. decreasers) was first outlined by Smith (1940), further developed in subsequent years (e.g., Weaver and Hansen 1941, Dyksterhuis 1948), and remains in use today, with the caveat that the exact behavior of a species under grazing is not a purely inherent trait, but depends on site factors as well (Vesk and Westoby 2001).

Blue grama is considered tolerant of grazing, generally increasing under grazing except at the highest intensity (Anderson 2003), and buffalo grass is highly tolerant of disturbance, including heavy grazing (Ring et al. 1985, Hart 2001). There is some evidence that the dispersal of both species is facilitated by large herbivore grazing (Quinn et al. 1994). Where bluffs, breaks, or swales provide refuge from grazing, plant species that are rare in adjacent grazed areas become more common (Milchunas and Noy-Meir 2004).

Effects of livestock grazing in shortgrass are not limited to changes in species composition, but can also impact ecosystem structure and function by changing litter accumulation rates, increasing soil compaction or erosion, decreasing moisture infiltration and removing biological soil crusts

(Fleischner 1994). Ancillary effects from livestock ranching (summarized by Freilich et al. 2003) in the shortgrass prarie include the disruption of the historic foodweb through removal of "problem animals" (e.g., wolves, bears, coyotes, prairie dogs, raptors, snakes) or biomass removal that eliminates resources for scavengers and decomposers. Fencing and roads associated with ranching have greatly fragmented the shortgrass prairie habitat, and allowed the invasion of exotic species.

### 8.2.4 Small-scale Disturbances

Soil disturbance is a naturally-occurring element in the shortgrass steppe. Small-patch sources of disturbance in shortgrass prairie include small animal burrows (e.g., skunks and badgers), western harvester ant (*Pogonomyrmex occidentalis*) mounds, and fecal pats of domestic cattle (Coffin and Lauenroth 1988). Disturbances at this scale can be important in the persistence of non-dominant species, as well as the the population dynamics of the characteristic grasses. Larger but localized disturbance is also produced by colonies of burrowing animals (black-tailed prairie dogs, *Cynomys ludovicianus*).

Preferential grazing of blue grama by prairie dogs can favor buffalograss in prairie dog "towns," and alter plant species composition in general (Bonham and Lerwick 1976). There has been disagreement about the role of prairie dogs as a shortgrass prairie keystone species, as well as controversy over the accuracy of estimates of prairie dog numbers prior to settlement. Vermeire et al. (2004) suggested that even more conservative estimates of area occupied by prairie dogs were reflective of artificially high population numbers due to human activities during the late 1800s. Forrest (2005), however, counters that even the high population numbers of the late 19$^{th}$ century may well be within the natural range of variation for these animals adapted to a dynamic and fluctuating environment. Controversy aside, it is generally acknowledged that area occupied by prairie dogs has declined over the past century to an extent that these animals are no longer acting in the same evolutionary and ecological function as previously obtained (Miller et al. 2007). Prairie dog towns are a key ecological resource for persistence of the black-footed ferret (*Mustela nigripes*), mountain plover (*Charadrius montanus*), and burrowing owl (*Athene cunicularia*).
Although the shortgrass prairie vegetation we see today has been shaped by these and other disturbances, changes in the physical and biological environment of the region over the past century may alter the impacts of these factors in the future (Ford and McPherson 1997).

### 8.2.5 Military Training Disturbance

Military training impacts include soil compaction and loss, reduced hydrologic/site stability associated with vegetation loss and soil disturbance, reduced infiltration and increased runoff, increased fire frequency from military ignition sources, and damage to native vegetation, including promotion of weed establishment through soil disturbance and seed transport. The most significant sources of damage to upland vegetation are off-road vehicle maneuvers and administrative/support activities. In terms of maneuver damage, tracked vehicles are responsible for the majority of damage, but significant disturbance can also result from wheeled vehicles, especially during wet soil conditions when rutting is more likely.

Numerous studies have documented the effects of tracked vehicles on soils and vegetation in military training areas (see reviews in Anderson et al. (2005) and Guretzky et al. (2005)). However, more information is needed on vegetation response and recovery rates following military disturbance in shortgrass steppe environments. Military vehicle traffic impacts to soil physical properties include increased bulk density (soil compaction), decreased surface soil strength, and decreased hydraulic conductivity (Braunack 1986, Thurow et al. 1995). Soil compaction affects erosion potential by altering the stability and size distribution of soil aggregates, and increasing soil bulk density and penetration resistance (Thurow et al. 1995, Gatto 1997). The susceptibility of a soil to compaction is primarily a function of soil moisture, texture, and organic matter (Koolen 1987, Unger and Kaspar 1994). Loamy and clayey soils and soils with a mixture of particle sizes are more susceptible to compaction than sandy soils (Webb 1982, Unger and Kaspar 1994). Increases in soil bulk density and penetration resistance are generally minimal at the surface, where recovery is more rapid, but are more pronounced and may persist for longer periods at depths ranging from 10-50 cm (Prose 1985, Gatto 1997). Braunack (1986) found that the magnitude of tracked vehicle impact was dependent on the soil type, number of passes, and whether the vehicle was turning or traveling in a straight line. These changes in soil physical properties can increase interrill erosion rates on western rangelands (Thurow et al. 1995). Soil property changes may also retard or prevent reestablishment of the original plant communities (Shaw and Diersing 1990). Impacts to soils from a single tank pass may persist for decades in fragile ecosystems (Prose 1985). Weakened soil aggregate stability and disturbance to microphytic soil crusts following vehicle maneuvers can also increase wind erosion potential (Grantham et al. 2001, Belnap et al. 2007). Soil moisture conditions at the time of tracking can influence the post-tracking hydrological characteristics of soils (Thurow et al. 1995, Halvorson et al. 2001, Jones 2003, Althoff and Thien 2005), with higher indices of compaction associated with moist soil conditions.

Tracked vehicle damage to vegetation includes crushing and shearing of above-ground plant parts and damage or destruction of roots and other below-ground structures. Vegetation loss may be influenced more by shearing forces exerted by the vehicle on the soil surface than by soil compaction caused by ground pressure forces (Ayers 1994). Military vehicle impacts to vegetation communities include decreased woody plant density and canopy cover (Wilshire and Nata 1976; Jones and Bagley 1998; Watts 1998), loss of native bunchgrasses (Thurow et al. 1995, Jones and Bagley 1998, Watts 1998, Jones 2003), an increase in non-native annual grasses and forbs (Goran et al. 1983, Shaw and Diersing 1990, Thurow et al. 1995, Watts 1998, Jones 2003), and decreased plant diversity (Lathrop 1983). In a shrub-grassland community in southeastern Colorado, Milchunas et al. (1999) found that increasing disturbance by tracked vehicles was associated with reduced vegetation basal cover and litter ground cover, and the replacement of long-lived perennials with short-lived perennials. In a southeast Montana rangeland community, Leininger and Payne (1980) found that off-road traffic in moist soil conditions resulted in significantly more vegetation damage than in drier conditions. However, in a study in a central Texas grassland, Thurow et al. (1995) found that reduction of late-succession bunchgrass cover was related to the number of passes and was not affected by soil moisture status at the time of vehicle tracking. Similar results were reported for wet tracking treatments in sagebrush steppe at Yakima Training Center using M1A1 and M2A2 vehicles (Jones and Bagley 1998). Damage to vegetation and biological crusts from tracked vehicle neutral-steer turns (i.e., severe scraping, rutting, and mounding) is generally more severe than damage resulting from straight-line travel (Watts 1998; Haugen et al. 2003).

Disturbance to native vegetation may lead to the establishment of non-native species that out compete native species for resources such as physical space, moisture, nutrients, and sunlight. Where non-native annual species colonize disturbed areas, the lack of year-round foliage results in poor, short-term soil surface protection. Site conditions may become more extreme (i.e., elevated temperatures and more xeric) due to reduced microclimatic influences of larger perennial vegetation thus inhibiting germination and establishment of some species (Wight et al. 1991). In a study at Fort Hood, TX, repeated military tracking resulted in significant shifts in herbaceous communities from relatively large perennial plants to relatively small stature annual plants. Woody species composition was relatively unchanged but density and cover were significantly reduced (Severinghaus et al. 1981). Although total plant cover may recover to pre-disturbance levels, species composition may significantly shift from native perennial species to invading early successional species (Jones 2003). In many cases, annual plants provide reduced above and below-ground structure, groundcover, and soil stability compared to larger perennial plants. Loss of vegetation also increases erosion rates due to decreased rainfall interception and lower infiltration rates.

Based on observations at Fort Carson, CO, Goran et al. (1983) hypothesized that semi-arid vegetation communities appear to have a lower tolerance to military disturbance than either the more xeric shrublands of installations in Texas and California or the more mesic grasslands and woodlands of installations in the eastern U.S. This low tolerance may arise from several factors, including narrow ecological tolerance ranges of native plants near the edge of their geographic range, and susceptibility to weed invasion following disturbance. The response of shrub communities to disturbance is highly influenced by the adaptations of individual species (e.g., sprouting ability). An analysis of RTLA data by Milchunas et al. (1999) concluded that plant communities at semi-arid Fort Carson appear highly resistant to vehicle disturbance, but show low resilience once the community is altered beyond a particular ecological threshold. Once initiated, shifts in community composition may take decades or longer to return to the original vegetation, or may result in alternative potential communities.

Although M1A1 tanks have been referred to as 60-ton non-selective grazers, there are important differences between maneuver training disturbance and the disturbance associated with large grazers such as cattle. Grazers remove only the aboveground plant portions; roots and the apical meristem, which is just above ground level and where new leaf growth originates, are left intact. This promotes growth and increases basal area of dominant shortgrass prairie species over time. In contrast, maneuver vehicles can remove the above ground plant portions, including the apical meristem, and often also disturb below ground plant portions. This results in plant mortality or a loss of basal area, loss of storage organs, the ability for a plant to spread vegetatively (i.e., tiller), and can lead to reduced resistance to weed invasion. Both vehicles and cattle compact soils to some degree, and both disturbances are relatively indiscriminate, although cattle have some species preferences and tanks have some topographic and vegetation structure preferences. Disturbance effects of cattle and tanks can sometimes be similar at low maneuver training intensities, where little meristem and belowground damage occurs, and disturbance is spread fairly uniformly over the area. In practice, this rarely occurs, and training disturbance tends to push communities toward earlier seral states, while grazing tends to favor healthy stands of later-seral shortgrass prairie dominants. Disturbance effects of cattle and tank are most dissimilar at high maneuver intensities, where there is considerable rutting, shearing, neutral-steer turning, and corresponding plant mortality and damage to meristems and belowground plant portions.

Multiple stressors can have compounding (concurrent) or cumulative effects. There is considerable uncertainty about how ecosystems, communities, and species may respond to multiple stressors, and the thresholds for damage associated with the resource and the stressors. Severe grazing during drought periods can lead to grass mortality, as can drought in associated with grub worm and other localized insect infestations. Following drought, moderate grazing can help stimulate recovery of native grass basal cover and production levels. In grasslands, fire is typically not a stressor concurrent with other stressors such as drought, soil disturbance, and livestock grazing, since these latter agents significantly reduce fuels loads essential to carrying fire. However, when they do occur, fires following extreme drought can stress vegetation, result in some grassland plant mortality, and reduce production. Heavy training disturbance coupled with drought may compound damage. This latter scenario has not occurred to a significant degree on Front Range installations in recent years.

Our understanding of how maneuver lands in shortgrasss steppe may respond to multiple simultaneous stressors (i.e., drought, nonnative invasives, and increased training loads) is imperfect. Higher post-deployment training loads and restationing actions could result in more training rotations that are more frequent and of longer durations than historic training rotations.

### 8.2.6 Generalized Conceptual Ecological Model for Shortgrass Prairie

The previous sections described the biotic and abiotic drivers affecting the shortgrass prairie system. At more local scales such as at the installation scale, these dynamics can be represented as management-oriented conceptual models, also referred to as state-transition-threshold or state-transition models (STMs). STMS are a critical tool for adaptive management. Once the primary ecological communities of interest and other priorities are known, the process of understanding the important elements and processes begins. Although they are simplifications of the real world, models can capture relationships that are the basis for predicting changes in our management goals or conservation targets over time. Conceptual ecological models can be created for a variety of conservation targets, including individual or groups of species, vegetation community types or assemblages of community types. The type of model constructed depends on the scientific questions asked, goals and objectives of the project, and characteristics of the conservation targets at the site (Poiani 1999). Models developed help determine specific management and monitoring goals and objectives, support the selection of specific attributes or indicators, and provide a framework for interpreting monitoring results in an adaptive management context and prioritizing management actions. They can also help identify thresholds of condition that may be difficult or impossible to reverse.

Different communities have varying abilities in terms of resistance and resilience. These properties influence stability and persistence of these plant population assemblages through time. Resistance has been described as the ability of a system or population to remain essentially unchanged despite disturbances (i.e., how sensitive is it?). Resilience is the ability of a system to recover after disturbance and return to its original state (Holling 1973, Grimm et al. 1992). However, the degree of resilience exhibited may sometimes be masked by normal fluctuations within the system (Noy-Meir and Walker 1986). Approximately 90% of grassland plant biomass in the shortgrass steppe is below ground - this system is adapted to be conservative in response to drought conditions. It is somewhat resistant and resilient to low levels of vegetation removal disturbance. However, it is poorly adapted to intensive soil-disturbing activities that damage plant growth and storage organs. Heavy levels of soil disturbance can therefore cause major shifts in community composition and reduce watershed function.

For arid and semiarid systems, state-transition (also known as state-transition-threshold) models are often applied (Westoby et al. 1989, Stringham et al. 2001, Bestelmeyer et al. 2003). State-transition models are widely used by the Natural Resources Conservation Service (NRCS), often in the context of grazing management, but they are useful in a wide variety of management settings. Under this model, plant communities or ecosystem types are grouped into “states” that are distinguished from other states by large differences in plant functional groups, ecosystem processes, and the resultant characteristics, including management requirements. Transitions are the shifts between states caused by internal and external factors including natural phenomena (e.g., weather, fire, weed invasion), management actions (e.g., grazing, training disturbance, revegetation), or a combination of both. Some transitions are difficult to reverse through natural processes, and these thresholds of condition that delineate irreversible damage are highlighted in these models. The primary systems that are actively managed and provide important training environments include grasslands and juniper-pinyon woodlands.

We explored possibilities for building on existing published STMs in order to make them more broadly applicable to military land managers on the Front Range. An example was developed using one of the more common ecological units found on Fort Carson and PCMS. The Loamy 10-14” ecological site (Ecological Site R069XY006CO, MLRA 69 – Upper Arkansas Valley Rolling Plains) occupies the largest acreage of any ecological site at both Fort Carson and PCMS. This ecological site is found on loamy soils within the 10-14” precipitation zone, occurs on nearly level to gently-sloping plains, and occupies approximately 32 percent (~74,00 acres) of PCMS and 22 percent (~33,000 acres) of Fort Carson. The type dominates in the rolling uplands often favored for vehicle maneuvers. The published STM for the Loamy 10-14 PZ ecological site is shown in Figure 47.

The STM for the same type was broadened and enhanced to accommodate a wider set of conditions and management scenarios and incorporates military and non-military drivers, site-specific considerations, and input from local military resource managers (Figure 48). Although livestock grazing does currently occur on these military properties, it is included in the STM nonetheless as a potential drover that could be used as a management tool. Military disturbance is introduced as a new driver, and additional states and communities have been added to represent a wide range of conditions found on the landscape and as a result of different disturbances or conditions. Simplified fire regimes that are more detailed than those included in the original published (e.g., fire vs. no fire) model are incorporated as well as are additional pathways related to undesirable weedy states and early seral scenarios.

Whereas traditional concepts hold that a given vegetation type or ecological site has a single "climax" end state, with linear movement in either a forward successional direction or backwards in retrograde, more recent ideas promote the concept of multiple steady states. A number of studies have found that, following removal of heavy livestock grazing on arid and semiarid rangelands, vegetation often changes little, does not change in the predicted direction, or increases in quantity without changes in species composition (results summarized by Westoby et al. 1989). Vehicle training disturbance has been described by some as nonselective grazing, and in fact exhibits some characteristics of grazing through the removal of biomass and soil disturbance. However, the distribution of vehicle maneuver disturbance tends to be less uniform than the distribution of livestock across the landscape, and where it occurs, disturbance severity often exceeds disturbance associated with grazing.

Understanding the ecosystem dynamics of the training landscape is crucial to understanding and planning stewardship activities and sustainable training. Moreover, by examining the role of ecosystem processes and drivers, a better understanding of the complexity of the system is possible. The three primary natural drivers of the shortgrass steppe ecosystem are the semiarid climate, grazing, and fire. A fourth driver, military training disturbance, is also an important driver, predominantly at localized scales, that influences ecosystem dynamics. Military training disturbance can be an important driver at the site scale, but current training doctrine and intensities are not generally having landscape-scale impacts, perhaps with the exception of accelerated weed spread. High fire frequency in range areas is an example of training activities promoting a more natural ecological dynamic.

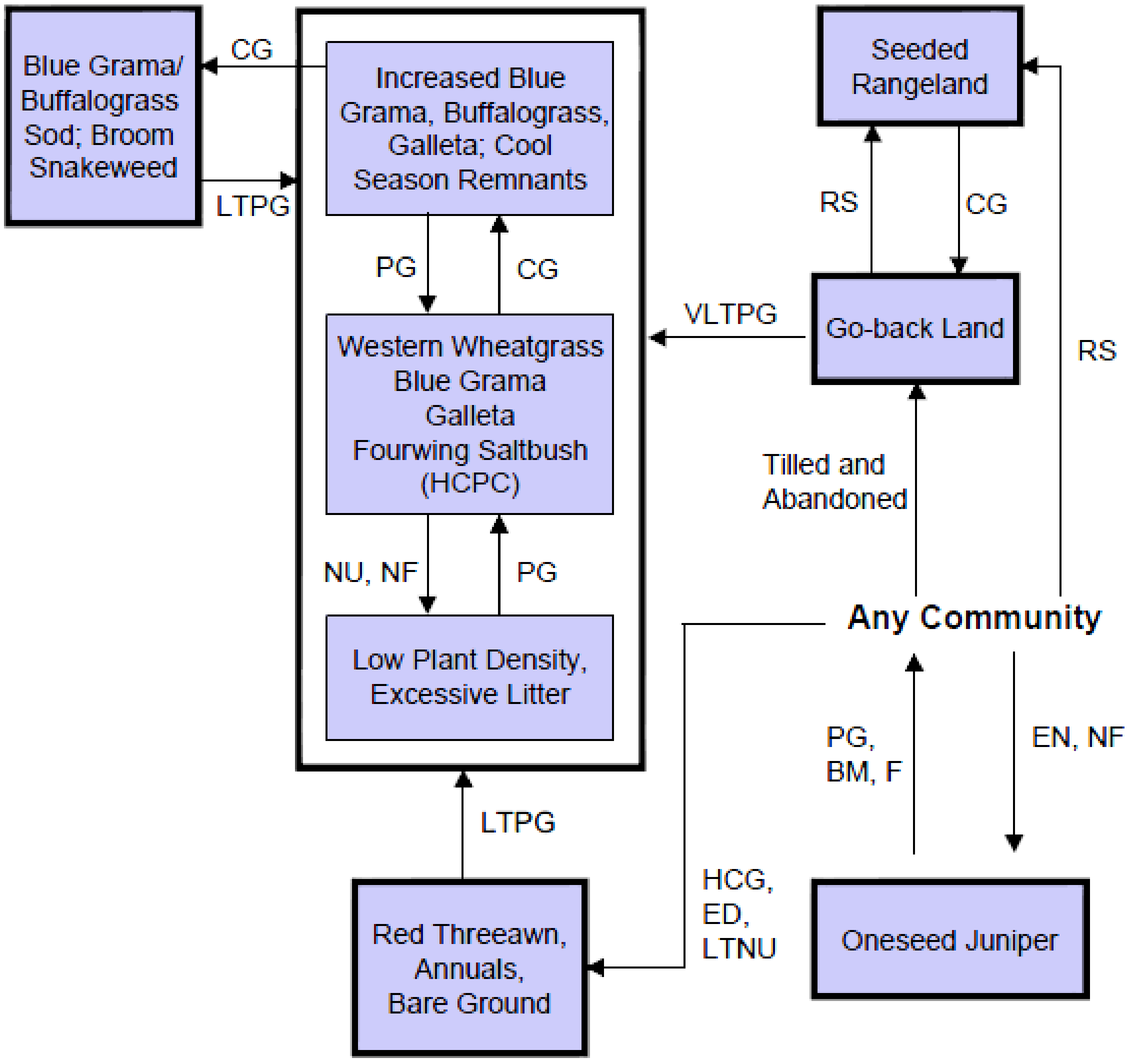
Alteration of these drivers is another form of threat to the system. A few critical questions help us understand the current condition of the landscape within the context of the state-transition models (e.g., Figure 47), the possible repercussions of different stressors/drivers and management activities (both strategies and techniques) on habitats and species of concern, and implications of changes to the system on military training environments. For example:

1. Are all the major drivers present and within their historic range of variation?
2. Are other undesirable drivers present?
3. Which ecological states favor or threaten individual priority species, groups of species, or certain training environments?
4. Which ecological states or communities favor or potentially constrain different of critical training missions?

The influence of grazing, fire, drought, military and other disturbances is summarized in the conceptual model presented in Figure 48 for one of the predominant ecological sites found at PCMS. Whereas heavy soil disturbance is the primary driver of the early seral plant communities (early seral A, B, and C), grazing is historically the most important driver of the mid- to late-seral grassland communities (grassland A, B, and C). Grasslands A, B, and C can be loosely described as ungrazed, lightly grazed, and moderately grazed grasslands, respectively. Heavy grazing tends to push the grasslands to a sod-dominated state that is not currently represented at PCMS.

Site Type: Rangeland — Loamy
MLRA: 69 – Upper Arkansas Valley Rolling Plains — R069XY006CO

**Plant Communities and Transitional Pathways**




**BM** - brush management, **CG** - continuous grazing w/o adequate recovery opportunity, **ED** - excessive defoliation, **EN** - encroachment, **F** - fire, **HCG** - heavy continuous grazing (>30 yrs), **HCPC** - Historic Climax Plant Community, **LTNU** - long term non-use (>20 yrs), **LTPG** - long term prescribed grazing (>40 yrs), **NF** - no fire, **NU** - non use, **PG** - prescribed grazing with adequate recovery period, **RS** - range seeding, **VLTPG** - very long-term prescribed grazing (>80 yrs)

**Figure 47. State-transition model for the Loamy 10-14" PZ Ecological Site (NRCS, 2004), as published.**

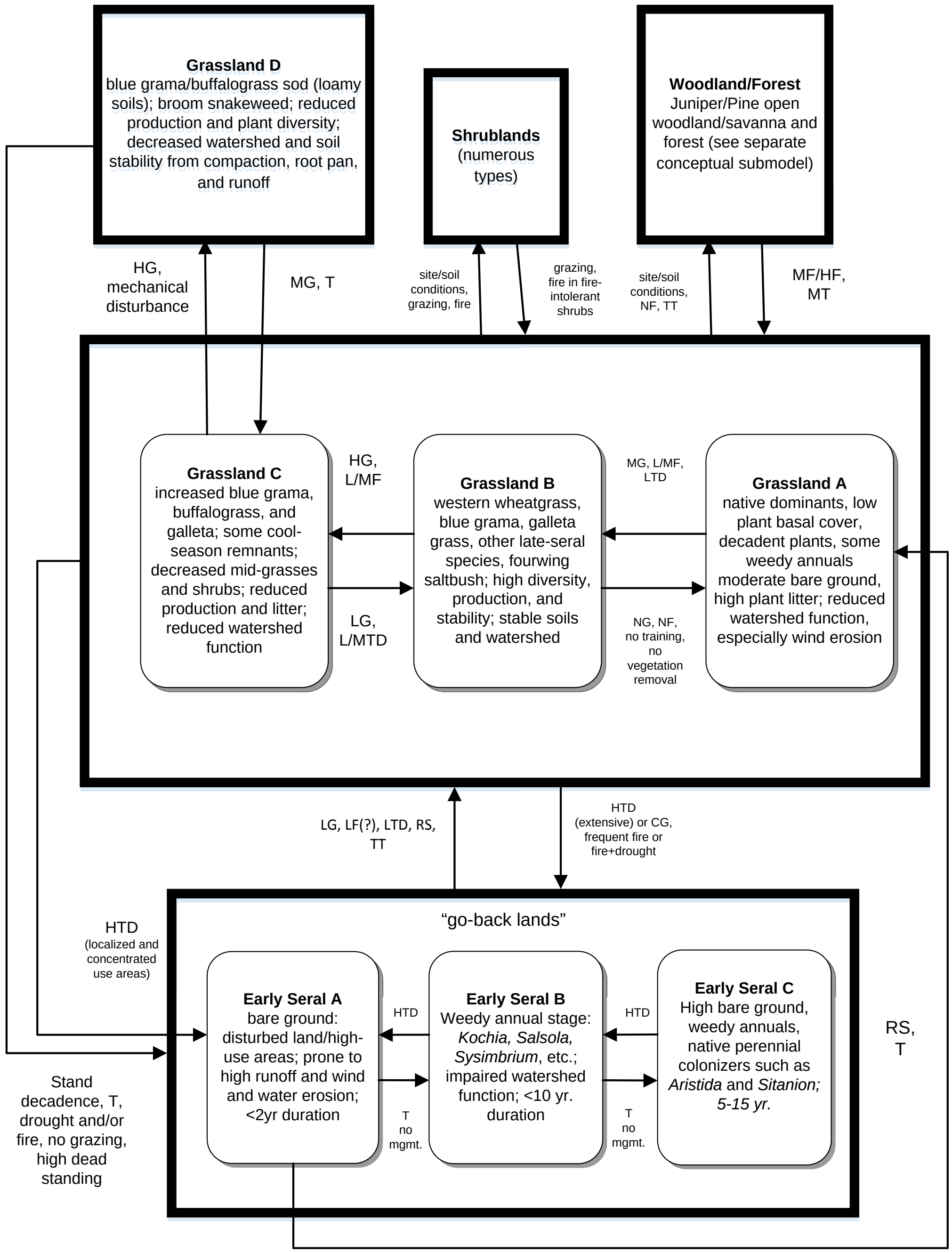



**Figure 48. Generalized state-transition model for portions of the upland shortgrass prairie ecosystem at Pinyon Canyon Maneuver Site and Fort Carson.** Bold boxes represent ecological states; smaller boxes within bold boxes represent communities within a state. Arrows represent drivers that can move a stand from one community or state to another. All communities can be converted to "go-back" lands or Early Seral A via intensive disturbance. Key to drivers: LTD=light training disturbance, MTD=moderate training disturbance, HTD=heavy training disturbance, NG=no grazing (only native grazers), LG=light grazing (20% removal), MG=moderate grazing (40% removal), HG=heavy grazing (60% removal), NF=no fire, LF=low severity fire, MF=mixed-severity fire, HF=high severity fire (stand replacing), PF=prescribed fire or F=fire, MT=mechanical thinning, RS=range seeding, T= time (<20 yrs.), TT=time (20-100 yrs.), ?=scientific uncertainty.

Heavy training disturbance that disturbs below-ground vegetation parts tends to drive grasslands toward an earlier seral state. Lack of grazing can lead to increased production and cover, increased litter production, increased plant species diversity, and reduced basal cover. The latter effect can increase the risk of excessive runoff and soil erosion following fire or during the dormant season. Ungrazed areas may also develop increased cover of nonnative plants, as there is no grazing pressure on their vegetative portions and seeds. Examples of undesirable species that may benefit from grazing exclusion include the nonnatives *Kochia scoparia, Salsola kali,* and *Sysimbrium altissimum*, and the native *Gutierrezia sarothrae* (broom snakeweed). Excessive grazing can lead to plant stress and mortality, which also reduces soil and hydrologic stability. Ungrazed areas invaded by early seral nonnatives may in some cases resemble disturbed areas that have been colonized by nonnatives.

Two main grazing management systems are used on most lands in the region. The first is an intensive grazing rotation approach that uses short-duration, high utilization periods in conjunction with rotation among pastures to stimulate forage production and achieve cattle weight gains. The second uses seasonal grazing of larger pastures/allotments, usually from spring to fall or from fall to winter. This approach tends to result in more patchy utilization, requires less effort to manage and move the livestock, and uses larger pastures. Seasonal grazing often requires that winter pastures are near the ranch.

During presettlement times, most of the PCMS grasslands on loamy soils would have been characterized by the grassland B community (Dr. Daniel Milchunas, Colorado State University, personal comm.). However, due to land-use changes over time, most of the grasslands on PCMS are currently in the grassland A community. This is a mid-seral community that is favored by no grazing and also can develop from disturbed or seeded areas over time. Some grassland areas are dominated by grassland B or any of the early seral communities. Understanding the relationships between these ecological states and communities is important because it allows land managers to make inferences about possible land condition scenarios based on current conditions and land uses/drivers applied. For example, if most of PCMS is in grassland A, heavy maneuver damage can move it more easily to an early seral community (e.g., early seral a, B, or C), which is less resistant and resilient to changes and has a lower watershed function (i.e., is more prone to increased runoff, erosion, and deposition of sediment into surface waters) (Figure 48).

A variety of small mammals and invertebrates, including prairie dogs, badgers, and harvester ants also disturb soil, generally at small spatial scales but intensely. The microhabitats resulting from these soil-disturbing species create small-scale niche variety and habitat heterogeneity in these communities. Small-scale soil disturbance does not significantly favor invasive plant species, which are largely limited by climate, but the vegetation response to disturbance is highly variable with location, environmental conditions, prior land use/condition, and availability of plant propagules. Larger-scale disturbances can favor nonnative plant invasions if seed sources are present and native seed sources are limited to the edges of the disturbed areas. Effects of military training on soils and vegetation are described above.

## 8.3 Associated Species of Conservation Concern

According to Colorado's state wildlife action plan (CPW 2015), shortgrass prairie supports 48 Species of Greatest Conservation Need (Table 13). Of these, one species is federally listed (black-footed ferret), and 33 are considered vulnerable, imperiled, or critically imperiled by NatureServe or the Colorado Natural Heritage Program. Of Colorado species inhabiting shortgrass prairie, this habitat type is *the* primary, or *a* primary habitat for almost all of them (37 species). Eight species have been named by DoD PIF as Mission-Sensitive Priority Bird Species: bald eagle, burrowing owl, golden eagle, grasshopper sparrow, loggerhead shrike, long-billed curlew, mountain plover, and prairie falcon. See Section 9 and 11 for additional information on the burrowing owl and golden eagle, respectively. Of the remaining mission-sensitive species, the mountain plover has the most restricted range. Though the bald eagle is a Species of Greatest Conservation Need in six western states, including Colorado, populations are increasing across the nation (Rosenberg et al. 2016) and in Colorado (CPW 2015). The grasshopper sparrow is a Species of Greatest Conservation Need in four western states, including Colorado. Both species have been identified in the most recent PIF Landbird Plan (Rosenberg et al. 2016) as a common species in steep decline. There is a declining trend for this species in Colorado as well (CPW 2015). Loggerhead shrike, long-billed curlew, and mountain plover are all Species of Greatest Conservation Need in six western states, including Colorado. Rosenberg et al. (2016) identified the shrike as a common bird in steep decline, but Colorado populations of the shrike, curlew, and plover are all considered stable at this time (CPW 2015). The prairie falcon is a Species of Greatest Conservation Need in three western states, including Colorado; population trend is unknown (CPW 2015).

**Table 13. Colorado Species of Greatest Conservation Need that occur in shortgrass prairie habitat (CPW 2015).** Table codes: **Federal listing status** – E=endangered; T=threatened. **Colorado listing status** – E=endangered; T=threatened; SC=Special Consern. **NatureServe Global Status Rank** and **Colorado Status Rank** – 1=Critically Imperiled; 2=Imperiled; 3=Vulnerable; 4=Presumed Secure; 5=Demonstrably Secure; B=breeding; N=non-breeding; T=subspecies; NR=not ranked; X=extirpated. * = species is on the Partners in Flight National Watchlist.

| Species Common Name | *Species Scientific Name* | Shortgrass is a Primary Habitat? | Federal Listing Status | Colorado Listing Status | Other State Listings | Colorado SGCN Tier | SGCN in Other States | Colorado Trend | NatureServe Global Status Rank | NatureServe Colorado Status Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| Couch's spadefoot | *Scaphiopus couchii* | X | | SC | | 2 | | Stable | G5 | S1 |
| Green toad | *Anaxyrus debilis* | | | | KS | 2 | KS | Unknown | G5 | S2 |
| | | | | | | | | | | |
| American bittern | *Botaurus lentiginosus* | | | | | 2 | KS, NM | Unknown | G4 | S3S4B |
| Bald eagle | *Haliaeetus leucocephalus* | | | SC | TX | 2 | KS, NE, NM, OK, TX | Increasing | G5 | S1B,S3N |
| Burrowing owl | *Athene cunicularia* | X | | T | | 1 | NE, NM, OK, TX | Stable | G4 | S4B |
| Cassin's sparrow | *Aimophila cassinii* | X | | | | 2 | KS, NE, OK, TX | Declining | G5 | S4B |
| Chestnut-collared longspur | *Calcarius ornatus* | X | | | | 2 | KS, NE, OK | Unknown* | G5 | S1B,S3N |
| Ferruginous hawk | *Buteo regalis* | X | | SC | | 2 | KS, NE, NM, OK, TX | Stable | G4 | S3B,S4N |
| Golden eagle | *Aquila chrysaetos* | X | | | | 1 | KS, NE, NM, OK, TX | Unknown | G5 | S3S4B |
| Grasshopper sparrow | *Ammodramus savannarum* | X | | | NM | 2 | KS, NM, TX | Declining | G5 | S3S4B |
| Lark bunting | *Calamospiza melanocorys* | X | | | | 2 | KS | Declining | G5 | S4 |
| Loggerhead shrike | *Lanius ludovicianus* | X | | | | 2 | KS, NE, NM, OK, TX | Stable | G4 | S3S4B |
| Long-billed curlew | *Numenius americanus* | X | | SC | | 2 | KS, NE, NM, OK, TX | Stable | G5 | S2B |
| McCown's longspur | *Rhynchophanes mccownii* | X | | | | 2 | KS, NE, OK, TX | Unknown* | G4 | S2B |

| Species Common Name | Species Scientific Name | Shortgrass is a Primary Habitat? | Federal Listing Status | Colorado Listing Status | Other State Listings | Colorado SGCN Tier | SGCN in Other States | Colorado Trend | NatureServe Global Status Rank | NatureServe Colorado Status Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| Mountain plover | *Charadrius montanus* | X | | SC | NE | 1 | KS, NE, NM, OK, TX | Stable | G3 | S2B |
| Northern harrier | *Circus cyaneus* | X | | | | 2 | NM, TX | Stable | G5 | S3B |
| Prairie falcon | *Falco mexicanus* | | | | | 2 | NE, OK | Unknown | G5 | S4B,S4N |
| Short-eared owl | *Asio flammeus* | X | | | | 2 | KS, NE, OK, TX | Declining | G5 | S2B |
| Swainson's hawk | *Buteo swainsoni* | X | | | | 2 | KS, NE, OK, TX | Declining | G5 | S5B |
| | | | | | | | | | | |
| American bumble bee | *Bombus pensylvanicus* | X | | | | 2 | OK, TX | Declining | G3G4 | SNR |
| Colorado blue | *Euphilotes rita coloradensis* | X | | | | 2 | | Declining | G3G4T2T3 | S2 |
| Monarch butterfly | *Danaus plexippus* | X | | | | 2 | KS | Declining? | G4 | S5 |
| Morrison bumble bee | *Bombus morrisoni* | X | | | | 2 | | Declining | G4G5 | SNR |
| Northern hairstreak | *Eurystrymon favonius Ontario* | | | | | 2 | | | NF | NF |
| Regal fritillary | *Speyeria idalia* | X | | | | 2 | KS, NE, OK | Declining | G3 | S1 |
| Rhesus skipper | *Polites rhesus* | X | | | | 2 | | Declining | G4 | S2S3 |
| Sandia hairstreak | *Callophrys mcfarlandi* | X | | | | 2 | NM | Unknown | G4 | S1 |
| Southern plains bumble bee | *Bombus fraternus* | X | | | | 2 | OK | Declining | G2G3 | SNR |
| Suckley cuckoo bumble bee | *Bombus suckleyi* | X | | | | 2 | | Declining | G1G3 | not in CO |
| Two-spotted skipper | *Euphyes bimacula* | | | | | 2 | KS | | G4 | S2 |
| Western bumble bee | *Bombus occidentalis* | X | | | | 2 | | Unknown | G4 | SNR |

| Species Common Name | Species Scientific Name | Shortgrass is a Primary Habitat? | Federal Listing Status | Colorado Listing Status | Other State Listings | Colorado SGCN Tier | SGCN in Other States | Colorado Trend | NatureServe Global Status Rank | NatureServe Colorado Status Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| Wiest's sphinx moth | *Euproserpinus wiesti* | | | | | 2 | | | G3G4 | S2 |
| Yellow bumble bee | *Bombus fervidus* | X | | | | 2 | | Declining | G4? | SNR |
| | | | | | | | | | | |
| Black-footed ferret | *Mustela nigripes* | X | E | E | KS, NE | 1 | KS, TX | Unknown | G1 | S1 |
| Black-tailed prairie dog | *Cynomys ludovicianus* | X | | SC | | 2 | KS, NM, OK, TX | Stable | G4 | S3 |
| Olive-backed pocket mouse | *Perognathus fasciatus* | X | | | | 1 | NE | Unknown | G5 | S3 |
| Swift fox | *Vulpes velox* | X | | SC | NE | 2 | KS, NE, NM, OK, TX | Stable | G3 | S3 |
| White-tailed jackrabbit | *Lepus townsendii* | X | | | | 2 | NE | Unknown | G5 | S4 |
| | | | | | | | | | | |
| Black-necked gartersnake | *Thamnophis cyrtopsis* | | | | | 2 | | | G5 | S2? |
| Colorado checkered whiptail | *Aspidoscelis neotesselata* | | | | | 1 | | | G2G3 | S2 |
| Long-nosed snake | *Rhinocheilus lecontei* | X | | | | 2 | KS | Unknown | G5 | S1? |
| Massasauga | *Sistrurus catenatus* | X | | SC | NE | 1 | KS, NE, NM, TX | Stable | G4 | S2 |
| Utah Milksnake | *Lampropeltis triangulum* | X | | | | 2 | | Unknown | G5 | S5 |
| New Mexico threadsnake | *Rena dissectus* | X | | | KS | 2 | KS | Unknown | G4G5 | S1 |
| Night snake | *Hypsiglena chlorophaea* | | | | | 2 | | | G5 | S3 |
| Round-tailed horned lizard | *Phrynosoma modestum* | X | | SC | | 2 | TX | Unknown | G5 | S1 |
| Texas horned lizard | *Phrynosoma cornutum* | X | | SC | TX | 2 | KS, TX | Stable | G4G5 | S3 |
| Yellow mud turtle | *Kinosternon flavescens* | | | SC | | 2 | | | G5 | S1 |

## 8.4 Incompatible Land Uses and Other Stresses

Rangewide, approximately half of the historic distribution of shortgrass prairie has been converted to other uses (Neely et al. 2006). Across its remaining distribution, only about seven percent of the shortgrass prairie is unaffected by at least one incompatible land use (Table 14). Surrounding land uses with the greatest potential to influence Fort Carson and PCMS are residential/commercial development and roads (Table 9).

**Table 14. Acres of potential impact from incompatible land uses in the shortgrass prairie.**

| Shortgrass Prairie<br>Total acres: 33,731,815 | | |
|---|---|---|
| **Threat** | **Acres Vulnerable** | **% of total** |
| Development - High Intensity | 2,372,894 | 7% |
| Development - Low Intensity | 2,221,038 | 7% |
| Agriculture (crops) | 10,973,715 | 33% |
| Energy - Oil and Gas | 3,389,693 | 10% |
| Energy - Wind | 300,080 | 1% |
| Transportation – Major Roads (interstates, state highways, roads with four or more lanes) | 5,729,437 | 17% |
| Transportation – Minor Roads (local roads with fewer than four lanes) | 30,453,495 | 90% |
| **Total Acres *Not* within one mile of a mappable threat** | **2,205,300** | **7%** |

### 8.4.1 Residential and Commercial Development

The shortgrass prairie region is sparsely populated in most areas, but development is a significant source of habitat loss in some places. This is especially true along the mountain front where most DoD installations with shortgrass occur. Conversion of shortgrass prairie to urbanization has largely surpassed conversion to cropland as an ongoing threat, though there is some possibility that this could reverse if demand for dryland biofuel crops were to accelerate. Residential and commercial development impacts are concentrated on the western margins of the shortgrass prairie. In these areas, future land use changes are most likely to convert areas of previously low intensity development into higher intensity development, contributing to a gradual increase in habitat fragmentation, and eventual loss of high quality habitat. Forecasts of future residential development (urban, suburban, exurban, and rural) indicate little change in residential development levels (generally less than 1% increase or decrease) near these habitats over the coming century (EPA 2010).

Within the range of shortgrass prairie, more than 2.3 million acres of this habitat are within one mile of high intensity development, and a similar quantity is within one mile of low intensity development (Figure 50, Table 14).

***Installation Management for this Threat***

### *Fort Carson/PCMS*

The Army Compatible Use Buffer Program (ACUB) is a tool used to address incompatible development surrounding Army installations. Although originally designed to address incompatible development in terms of military training, it is also used to achieve local, regional, and federal conservation objectives.
Title 10, Section 2684a of the United States Code authorizes the DoD to enter into cooperative agreements with states, local governments, or private conservation organizations with a purpose of (DECAM 2015):

- Preserving habitat in a manner that is compatible with environmental requirements and may eliminate or relieve environmental restrictions that may otherwise restrict, impede, or otherwise interfere with military training, testing, or operations on a military installation, or
- Limiting development or use of property that would be incompatible with the training mission of the installation.

ACUB funds may also be used under Section 10 USC 670c-1(a)(2) of the Sikes Act. This provision allows Fort Carson and PCMS to enter into cooperative agreements with state and local governments, NGO's, and individual landowners to establish buffer areas around the installation. Past ACUB Program funds have been used to enter cooperative agreements with The Nature Conservancy and El Paso County (DPW 2015).

The Fort Carson DPW-Environmental stormwater program, although not directly involved in preventative measures to incompatible devleopment, focuses on mitigating the effects of development on local hydrology. The installation also works with USACE to develop floodplain management plans to minimize potential damage and associated costs due to future flooding at Fort Carson and PCMS. Information on both of these programs can be found in Fort Carson's Stormwater Management Plan (DPW 2015).

These programs help restrict the effects of residential and commercial development within Fort Carson/PCMS as well as within the immediate vicinity of the installations. Habitat loss is the primary threat to most species of concern (IUCN 2016), including those discussed in this report.

### *Air Force Academy*

Although the Land Use Plan of the Academy's Base Comprehensive Plan stresses the importance of maintaining natural open space within the installation, there is to date no formal buffer program for the Air Force or at the Academy. The installation is already surrounded by residential and commercial development to the north, east, and south and protected by Pike National Forest to the west, thus potential for this type of program to be effective is limited.

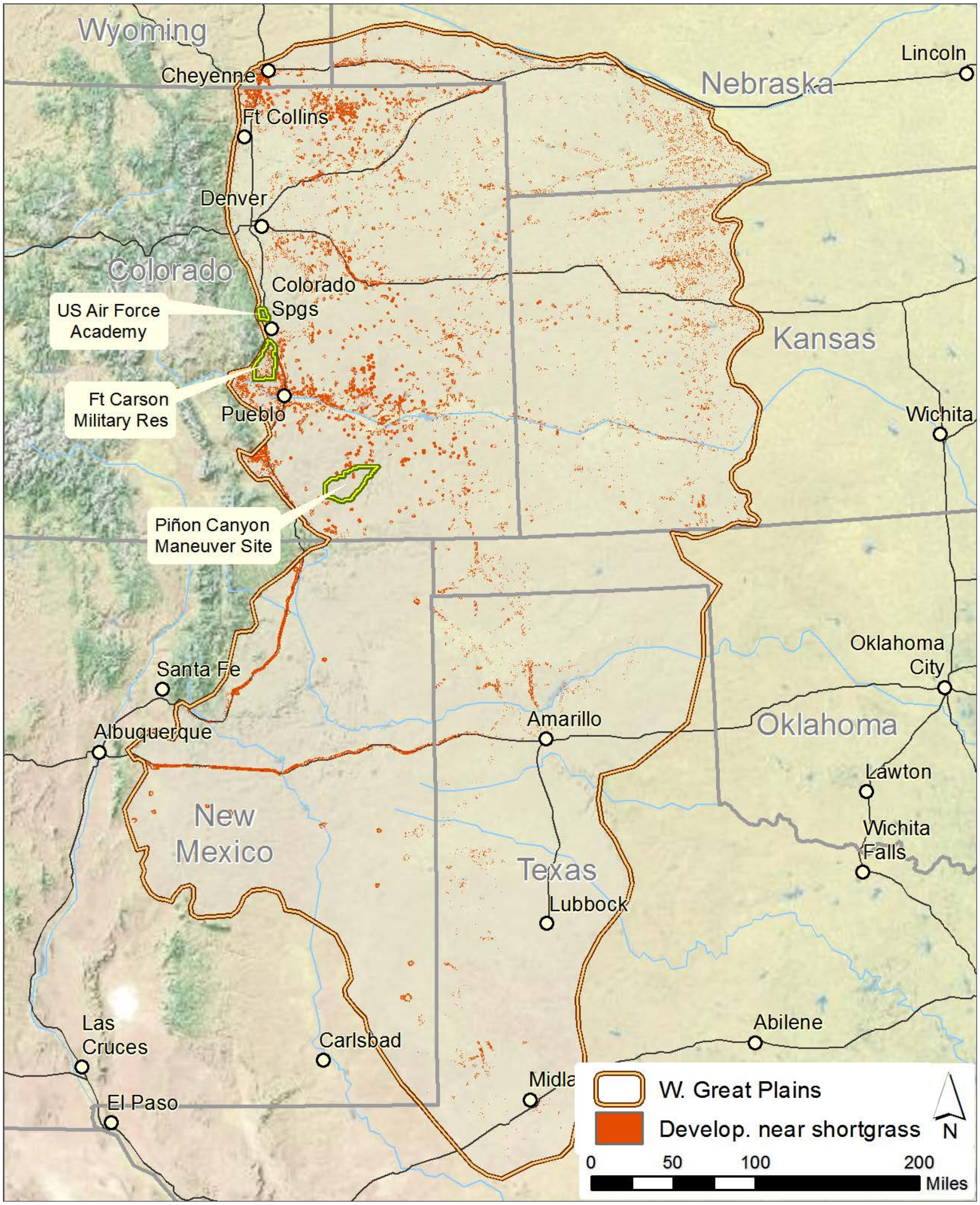



**Figure 49. Distribution of shortgrass prairie within one mile of residential and commercial development (low and high intensity combined).**

### 8.4.2 Incompatible Agriculture

Extensive portions of shortgrass prairie have been converted to cropland (Brown et al. 2005, Neely et al. 2006). Conversion to cropland replaces native shortgrass prairie with row crops, hay fields, and similar vegetation, with a consequent loss and fragmentation of habitat for native wildlife. Ground-water pumping of the Ogallala aquifer has already led to aquifer drops of more than 15 m in parts of the central and southern Great Plains (Woodhouse and Overpeck 1998). Due to increasing water limitations, the threat of additional conversion is generally low, unless new dryland crops are developed.

The Conservation Reserve Program (CRP) is intended to remove land from agricultural production and restore perennial vegetation by seeding native grasses. However, full recovery to a level of species composition and cover similar to that of undisturbed shortgrass prairie is likely to require decades (Munson and Lauenroth 2012). CRP enrollment contracts are 10-15 years in length, and rates of previously enrolled lands exiting CRP have varied from 1-16% per year in the region (USDA-FSA 2013). Though CRP lands provide some habitat benefit for certain wildlife species, they replace complete restoration of shortgrass prairie function with often temporary perennial plantings. The mean number of acres within the range of shortgrass prairie under CRP contract during the period 1986-2013 was about 3.6 million acres (USDA-FSA 2013).

Agricultural use of the remaining intact shortgrass prairie is dominated by domestic livestock grazing. Grasslands that are managed for increased livestock production tend to become more homogeneous and dominated by key forage species (Fuhlendorf and Engle 2001). In addition, fencing for livestock control fragments habitat for some species (e.g., pronghorn, lesser prairie-chicken). Pest control (e.g., prairie dog control) or shrub control (e.g., removal of cholla and other shrubs) to improve range condition for livestock are significant sources of disturbance in some places. Impacts may include alteration in the composition and function of the grasslands. Although maintaining rangeland for grazing use can preserve open space in the face of urban development pressure, compatible management is needed to maintain or restore a mosaic of habitat structure suitable for the full suite of characteristic wildlife species.

Shortgrass prairie areas at PCMS were grazed by bison prior to settlement, and then by domestic livestock (primarily cattle). After the 1985 acquisition of PCMS by the DoD, there has been no grazing by large ungulates on the installation. The absence of grazing has resulted in a buildup of standing dead biomass that is not typical of grazed grasslands.

Spatial data depicting agricultural rangeland are not available. Within the range of shortgrass prairie, nearly 11 million acres of this habitat are within a mile of cropland (Figure 51, Table 14).

***Installation Management for this Threat***

Incompatible agriculture is not a threat within the installation boundaries. Instituting grazing programs has been discussed by Fort Carson managers as a possible management tool for use at PCMS. There are currently no agricultural management programs at Fort Carson, PCMS, or the Air Force Academy. Shortgrass prairie areas on Front Range foothills and plains were grazed by and

and evolved with bison prior to settlement, and subsequently by domestic livestock (primarily cattle). After acquisition by DoD, these particular installations were no longer grazed by livestock. The absence of significant large ungulate grazing has resulted in a buildup of standing dead biomass and litter buildup on the ground. The resulting decadence and litter accumulation is outside the natural range of variability for the shortgrass steppe, although areas that are periodically burned have reduced litter buildup.The presence of cattle on active ranges and training areas, the infrastructure required to manage them effectively, and the administrative requirements for planning and allocating other uses such as military training, appear to be insurmountable obstacles to a cattle grazing program. The presence of exotic invasive plants can also complicate achieving ecological goals associated with grazing. Grazing-related ecology threats and management are discussed in Section 8.4.6 *Natural System Modifications*.

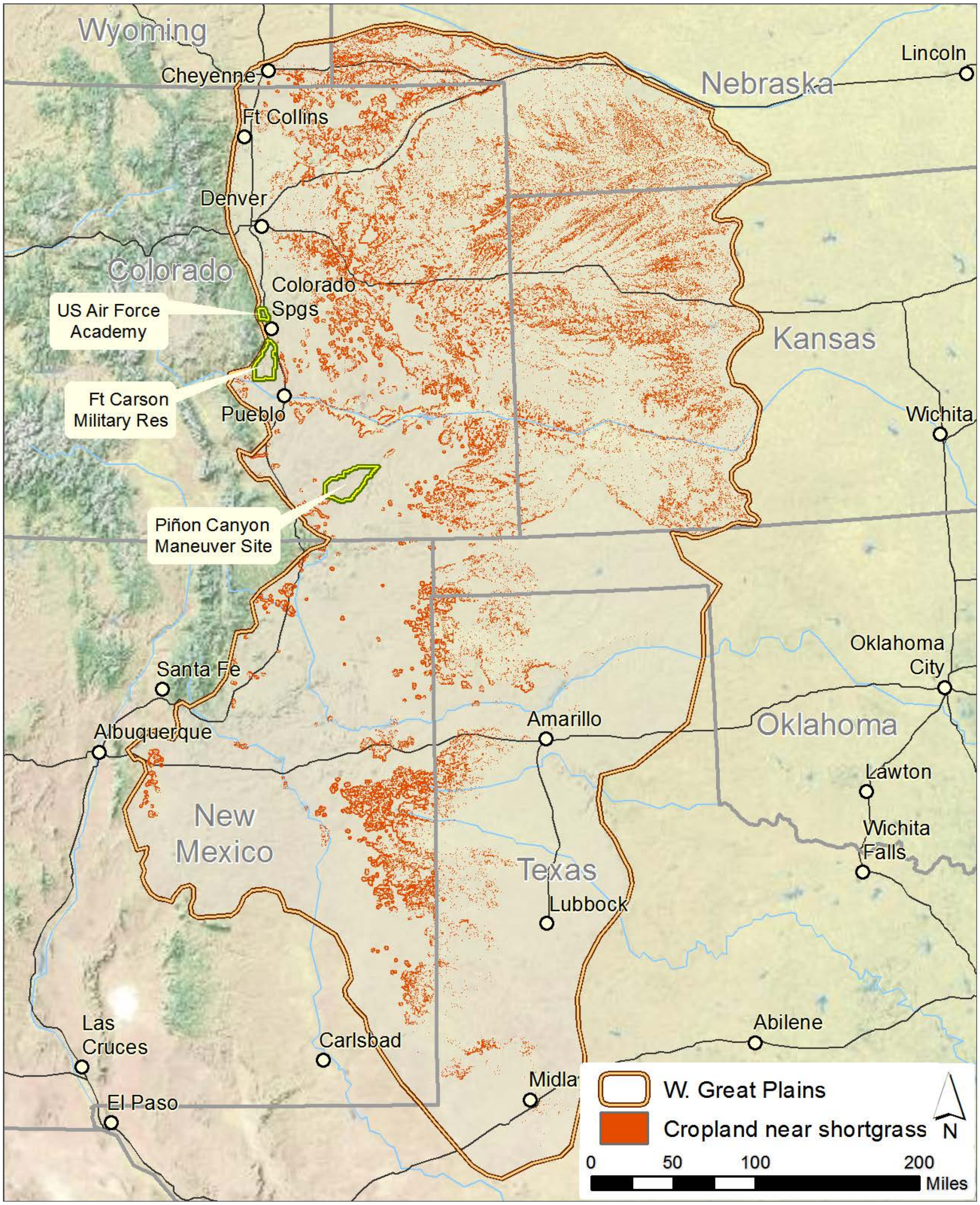



**Figure 50. Distribution of shortgrass prairie within one mile of cropland.**

### 8.4.3 Energy Production

Energy development, with its associated roads, pipeline corridors, and infrastructure is a primary source of anthropogenic disturbance, fragmentation, and loss across much of the shortgrass prairie, although there is also significant area largely untouched by this activity. Within the range of shortgrass prairie, oil and gas production is concentrated in northeastern Colorado (Denver Basin), the area including the southwestern and adjacent Oklahoma and Texas panhandles (Anadarko Basin), and southeastern New Mexico/western Texas (Permian Basin) (Figure 52). In comparison, disturbance from renewable energy development remains small, and to date is largely due to concentrated wind farms (Figure 53), which are often on uncropped rangeland. Construction of additional wind facilities is likely to continue in the future. For example, a new wind facility has been built near PCMS since the date of the wind data layer used in our analysis. Utility-scale solar installations are generally confined to areas near urban development; future construction of these facilities in currently undeveloped areas may require additional utility corridor development.

Within the range of shortgrass prairie, more than 3.3 million acres of this habitat are within a mile of oil and gas development, and about 300,000 acres are within a mile of a wind turbine facility (Table 14).

***Installation Management for this Threat***

Although not specifically used for oil and gas or wind power development, the ACUB Program could be used in relation to efforts to prevent this type of development from occuring near the borders of Fort Carson and PCMS.

Stormwater management and water quality monitoring programs at Fort Carson/PCMS and the Air Force Academy could be used to detect sedimentation or chemical contamination of aquatic habitats, which could lead to the contamination and degradation of food sources for the golden eagle.

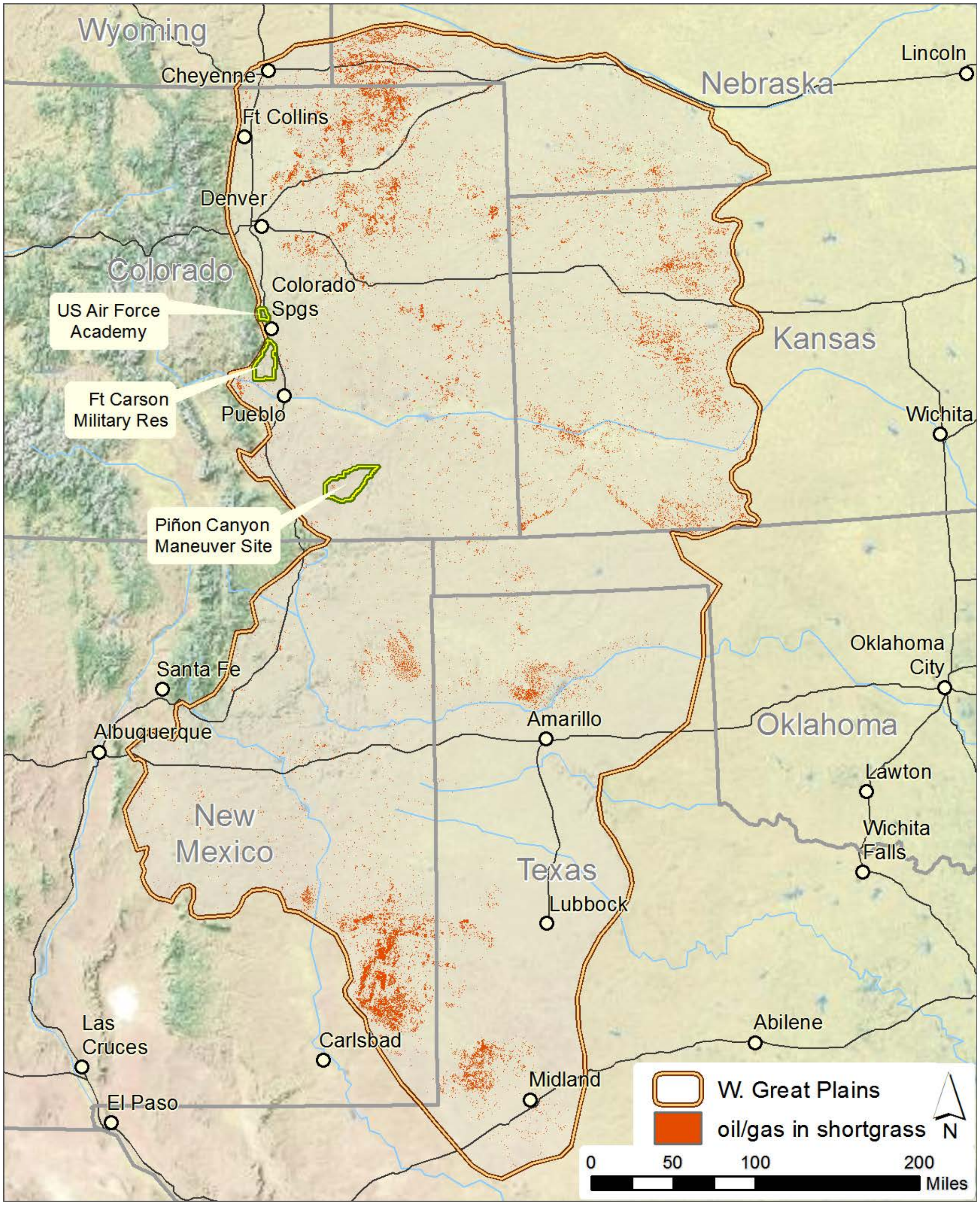


**Figure 51. Distribution of shortgrass prairie within one mile of oil and gas development.**

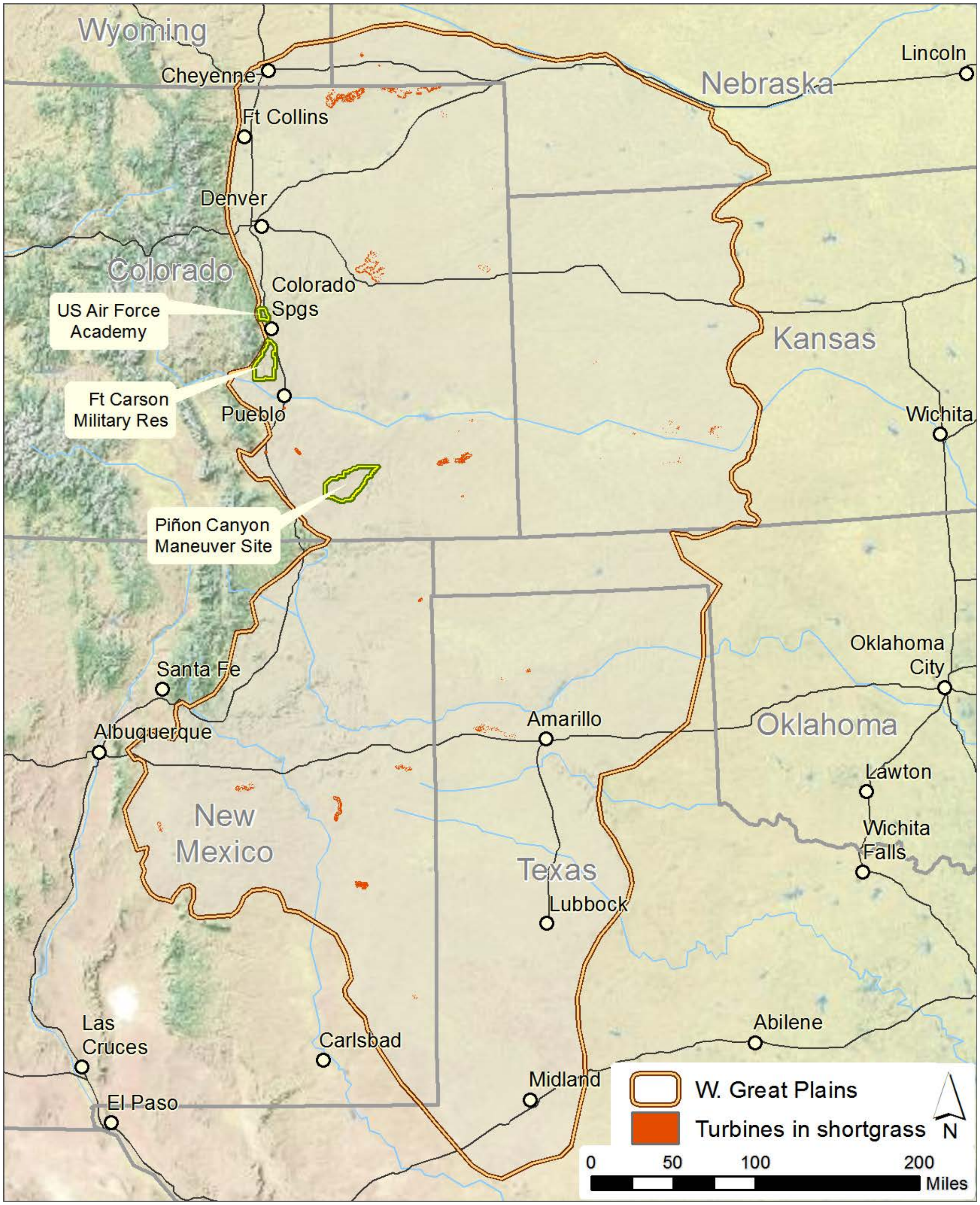



**Figure 52. Distribution of shortgrass prairie within one mile of wind energy development.**

### 8.4.4 Transportation and Service Corridors

Roads and utility corridors associated with urban, suburban, exurban, and energy development are a source of habitat fragmentation in shortgrass prairie. Major highways with high traffic loads are limited in extent within the shortgrass region, and little increase except as associated with residential or energy development is expected. However, the density of smaller roads associated with these developments can be significant in places. Depending of the extent, use patterns, and associated fencing, roads of any type can be a source of disturbance to wildlife. Other impacts may include introduction or spread of noxious weeds, changes in hydrology, and pollution.

Within the range of shortgrass prairie, more than 30 million acres of this habitat are within a mile of a minor road, and about 5.7 million acres are within a mile of a major road (Figures 54 and 55, Table 14). Major roads are defined as Interstate highways, state highways, and roads with four or more lanes. Minor roads are local roads with fewer than four lanes, either paved or unpaved (two-tracks are not included).

***Installation Management for this Threat***

The ACUB Program could be used to deter road construction within the vicinity of Fort Carson and PCMS. LRAM projects are occasionally completed on small roads and trails within Fort Carson/PCMS. These projects aim to reduce erosion and sedimentation, possibly reducing negative effects on burrowing species of concern (burrowing owl) and burrowing prey of predators, including the golden eagle.

Most of the land surrounding the Air Force Academy is already developed or a part of Pike National Forest. Nearly all roads on the installation are paved and for transportation only (no maneuvers). Installation management ability for this threat is minimal.

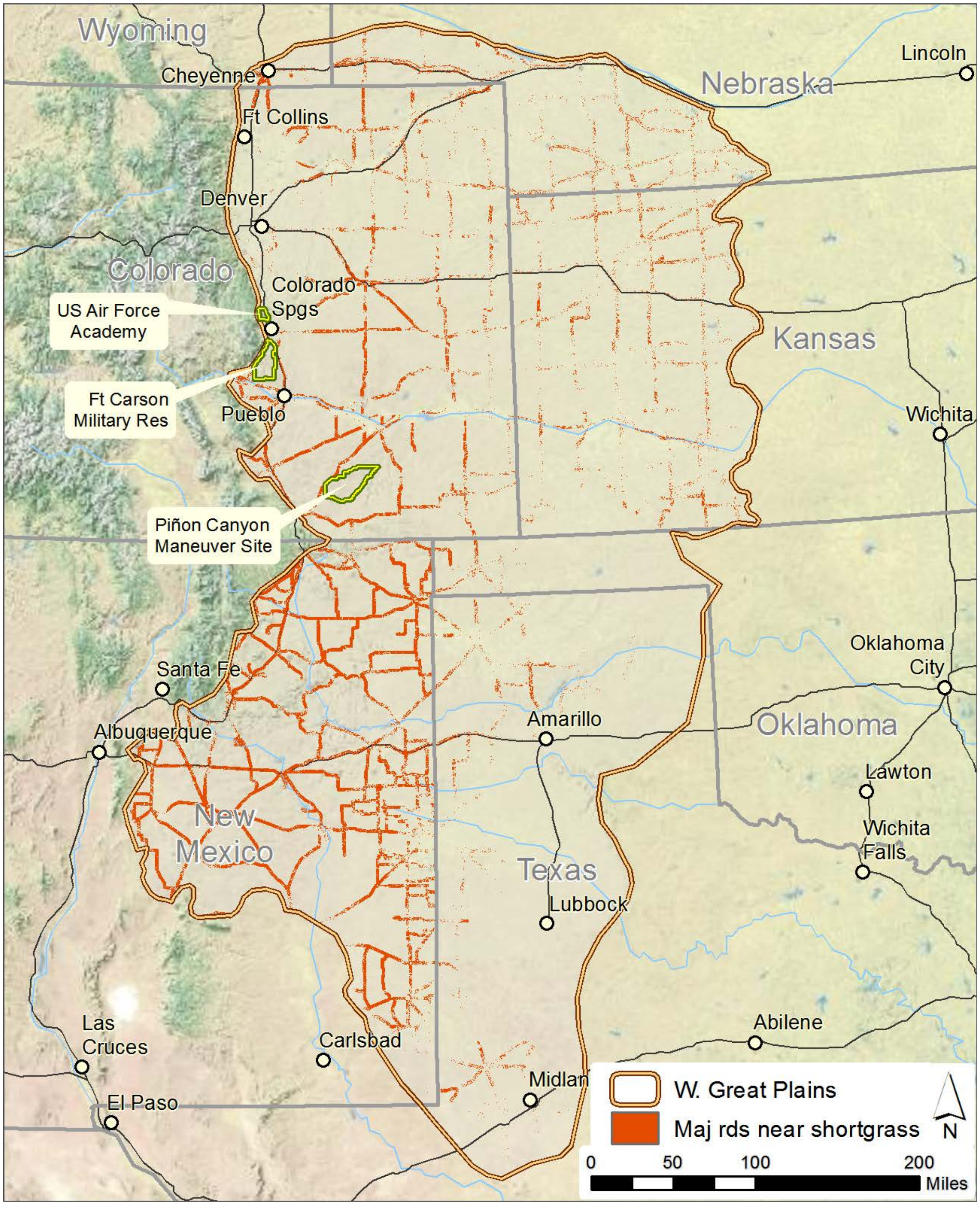



**Figure 53. Distribution of shortgrass prairie within one mile of major roads.**

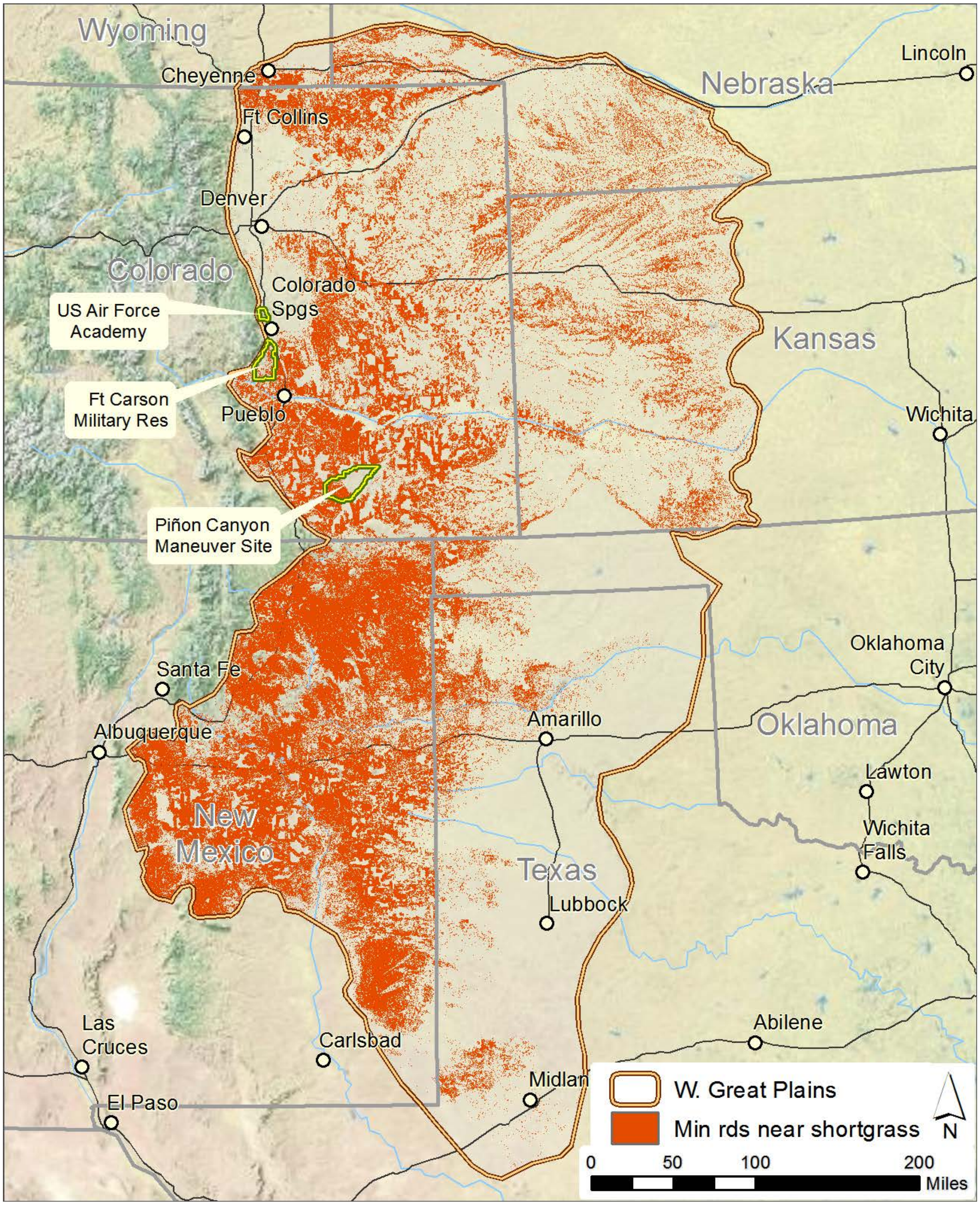



**Figure 54. Distribution of shortgrass prairie within one mile of minor roads.**

### 8.4.5 Human Intrusions and Disturbance

Public land in the shortgrass prairie is relatively limited, but where it occurs off-road vehicle use, hiking, and camping are a local source of disturbance.

Military training exercises occur on shortgrass prairie areas on DoD installations, with varying levels of disturbance. A number of former launch facilities of the 90th Strategic Missile Wing are still present as a minor source of fragmentation in the portion of the shortgrass prairie north of the South Platte River.

Anthropogenic surface disturbance due to military training activities or recreational use can change soil or reduce vegetation cover, potentially increasing soil erosion. Tracked vehicles are exceptional in their ability to dramatically change soil structure in a single pass, but any vehicular activity can affect soil and vegetation under certain conditions. Fine-textured soils, including those at PCMS, are generally most susceptible to damage by vehicular disturbance (Milchunas et al. 1999). A large percentage of the shortgrass prairie areas at PCMS is included in maneuver training or range areas. Shortgrass prairie areas at PCMS that have been disturbed by training activities are reseeded after the application of various soil surface treatments (e.g., disking, blading, scraping) that are intended to reduce erosion vulnerability. These treatments have a severe impact on the soil structure, essentially destroying the shallow A-horizon. Post-seeding vegetation is initially dominated by weedy annual species; the reestablishment of native perennial grasses is dependent on suitable seed germination and subsequent adequate growth conditions (James Kulbeth, Natural Resources Specialist, personal communication).

***Installation Management for this Threat***

Fort Carson and PCMS have numerous management programs related to military training impacts. These programs include: off-limit areas, non-vehicular use areas, rest/rotation/deferment program, maneuver damage assessment, and rare species restrictions on use. Information on these and other programs used at Fort Carson and PCMS can be found in Chapter 4 of this document.

- The Directorate of Family, Morale, Welfare, and Recreation is in charge of regulating various consumptive and non-consumptive recreational activities, including off-road use and hiking/equestrian trails.
- At the Air Force Academy, Academy Security Forces monitor illegal or unnecessary off-road and military training activity.
- All installations have wildland fire management programs to reduce the likelihood of large, uncontrolled fires from escaping training lands.

On the ground military training at the Air Force Academy is generally infrequent and of low impact. Programs and policies pertaining to the attenuation of military use impacts include the Environmental Restoration Program, several watershed plans administered in cooperation with local agencies, and threatened and endangered species management.

### 8.4.6 Invasive and Other Problematic Species

Invasive plant species (plants that have been introduced, usually as a result of human activity) may out-compete native species, especially in disturbed areas, changing the characteristic species composition and functioning of the grassland, and reducing biological diversity (Westbrooks 1998, DiTomaso 2000). However, it may be difficult to distinguish between the effects of the disturbance that facilitates invasion and the effects due to the actual presence of the invasive species (Didham et al. 2005). Invasive-related changes in vegetation can impact the survival, reproductive success, and overall persistence of grassland animal populations (Samson and Knopf 1996). In the shortgrass prairie, major problem species are field bindweed (*Convolvulus arvensis*), kochia (*Kochia scoparia*), Russian thistle (*Salsola kali*), cheatgrass (*Bromus tectorum*), and lovegrasses (*Eragrostis* spp.). However, the real extent and specific effects of these invaders in shortgrass vegetation is not known.

Range and Training Land Assessments for PCMS indicates that invasive plant species cover levels are generally low across most training areas. Some areas near the cantonment on the western end have experienced increased levels of invasive or noxious species, in some cases to levels above baseline targets. Annual brome species (*Bromus japonicus and B. tectorum*) are common at PCMS. Fort Carson generally has more widespread invasive plant problems, due to its higher traffic levels and year-round training activity. US Air Force Academy also has widespread invasive plant species, especially in high traffic areas. However, grasslands on this installation are not classified as shortgrass prairie.

***Installation Management for this Threat***

The Federal Noxious Weed Act (§2814 of 7 USC 360), part of the Plant Protection Act of 2000, mandates federal agencies to (DECAM 2015):

- have an office or person trained to coordinate an undesirable plant management program
- adequately fund the program
- implement cooperative agreements with state agencies, and
- conduct integrated pest management techniques for managing undesirable plant species.

Fort Carson, PCMS, the Air Force Academy, and several other Front Range military installations participate in the Noxious Weed Biological Control Program (DPW 2015). The program is an integrated control program that uses chemical, cultural, and mechanical methods of weed control. Due to the size of PCMS, the widespread application of pesticides is difficult; prescribed burns have been used in the past, though not in recent years, to control invasive weeds. An updated invasive species plan is currently in production for Fort Carson and PCMS.

### 8.4.7 Pollution

Non-point source pollution is high in agricultural and urban landscapes within the shortgrass region. Runoff of herbicides and pesticides from cropland can be a local source of water-borne pollutants in the shortgrass region. Both urban areas and rural croplands are sources of pesticide (Kimbrough and Litke 1996) or fertilizer runoff (Carpenter et al. 1998).

Although the shortgrass prairie region is sparsely populated on the whole, human presence does introduce artificial light and noise pollution into the environment, especially around population centers. These disturbances can affect the behavior and physiology of many types of wildlife that use these areas, including mammals, birds, insects, fish, reptiles, and amphibians (Rich and Longcore 2006, Francis et al. 2009, Hölker et al. 2010, Barber et al. 2010).

***Installation Management for this Threat***

Water quality monitoring programs at all installations could be used to detect chemicals that are the product of non-point sources that are affecting the water supply. Air and water quality are tied to federal, state, and DOD standards and each installation is responsible for meeting these standards. Noise and artificial light are generally not addressed unless needed.

### 8.4.8 Climate Change and Severe Weather

Climate change vulnerability assessments have been conducted for shortgrass prairie in Colorado under three greenhouse gas emissions scenarios (RCP 4.5, 6.0, and 8.5) (Decker and Fink 2014, Colorado Natural Heritage Program 2015). Though technical analysis methods differed, shortgrass prairie ranked as highly vulnerable to climate change within a mid-cetury timeframe under all three emissions scenarios. Key effects that have potential to impact shortgrass prairie include warmer summer nighttime low temperatures and extended periods of drought.

***Climate Projections for the Western Great Plains***

Projected means for temperature and precipitation indicate that all areas of the shortgrass prairie distribution will experience some degree of warming, and potentially changes in precipitation as well. In combination with expected changes in temperature, however, even a wetter future may not be sufficient to maintain runoff and soil moisture conditions similar to those of the recent past. Hydrologic modeling for the Colorado River and other basins has indicated that, as a generalized rule-of-thumb, for each 1.8°F (1°C) of warming, an approximate 5% increase in precipitation would be required for runoff levels to remain unchanged (e.g., Nash and Gleick 1991, 1993). How relevant a model based on the Colorado River basin runoff may be to soil moisture in the South Platte and Arkansas River basins is unknown. However, assuming that this rule-of-thumb is at least somewhat applicable, a temperature increase of 5°F degrees would mean that a corresponding increase of roughly 45% would be needed to maintain the status quo. That amount is more than double the projected increase in precipitation we might expect.

Figure 56 depicts projected *change from recent past* (1980 – 2012) conditions across the western Great Plains. Projected changes indicate average seasonal temperature increases of anywhere from about 3.7-5.8 °F (2.0-3.1°C), with mean increases of about 4.0-5.2 °F (2.2-2.9 °C). Summer and fall

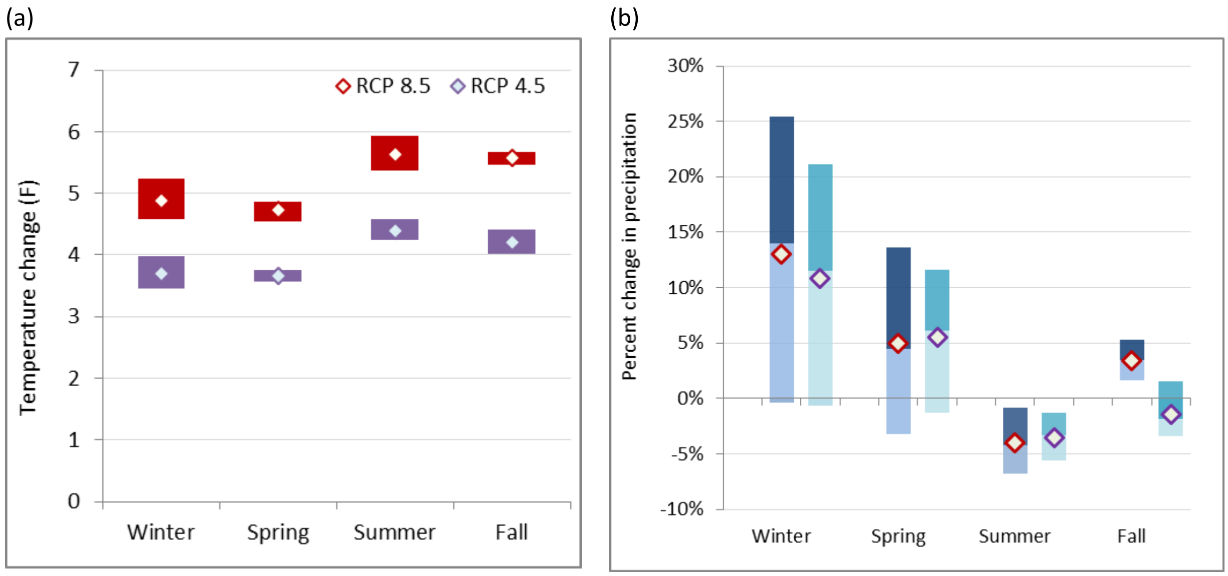



**Figure 55. Seasonal projected temperature (a) and precipitation (b) changes by mid-21st century (2050; centered around 2035-2064 period) for the western Great Plains.** For temperature (a), the bottom of each bar represents the 10th percentile, and the top of the bar is the 90th. Open diamonds represent the mean. For precipitation (b), the bottom of each bar represents the 10th percentile, the middle line is the 50th, and the top of the bar is the 90th. Left-hand bars are the RCP8.5 emissions scenario; right-hand bars are RCP4.5. Seasons are: winter=DJF, spring=MAM, summer=JJA, and fall=SON. Climate scenarios used were from the NEX-DCP30 dataset, prepared by the Climate Analytics Group and NASA Ames Research Center using the NASA Earth Exchange, and distributed by the NASA Center for Climate Simulation (NCCS).

temperatures are projected to show the greatest increases, and not surprisingly, larger increases are projected under the higher emission scenario (RCP8.5) in comparison with the lower emission scenario (RCP4.5) at mid-century. According to projections, winter and spring precipitation is likely to increase under both scenarios, while summer precipitation is expected to decrease.

### *Climate Projections for Colorado*

Information in this section has been summarized from Colorado Natural Heritage Program (2015). Under the most severe climate scenario, ecosystems are projected to experience annual mean temperatures that are 5-6°F warmer than in the recent past. Future precipitation projections are more variable, but levels are not projected to increase sufficiently to compensate even partially for increased moisture loss due to warmer temperatures (Figure 57)[20]. About 78% of shortgrass prairie in Colorado will therefore be exposed to effectively drier conditions, even under unchanged or slightly increased precipitation projected for mid-century. For shortgrass prairie in Colorado's eastern plains, more than half of the current range is projected to experience annual *mean* temperatures above the current statewide *maximum* temperature (Figure 58).

Shortgrass prairie is projected to experience spring and summer temperatures that are warmer than the current range in the majority of the current distribution. Projected precipitation levels are

[20] Of the ecosystems presented in Figure 57, only shortgrass prairie and pinyon-juniper are the focus of this current study. However ecosystem management requires maintaining a landscape scale viewpoint, so potential future conditions for adjancent and nearby habitats are also relevant.

projected to be lower than the driest end of the current range for nearly half of the lower elevation distribution (Figure 58). An increase in drought days, and fewer days with large precipitation events are projected for a substantial portion of the current distribution as well. Note that all of the climate projections presented here are summaries of long-term trends and do not track inter-annual variation, which will remain a source of variability, as it has been in the past

***Impacts to Shortgrass Prairie***

Warmer and drier future conditions will likely reduce soil water availability and otherwise have detrimental effects on ecosystem processes, while warmer and wetter conditions could be favorable for some species. Furthermore, a shift in the relative abundance and dominance of shortgrass prairie species under future climate conditions may result in novel plant communities (Polley et al. 2013). Because woody plants are more responsive to elevated CO2, and may have tap roots capable of reaching deep soil water, an increase of shrubby species (e.g., cholla, yucca, snakeweed, sandsage), or invasive exotic species, especially in areas that are disturbed may also result. Such changes would likely be detrimental to some wildlife species but favorable for others.

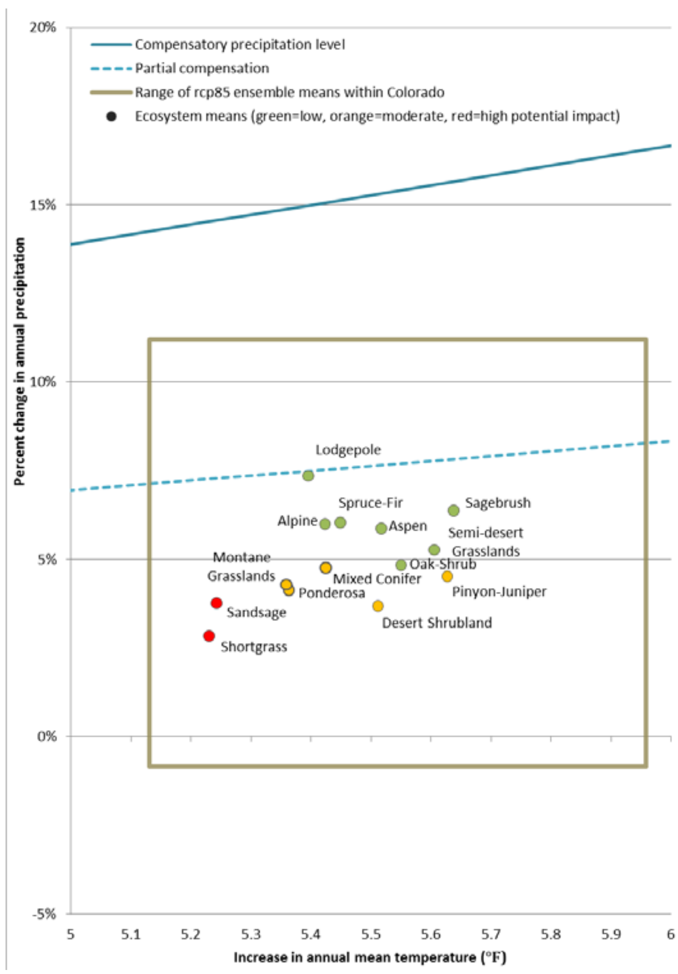



**Figure 56. Projected annual change in Colorado for upland ecosystems.** Ecosystem means are colored to indicate the degree to which the ecosystem is projected to experience conditions that are out of range of those in its current statewide distribution. Source: Colorado Natural Heritage Program 2015.

Grasslands in areas where mean annual temperature is above 50°F (10°C) are generally dominated by C4 (warm-season) grass species, which are tolerant of warmer temperatures and more efficient in water use (Sims and Risser 2000) than C3 (cool-season grasses). Alward et al. (1999) found that warming night-time temperatures in spring were detrimental to the growth of blue grama, and instead favored cool-season (C3) species. Thus, although shortgrass species are adapted to warm, dry conditions, potential for an earlier onset of growing season related to increasing temperatures (including warmer night-time lows), could result in a species composition shift towards cool-season species (Collins et al. 2010). There are some native C3 species (e.g., *Koeleria*, *Stipa* spp.), but the majority of native shortgrass species are C4. Thus, non-native C3 grasses are more likely to benefit. In addition, even if conditions are effectively drier, shrubs could benefit due to different root structures and ability to survive drought.

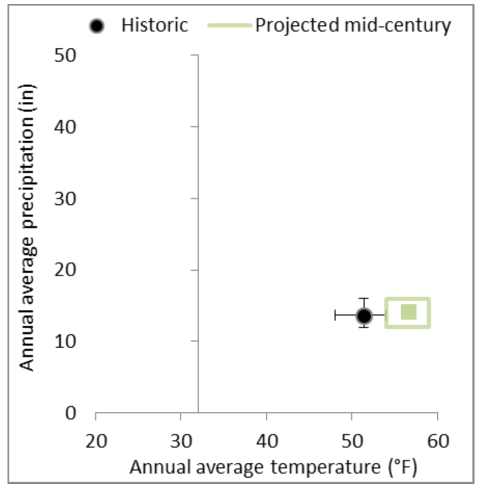



**Figure 57. Current annual mean temperature and precipitation and projected mid-century region of change for shortgrass prairie in Colorado.** Circles represent historic means with error bars representing one std. dev. Squares represent the middle 80% percent of the range of projected mid-century change. Source: Colorado Natural Heritage Program 2015.

Dry climate conditions can decrease the fuel load and relative fire frequency in shortgrass prairie. Currently, fire suppression and reduced fuel loads related to grazing patterns have contributed to a decrease in fire frequency. It is unlikely that fire frequency and intensity would increase simply due to projected warmer and drier climate conditions. On the other hand, more frequent occurrence of climate extremes (e.g., very wet conditions followed by very dry conditions) could result in higher fuel loads, potentially leading to increased frequency and extent of grassland wildfires (Polley et al. 2013).

Although the dominant shortgrass species are adapted to warm, dry conditions, stabilizing vegetation, especially blue grama, can be slow to recover after even a relatively short-term drought (Rondeau et al. 2013), and buffalograss is less drought tolerant than blue grama (Aguiar and Lauenroth 2001). Where soils are sandy, anything that reduces vegetation cover, whether from increasing drought or cultivation, will result in activation and loss of the soil (Woodhouse and Overpeck 1998).

The 2012 Range and Training Land Assessment for PCMS reported a large decline in basal ground cover between 2005 and 2012. All training areas had 2012 ground cover percentages lower than the 2003 baseline values, which were established in the year after a severe regional drought. However, 2012 total cover values (basal and canopy cover combined) were generally somewhat higher than 2003 baseline values. Furthermore, cover and canopy percent of perennial native species, although declining from 2005 levels was notably higher in 2012 than in 2003, indicating that post 2002-drought vegetation recovery has been maintained to some extent. Blue grama mortality has been observed even in deeper soils at PCMS following repeated drought years in southeastern Colorado (James Kulbeth, Natural Resources Specialist, personal communication). Continued or increasing drought conditions could result in the conversion to shrubland in some areas that were formerly dominated by shortgrass prairie.

## 8.5 Management Recommendations

The primary threats to the shortgrass prairie system around Fort Carson/PCMS are residential and commercial development, energy production, disturbance due to training, and climate change. In regard to these system-level threats, we recommend that installations pursue the following:

- Locate and use seed source that contains native variants resistant to drought, fire, and military disturbance.
- Expand the "hardening" of heavy use areas (bivouac, helipads, wet area crossings, etc.) that are too difficult or costly for restoration using gravel, road base, and rock to reduce fugitive dust and other erosion.
- Use erosion control blanket on critical areas if plausible, where high erosion rates and steep slopes are a concern.
- Limit high disturbance maneuvers (neutral-steer turns for tracked vehicles, high-speed turns in muddy areas by wheeled vehicles, bivouac training on non-hardened sites) in areas that are already partially degraded due to erosion, invasive plant species, poor soils, etc.
- Expand prescribed burn program in shortgrass prairie to landscape scales outside of SDZs and installation perimeter areas where burns are currently conducted. We recommend the installation target a historic fire return interval estimated at 5-30 years (mean 15-20 year fire return) to achieve multiple ecological benefits and manage fuel loads to avoid high-severity, large scale burns that cannot be managed. This effort would need to incorporate site-specific considerations with respect to fuels, weather/drought, weeds, and watershed condition.
- Increase the use of two-track over completely cleared roads/trails especially those that are used solely for transit/convoy and not maneuvers.
- Pursue a change in procedure to allow LRAM funding for all sites that negatively impact training, regardless of the site's environmental compliance status, or whether or not the issue was caused by training.
- Use prescribed fires and biological control for noxious weed management to complement mechanical or chemical control. Continue partnership with the Colorado Department of Agriculture's Palisade Insectary.

# 9 Burrowing Owl (*Athene cunicularia hypugaea*)

## 9.1 Range, Distribution, and Abundance

Burrowing owls occur in North, Central, and South America, and the West Indies (Haug et al. 1993; Desmond et al. 2001) (Figure 58). Two subspecies are found in North America: the Western burrowing owl (*A. c. hypugaea*) and the Florida burrowing owl (*A. c. floridana*) (Desmond et al. 2001, Korfanta 2001). This assessment focuses on the Western burrowing owl (burrowing owl hereafter), which is found in the central and western United States, as well as Mexico (Klute et al. 2003).

The breeding distribution of the burrowing owl appears to be changing, with contractions in the northern and eastern portion of its range, and expansion to the south, into areas of Mexico that formerly only supported wintering migrants (Klute et al. 2003, Marcias-Duarte and Conway 2015). Conway et al. (2010) determined that this apparent contraction in the burrowing owl's distribution was real as opposed to an artifact of the BBS sampling scheme. Their models confirmed a retraction of the burrowing owl's breeding range over the past 40 years, with extirpation of local populations in the northern, eastern, and western periphery. They went on to note that burrowing owl populations have increased dramatically in the irrigated agricultural valleys of California and Arizona (citing Sauer et al. 2008), with high densities in California's Imperial Valley and northwestern Mexico (citing A. Macı´as-Duarte unpubl. data). This directional shift is counter to the general expectation that climate change may shift species' ranges northward. The 2016 PIF Landbird Plan estimated the burrowing owl population in the U.S. and Canada population as 1,100,000 (Rosenberg et al. 2016). According to Breeding Bird Survey data, the greatest abundances occur in southeastern Colorado, followed by southern California and along the New Mexico/Texas border (Figure 59, Sauer et al. 2016).

Burrowing owls in the northern portion of the range, including southern Canada and most of the western coterminous U.S., are migratory; birds south of the extreme southern U.S. are resident. Migration is not well understood. In general, it appears that owls breeding in the Pacific Northwest migrate along the Pacific coast, while owls breeding in the interior west migrate along the western plains into south-central U.S. and Mexico (Klute et al. 2003). Most burrowing owls winter in the southwestern U.S., Mexico, and Central America, but may also occur in low abundances further north (e.g., Oklahoma, Kansas). However, a more recent study suggests a high level of connectivity throughout the burrowing owl's range. Conway et al. (2010) found that northern locations (Canada and the northern U.S.) received immigrants from locations as far south as central California, southern Nevada, and western Arizona. Populations at intermediate latitudes (e.g, eastern Colorado) received immigrants from Canada all the way to central Mexico. Their stable isotope, genetic, and telemetry data suggest that most burrowing owl populations throughout western North America have high connectivity and little or no genetic differentiation.

In Colorado, breeding records for burrowing owl have been documented across the Western Slope and the San Luis Valley, but the majority are on the eastern plains (Figure 60, Wickersham 2016), at the geographic center of this species' U.S. breeding range (VerCauteren et al. 2001, Wellicome and Holyroyd 2001). Total detections of breeding birds in the second Colordo Breeding Bird Atlas (BBA II, Wickersham 2016) increased over the first Colorado Breeding Bird Atlas (BBA I, Kingery 1998) by 38%. Distribution of breeding burrowing owls in BBA II compared to BBA I indicate a loss of breeding birds from North Park, but an expansion in the San Luis Valley and the Western Slope, with detections in every county along Colorado's western boundary (Figure 61, Wickersham 2016).

All DoD installations in Colorado occur within the burrowing owl's core breeding range and contain their preferred habitats. The most expansive areas of shortgrass prairie habitat are found at Fort Carson and PCMS. The following summary of burrowing owl occupancy on Fort Carson was taken from Clawges (2014). At Fort Carson, burrowing owls have been documented within Training Areas 1, 5, 30, 31, 36, 53, 54, and Range 119, with the highest concentrations of individuals in Training Areas 34 and 52 (Figures 3 and 62). All burrowing owl observations have been in active prairie dog colonies. The number and size of prairie dog colonies have been fluid, as is common in prairie dog colonies in general. In 2013, there were 77 colonies, totaling 2,702 acres, up from 65 colonies totaling 6,513 acres in 2009. Of the 2013 colonies, 26 (34%) showed some evidence of plague since 2009. Vehicular damage was observed in 20 (26%) of colonies. Mapping in 2013 included 13 additional colonies compared to 2009 (9 new colonies and 4 colonies inactive in 2009 but resettled 2013). Ten of the active colonies mapped in 2009 were inactive in 2013 (5 abandoned or died out, 3 lost to construction, and 2 from lethal control). Each of these 10 colonies was < 10 acres. Seven colonies lost more than 100 acres each between 2009 and 2013, with all showing signs of plague. One colony gained over 100 acres between 2009 and 2013 Clawges 2014).

Five prairie dog colonies had burrowing owls in 2013 (29, of which 25 were adults, 2 were juveniles, and ages of 2 were unknown). In 2012, owls were detected in 6 colonies (28 owls, 23 adults, 3 juveniles, 2 age unknown). There were 4 colonies with owls detected in both years. All of these colonies have experienced plague within the past 4 years. Owl numbers were greater in these colonies before plague events. Fewer burrowing owls were documented in 2012 – 2013 compared to previous years. This could be due to reduced acres of active prairie dog colonies, or it could reflect survey effort (i.e., there were more biologists available to survey from 2007-2011) (Clawges 2014).

Detailed information on prairie dog colonies and burrowing owl data for PCMS from 2012 to 2017 indicated widely fluctuating spatial extent of active prairie dog colonies (e.g., a high of 5,457 acres in 2014; a low of 303 acres in 2017). After a decline of approximately 94% in active acres of prairie dog colonies between 2015 and 2017, the declining colony was tested for the plague. Though the results came back negative, plague is still the most likely cause of the widespread decline (M. Blake, pers. comm.). Increased survey efforts and additional survey methodology (e.g., aerial surveys) after 2012 resulted in the discovery of additional colonies. Whether these are new colonies or existing colonies recently discovered is unknown.

Burrowing owl observations from PCMS include: 124 owls in 2012, 111 owls in 2013, 185 in 2014, 405 owls in 2015, 251 in 2016, and 225 in 2017. Beginning in 2014, all surveys were conducted after July 1, due to the fact that prior to this date chicks and females could be underground, thus avoiding detection. During two years owls were documented on PCMS as late as December. Distribution of prairie dog colonies are shown in Figure 63.

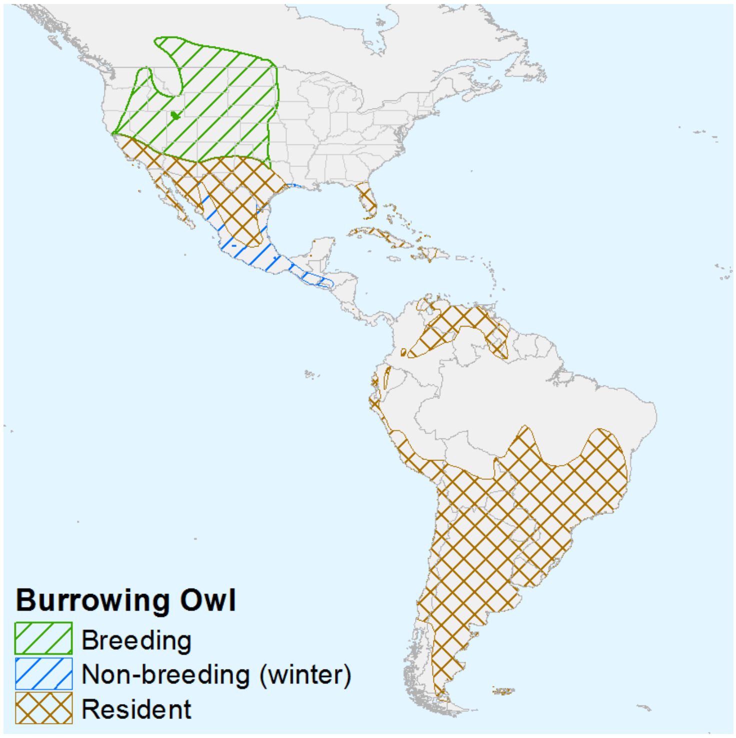



**Figure 58. Distribution of burrowing owl.** Both the western burrowing owl (*Athene cunicularia hypugaea*) and the Florida burrowing owl (*A. c. floridana*) are shown. All colored areas are within the western burrowing owl range, except Florida and the Bahamas, which represent the range of the Florida burrowing owl. Source: Birdlife International and NatureServe 2015.

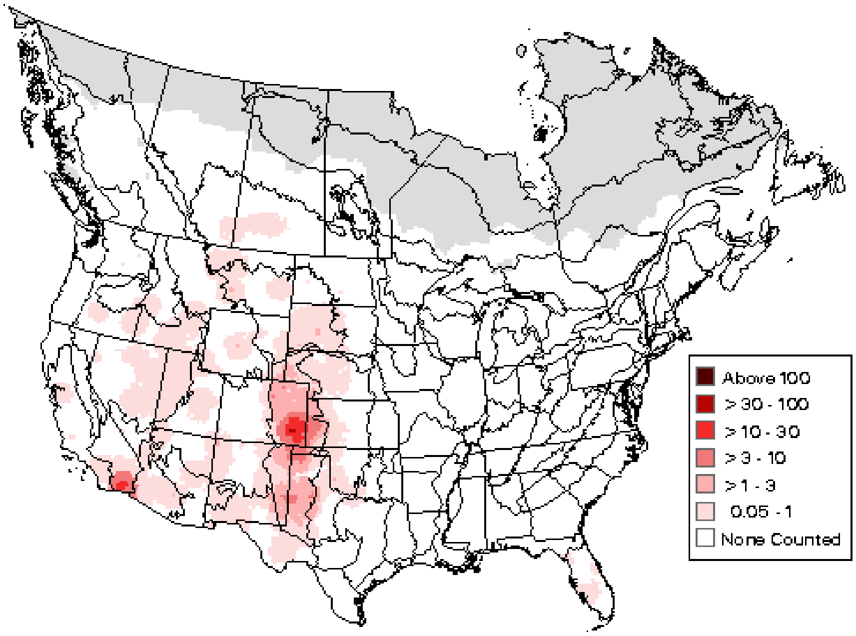



**Figure 59. BBS summer distribution 2007 – 2013.** This map is a simple summary of relative abundance based on raw BBS data, using average counts of burrowing owls observed on each route over the time interval (https://www.mbr-pwrc.usgs.gov/bbs/ra2013/ra03780.htm).

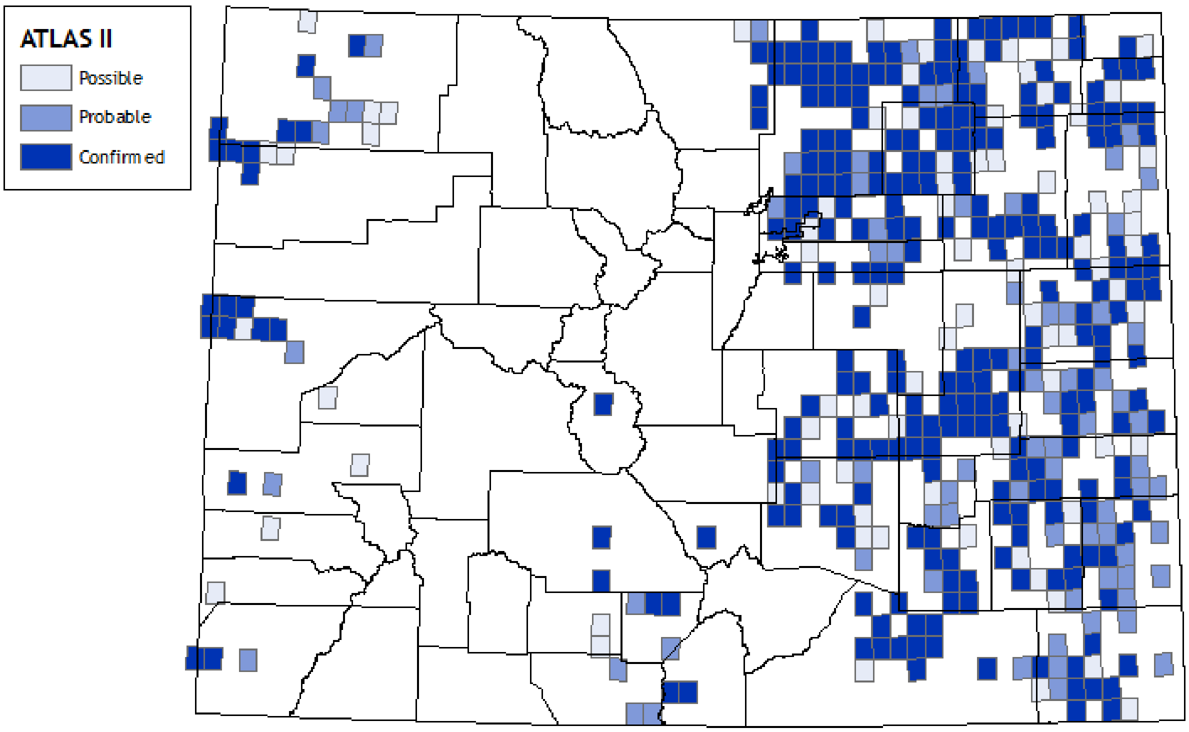



**Figure 60. Burrowing owl distribution in Colorado.** Source: Wickersham 2016.

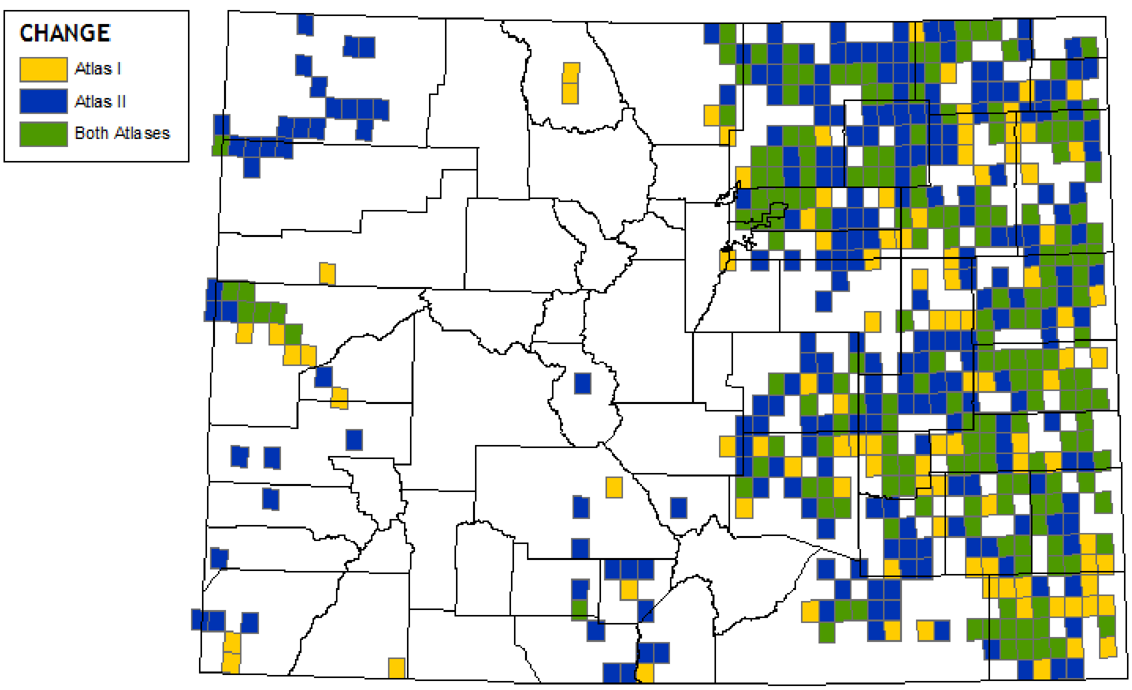



**Figure 61. Change in burrowing owl breeding distribution in Colorado from Breeding Bird Atlas I to Breeding Bird Atlas II.** Source: Wickersham 2016.

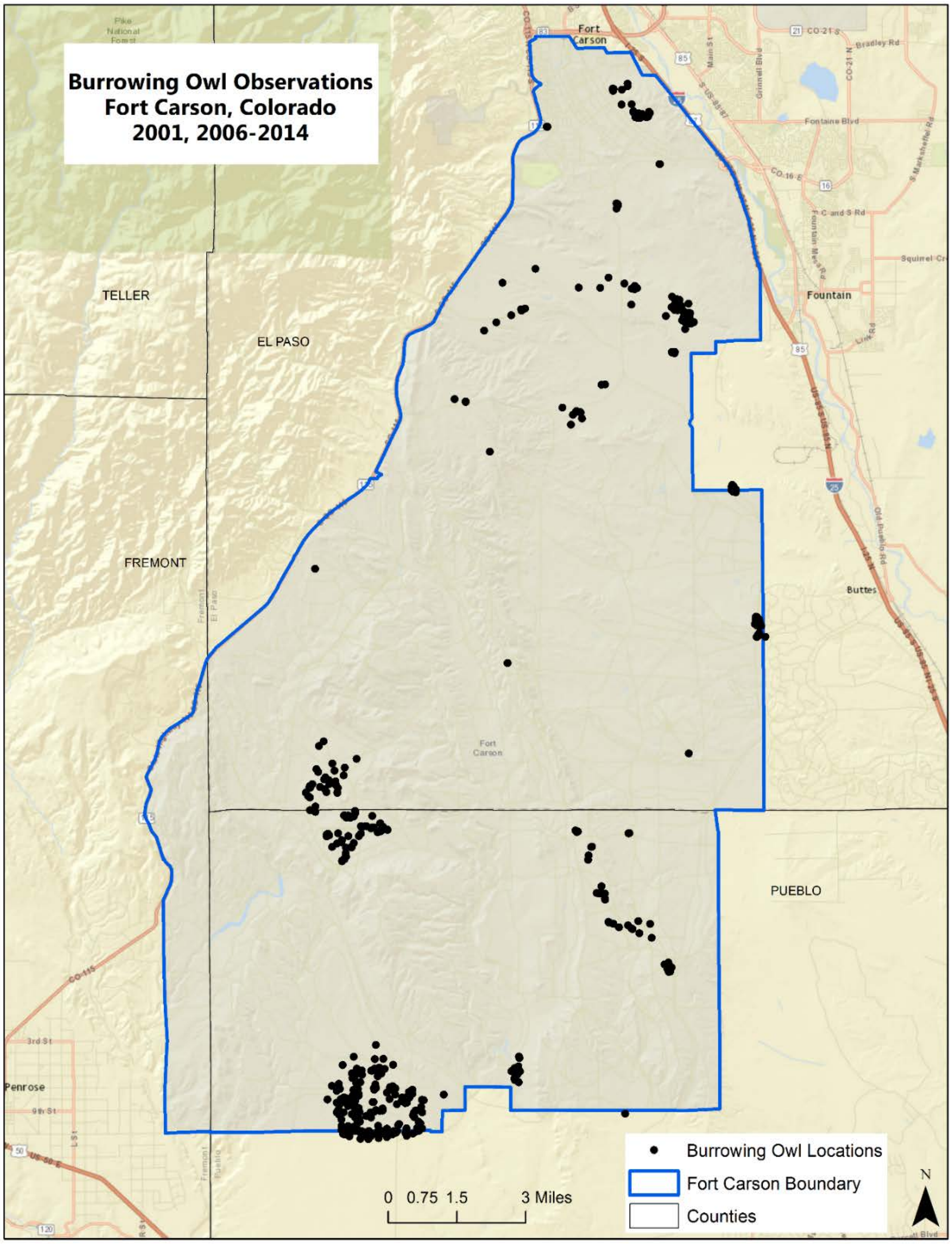



**Figure 62. Burrowing owl locations at Fort Carson during 2001, 2006-2014.** All observations were documented within prairie dog colonies. Source: Clawges 2014.

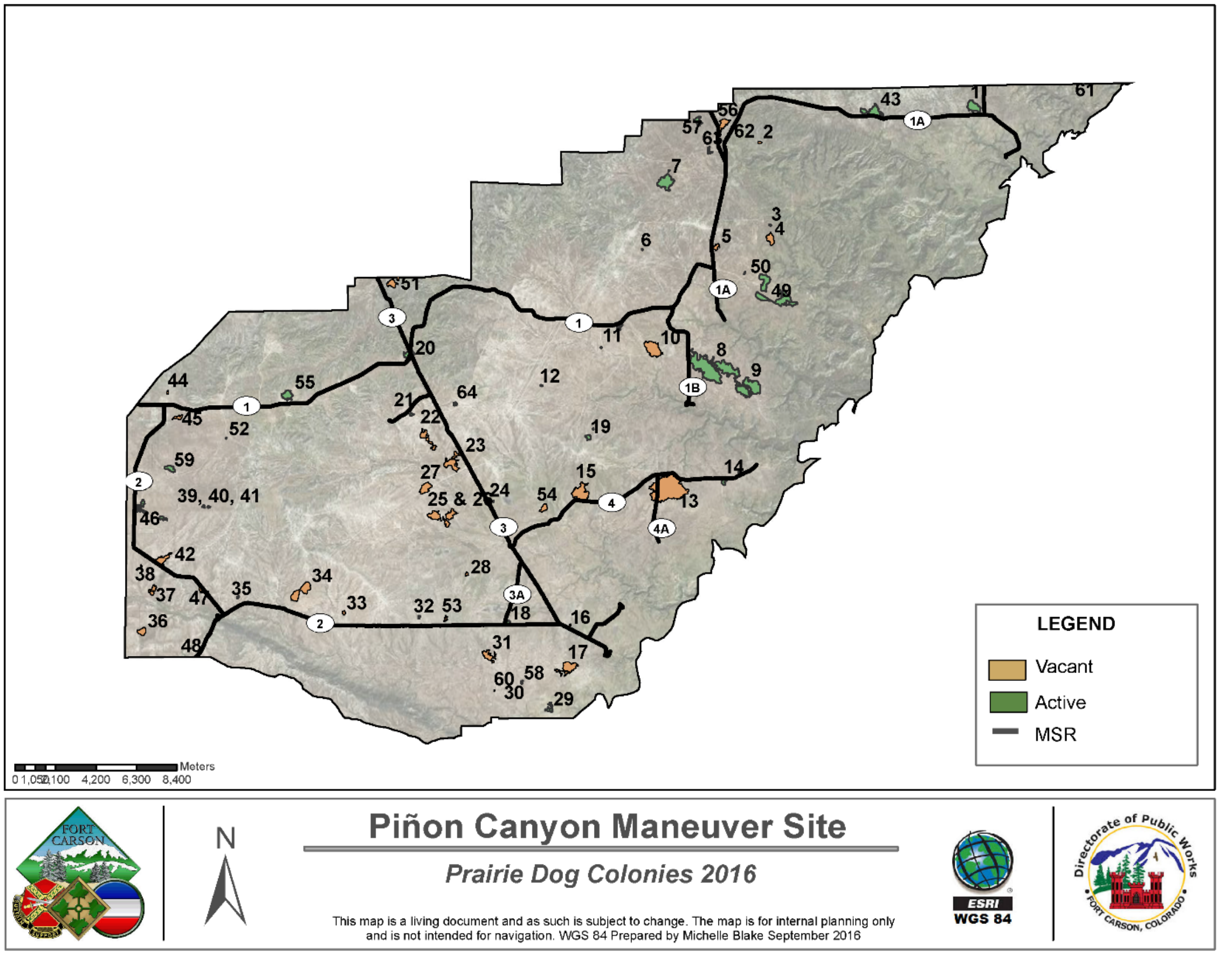



**Figure 63. Prairie dog colonies on PCMS.** Source: M. Blake, PCMS, unpublished data.

## 9.2 Conservation Status

Various sources report differing information on the status of this species. Based on Breeding Bird Survey data, Klute et al. (2003) reported that burrowing owl numbers have dropped significantly in Canada, with U.S. populations declining in the northern half of the Great Plains but increasing in the interior U.S. and southwestern deserts. The most recent analysis of Breeding Bird Survey data show a mixed trend for burrowing owl across the U.S. and Canada (1966-2013 data), with decreases in Canada, portions of the Great Basin, and the eastern and southern portions of its range, but increases in other areas including southeastern Colorado (Figure 64, Sauer et al. 2016). Klute et al. (2003) noted that the BBS does not adequately sample this species over a large portion of its range and that trend information is limited by small sample sizes. Conway et al. (2010) considered BBS data to be better for estimating change in burrowing owl distribution than abundance due to low population density, patchy distribution, and the tendency for breeding near roads. Rosenberg et al. (2016) estimated a 35% decrease overall across the U.S. and Canada during the 1970-2014 timeframe. Conway et al. (2010) theorized that inconsistent trends across the owl's range (i.e., decreasing in the northern and eastern periphery, but stable or increasing in the U.S. desert southwest U.S. and northwestern Mexico) may be due to owls becoming less migratory, with birds becoming resident in southern locations rather than continuing to migrate to northern locations. Breeding burrowing owls are no longer found in Minnesota, Iowa, the eastern portion of the Dakotas, British Columbia, or Manitoba (Wickersham 2016).

This species is included on the following conservation status lists:

***International***

- Endangered in Canada
- Threatened in Mexico

***National***

- U.S. Fish and Wildlife Service Birds of Conservation Concern
- U.S. Fish and Wildlife Service Migratory Birds Program Focal Species
- DoD PIF Mission-Sensitive Priority Bird Species (i.e., determined to have greatest potential impact on military mission if listed)
- Bureau of Land Management Sensitive Species in Arizona, California, Colorado, Montana, New Mexico, Oregon/Washington, and Wyoming
- U.S. Forest Service Regions 1 (Montana, North Dakota), 2 (Colorado, Kansas, Nebraska, South Dakota, Wyoming), and 3 (Arizona, New Mexico).

***State***

- Species of Greatest Conservation Need in Arizona, California, Colorado (Tier 1), Kansas, Idaho, Montana, Oregon, Nebraska (Tier 1), Nevada, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, Utah, Washington, and Wyoming (Tier 1)
- Natural Heritage Program conservation status ranked Imperiled in Texas, and Vulnerable in Arizona, Nevada, New Mexico, and Oregon.

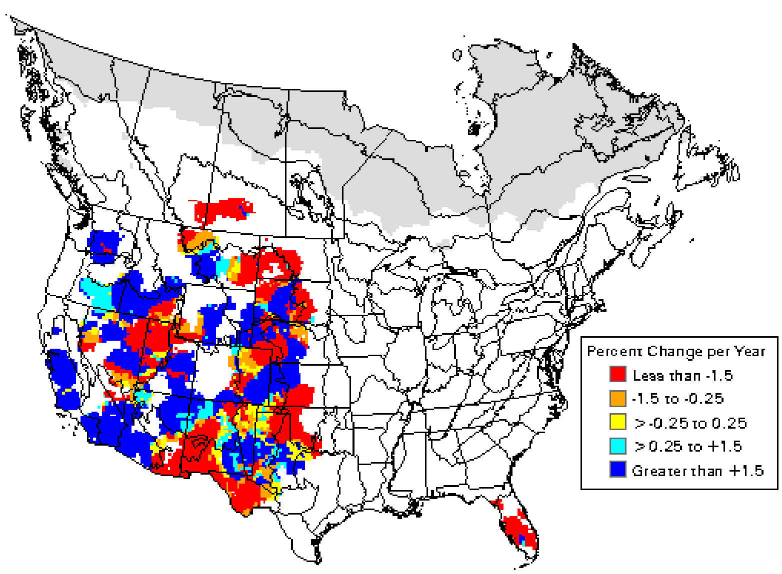



**Figure 64. Burrowing owl trend based on BBS data from 1966-2013.** Source: Sauer et al. 2014.

## 9.3 Species Requirements

### 9.3.1 Habitat

The burrowing owl typically nests in relatively flat, open, sparsely vegetated areas in North America, including deserts, grasslands, and shrubsteppe, as well as habitats that are highly altered by human activity, including golf courses, airports, vacant lots in urban settings, and cemeteries (Haug et al. 1993, Jones 1998, Dechant et al. 1999). Within these open habitats, burrowing owls rely on two key habitat characteristics: reduced vegetation and the presence of burrows (Butts 1973, Desmond 1991, Haug et al. 1993). Since burrowing owls generally do not excavate their own burrows for nesting sites, they rely on burrowing mammals such as prairie dogs (*Cynomys* spp.), badgers, and ground squirrels (Desmond 1991, Desmond and Savidge 1996, 1998, 1999, Sidle et al. 1998).

Components of preferred nesting sites include close proximity to other nesting burrowing owls and occupied prairie dog burrows, short vegetation around burrows along with low shrub and high forb densities, and presence of dried manure for lining nests (McDonald et al. 2004). Plumpton and Lutz (1993) found burrowing owls in Colorado to be significantly more likely to nest in sites with shorter grass and more bare ground than control sites.

Burrowing owls exhibit fidelity to general breeding areas and prairie dog colonies, and less frequently, particular nest burrows (Haug et al. 1993, Dechant et al. 1999). Owls are more likely to re-use nest burrows if they reproduced successfully during the previous year (Haug et al. 1993, Klute et al. 2003). Lutz and Plumption (1999), Griebel and Savidge (2007), and Lantz and Conway (2010) reported greater reproductive success at nests used the previous year compared to new nests in Colorado, South Dakota, and Wyoming, respectively. Lance and Conway suggested that reduced nest success in new nests could indicate differences between first year breeders and returning (i.e., more experienced birds).

In Colorado, burrowing owls are predominately found in shortgrass prairie habitats. Wickersham (2016) reports 78% of burrowing owl sightings from grasslands, of which 60% were in shortgrass prairie and the remainder in montane and introduced grasslands, followed by shrublands and cropland. Colorado's burrowing owls are strongly associated with prairie dog colonies (Martin 1983, Jones 1998, Wickersham 2016). Three species of prairie dog occur in Colorado: white–tailed prairie dog (*Cynonmys leucurus*) on the Western Slope, Gunnison's prairie dog (*Cynomys gunnisoni*) in central and western Colorado, and black-tailed prairie dog (*Cynomys ludovicianus*) on the eastern plains. Of these three species, only the black-tailed prairie dog occurs on Department of Defense lands along Colorado's Front Range.

#### *Use of Prairie Dog Colonies*

Burrowing owls nest in both active and inactive prairie dog colonies, although active colonies appear to be more important to the survival of the species (Desmond et al. 2000). Higher nesting density has been documented in prairie dog colonies where more prairie dog burrows are active (Hughes 1993). Studies have shown that burrowing owls in larger, well-populated prairie dog colonies are more likely to return to nesting sites, experience lower rates of nest depredation, and have higher rates of nesting success than owls in smaller colonies or in colonies with lower densities of prairie dogs (Butts 1973, Desmond and Savidge 1996, 1998, 1999, Toombs 1997).

Many studies have documented burrowing owls' preference for prairie dog colonies in general, and for active prairie dog colonies in particular. In eastern Colorado, burrowing owls are highly dependent on black-tailed prairie dog colonies (VerCauteren et al. 2001). Tipton et al. (2007) found significantly higher burrowing owl densities on prairie dog colonies compared to grasslands without prairie dogs or dryland agriculture in eastern Colorado. Restani et al. (2008) found that prairie dog colonies provided the vast majority of burrows used by burrowing owls in North Dakota despite an estimated 90% decline in prairie dogs there. Restani et al. (2001) found owl nests to be significantly closer to active than inactive prairie dog burrows (~15m v ~22m) in North Dakota. Desmond et al. (2000) found greater nest success in nests near active prairie dog burrows compared to inactive burrows. Tipton et al. (2007) found a strong association (~82%) between the probability of occupancy by burrowing owls and active prairie dog colonies in eastern Colorado. Bayless and Beier's (2011) study at Gunnison's prairie dog colonies in Arizona found occurrence of burrowing owl nests to be associated with mean number of active prairie dog burrows, total number of burrows, and the percent of active burrows within 50m. Burrowing owls will continue to use abandoned prairie dog colonies, though suitability of burrows declines about three years after disappearance of prairie dogs (Butts and Lewis 1982, McDonald et al. 2004).

Lance et al. (2006) studied active and inactive prairie dog colonies, both with and without burrowing owl nests, in Wyoming. They found that, regardless of colony category, burrows with nests had longer tunnels, higher burrow density within 30m, less shrub cover within 30m, and more prairie dog activity within 100 m than burrows without nests, with tunnel length being the most important variable. Burrows with nests were also closer to water (i.e., cattle tanks in their study area) than those without nests, which is consistent with previous findings of burrowing owls' attraction to water sources, possibly related to increased levels of prey (Rosenstock et al. 2004). Griebel and Savidge (2007), however, did not find either burrow length or nest distance to colony edge to be significantly related to reproductive success (i.e., clutch size, brood size, and number fledged per nesting attempt) in their South Dakota study.

Juveniles often roost in multiple satellite burrows near nest sites prior to dispersal, with active praire dog burrows often preferred over inactive burrows (Desmond and Savidge 1999). King and Belthoff (2001) found that, prior to dispersing, juveniles moved to satellite burrows between 38 and 280 m from their natal burrows. Juvenile used an average of over 5 satellite burrows, with individual satellite burrows being used for up to 14 days.

Reports describing the relationship between size of prairie dog colonies and occupation by owls are inconsistent. Several studies indicate that larger prairie dog colonies are preferable to smaller colonies. Griebel and Savidge (2007) found that colonies occupied by owls in their South Dakota study were significantly larger than unoccupied colonies, and that larger colonies supported more owl nests and produced more fledglings. Approximately 80-90% of unoccupied colonies in that study were smaller than 10ha. Alverson and Dinsmore (2014) found that prairie dog colony size had the greatest effect on patterns of burrowing owl occupancy at their study site in Montana. On the other hand, Orth and Kennedy (2001) did not find a difference in size between occupied and unoccupied prairie dog colonies in Colorado. Similarly, Bayless and Beier (2011) found that owl nests were not positively correlated with colony size or burrow density. Their results indicated that burrowing owls nested in areas with reduced slopes and lower elevations compared with random burrows in the same colonies, but suggested that owls may be selecting areas within the colony with greater prairie dog activity (i.e., gentler slopes are more attractive to prairie dogs due to less obstructed views) rather than responding to topography directly.

Characteristics of the landscape within which prairie dog colonies occur are important. Tipton et al. (2007) found that burrowing owl occupancy increased with landscape heterogeneity. In their study in eastern Colorado, owl occupancy was negatively affected by the amount of prairie dog colony in the surrounding landscape. They suggested that this result may reflect greater prey availability in more heterogeneous surroundings (i.e., over the larger foraging areas used by burrowing owls. Similarly, Restani et al. (2008) investigated the relationship between landscape characteristics surrounding prairie dog colonies with nesting burrowing owls in North Dakota. They found owl distribution and productivity were better predicted in landscapes with multiple cover types (crested wheatgrass, cropland, and prairie dog colonies), whereas amount of grassland and the number of habitat patches (an indicator of fragmentation) were unimportant. The authors suggested that once the requirement for nesting burrows were met, prairie dogs became comparatively unimportant for other habitat needs at the larger scale used for foraging, while presence of agricultural fields nearby provided greater abundance and variety of prey. Thiele et al. (2013) determined that, for burrowing owls nesting in prairie dog colonies in South Dakota, the percent of tree cover within 800 m of the burrow and level of visual obstruction at the burrow had the greatest effect on nest site selection. They further found that burrowing owls were less likely to nest in prairie dog colonies where trees were more abundant outside of the colony but within their home ranges, and suggested that small increases in tree cover can have disproportionately negative effects on nest site selection. They went on to note that even low levels of tree cover in the landscape can make a prairie dog colony unsuitable for burrowing owl nesting, regardless of local vegetation characteristics.

***Use of Agricultural Fields***

Burrowing owls commonly use agricultural fields, particularly in the southern and western portions of their range. Conway et al. (2010) reported that large breeding populations in deserts of the southern half of the range are all associated with irrigated agriculture and suburban areas rather than surrounding native vegetation. In the valleys of southern California, large populations of nesting burrowing owls occupy banks of irrigation canals, and in fact are highly dependent on them (Wilkerson and Siegel 2011). Rosenberg and Haley (2004) attributed high burrowing owl densities near irrigated agricultural fields in California's Imperial Valley to high quality foraging habitat. Moulton et al. (2006) noted frequent associations between burrowing owls and irrigated agricultural fields throughout some portions of their western range. They studied potential factors behind this association by comparing burrow availability, prey abundance, and predation between agricultural and nonagricultural sites in southwestern Idaho. Results indicated no difference in burrow availability and no difference in predation of dummy nests. More rodent species were trapped in agricultural habitat, and greater abundance and biomass of prey (primarily greater invertebrate prey) were indicated by analysis of pellets, suggesting that burrowing owls nesting near irrigated agricultural areas may be encouraged by increased availability and/or diversity of prey. The authors suggested that abundance of invertebrate prey in owl diets in agricultural habitat may allow them to breed more successfully in years of low rodent abundance compared to owls in nonagricultural habitat. Littles et al. (2007) suggested that burrowing owls' greater consumption of arthropods in agricultural areas may be a contributing factor in owl use of these environments.

Bartock and Conway (2010) documented characteristics of roadsides and irrigation systems in agricultural landscapes used by nesting burrowing owls. They found that roadsides with a higher number of banks and two parallel irrigation trenches side by side (and hence four banks) were more likely to have owls, and suggested that the presence of irrigation water probably increases prey availability (i.e., increased abundance of amphibians, aquatic insects, bats, and other prey, as well as higher abundance of herbivorous insects and small mammals supported by crops).

***Burrowing Owls in Urban Areas***

Carrete and Tella (2013) found a high level of consistency in fear of humans throughout individuals' lifespans in both urban and rural burrowing owls, suggesting that owls' tolerance of urban environments was not due to habituation. Rebolo-Ifrán et al. (2015) compared stress levels, as measured by flight initiation distance and levels of the stress hormone corticosterone, in burrowing owls inhabiting urban and rural areas in Argentina. They found shorter flight initiation distances in urban birds, no difference in hormone levels, and no correlation between hormone levels and flight initiation distance. Both rural and urban individuals showed a high level of consistency in flight initiation distance throughout their lifespan. The authors determined that urban environments did not constitute an additional source of stress, but rather urban areas were inhabited by individuals who were better able to cope with contant human disturbance.

***Diet and Foraging Habitat***

Burrowing owls are opportunistic feeders, with a wide variety of vertebrate and invertebrate prey species documented. Small mammals and insects form a large part of the adult and chick diet on the breeding grounds (Poulin et al. 2011). Common prey include deer mice (*Peromyscus maniculatus*), thirteen lined ground squirrels (*Spermophilus tridecemlineatus*), beetles (Coleoptera), and grasshoppers (Orthoptera) (Plumpton and Lutz 1993). Littles et al. (2007) found that 98% of prey items recovered in their study in Texas were arthropods, with crickets comprising approximately half, followed by lepidoptera, beetles, spiders, and earwigs. Small mammals and birds represented only 2% by number but 71% by biomass. Trulio and Higgins (2012) also found the greatest number of prey species were invertebrates, but the greatest biomass came from vertebrates. Hall et al. (2009) reported crickets, grasshoppers, beetles, rodents, sun spiders, and scorpions as the most frequently occurring prey in Nevada, with invertebrates less frequent in winter and vertebrates more frequent in spring. This is consistent with earlier reports of burrowing owls relying more heavily on rodents in spring and on insects in summer (Green and Anthony 1989).

The burrowing owl forages in a variety of relatively treeless habitats, including grasslands, pasture, hayland, and crop fields (Biddle 1996), with variable reports of preferred foraging habitat probably associated with degree of abundance and accessible of prey species. For example, some authors report that cropland is avoided (Haug and Oliphant 1990, Sissons et al. 2001), while others document owls using these areas (Butts 1973, Gleason 1978, Rich 1986) (but see discussion of prey availability in agricultural landscapes in the "Use of Agricultural Fields" section above.). Trulio and Higgins's (2012) study in urban grasslands near the San Francisco Bay region of California found that the rodent component of burrowing owl diets there was comparable to that of other portions of the owl's range in terms of importance, though the prey species were different.

Vegetation taller than 1m may be unsuitable for locating or catching prey (Wellicome 1994, Klute et al. 2003). However, Clayton and Schmutz (1999) observed burrowing owls foraging in tall vegetation from perches. McDonald et al. (2004) summarized the variability of vegetation height in foraging habitat as dependent upon local trade-offs between higher prey availability and higher predation risk.

***Migration and Winter Habitat***

Migration and winter habitats are not well understood, but are presumed to be similar to breeding habitat. Increased winter use of agricultural fields with culverts has been reported (Haug et al. 1993, Klute et al. 2003). Williford et al. (2009) studied wintering burrowing owls in an area of southern Texas that had undergone significant conversion of native habitat to farmland. They found that owls occupy culverts in agricultural landscapes, with culverts characterized by small diameter (≤16cm), absence of grass and woody vegetation, and presence of crop stubble more likely to be occupied. Unmowed roadside culverts were less likely to be used.

***Habitat on Fort Carson and PCMS***

Fort Carson contains 48,135 acres of shortgrass prairie. PCMS contains 170,826 acres. Buildings, air fields, storage tanks and other infrastructure have been built within burrowing owl habitat on both installations. Reports from recent sampling years at Fort Carson indicate that shortgrass prairie condition may be in decline. Composition of perennial native species across Fort Carson declined from 2009 to 2012, and erosion disturbance has increased (Schulte 2012)). During this timeframe, drought conditions were in effect, which resulted in decreased forage availability for prairie dogs (Clawges 2014). The distribution of prairie dogs has been highly variable since 2001, with boundaries changing and plague outbreaks occurring from year to year.

## 9.3.2 Spacing and Movement

Burrowing owls generally tend toward colonial nesting. Various studies have documented clumped distribution of nest sites, with loose aggregation in badger burrows (where coloniality of burrows is less than that in prairie dog colonies), as well as in large prairie dog colonies where excess burrows are available (Gleason 1978, Haug 1985, Green and Anthony 1989, Desmond et al. 1995, McDonald et al. 2004). Average reported nest densities are highly variable, ranging from 0.03 to 30 owls per hectare. Desmond and Savidge (1996) found densities of 0.03 to 0.4/ha in prairie dog colonies larger than 35 ha in Nebraska, but from 0.1 all the way up to 30/ha in prairie dog colonies smaller than 35 ha. Bayless and Beier (2011) found mean colony size of 16.6 ha and mean burrow densities of 57.7 active burrows/ha and 122.9 total burrows/ha, but reported that burrowing owl occupancy was not correlated with colony size or burrow density. They documented mean density of 2.9 owl nests per 100 ha of prairie dog colony, with an average 252 m between nearest neighbor nests in colonies with multiple pairs. There were fewer active, inactive, and total prairie dog burrows within 50 m of successful nests compared to unsuccessful nests. Griebel and Savidge's (2007) study in South Dakota found increased reproductive success (larger clutches, larger broods, and more fledglings) in owls with nests further from nearest neighbors or with fewer owl nests within 250 m of the nest burrow; neither of these metrics was related to size of prairie dog colonies. They suggested that the owls chose desirable portions within a large prairie dog colony, as opposed to randomly nesting throughout the prairie dog colony.

Home range sizes from 14 to 480 ha have been reported (Haug and Oliphant 1990). Other reports indicate average home range around 200 ha (McDonald 2004). Within home ranges, most movement is closer to burrows during the day compared to distances moved near sunrise and sunset (Klute et al. 2003). Reports of foraging distances are variable, with most daytime activity reported from 70 up to 600 m of burrows (Thompson and Anderson 1988, Haug and Oliphant 1990, Rosenberg and Haley cited as *in press* by McDonald et al. 2004). Moulton et al. (2004) used playback protocols to document that male burrowing owls defend their nest sites up to at least 100 m, a distance that encompassed some, but not all, of the area they used for foraging during nesting (i.e., up to 100m for invertebrate prey but up to 600 m for vertebrate prey).

Post-fledging movement is highly variable. Catlin and Rosenberg (2014) documented two female owls remaining within 100 m of their natal burrow in the Imperial Valley of California until the beginning of breeding season the following year. Other juvenile owls in that study left the nest throughout the year, moving up to 11.7 km between emergence and the following breeding season. Davies and Restani (2006) found that landscape context surrounding nest sites appeared to affect post-fledging movement at their study area in North Dakota. Juveniles generally remained relatively clost (mean maximum distance 140 m) during the post-fledging period, and then departed the area abruptly for autumn migration. They noted that the relatively small size of the colonies in their study area (35 ha) provided limited habitat for wider ranging movements.

Movement of over 53 km by adult burrowing owls during breeding season was documented in an unfragmented grassland in southern California by Rosier et al. (2006). The authors suggested that the high rate of nest failure may have been associated with owl movement, citing other studies documenting raptors in general and burrowing owls in particular dispersing in response to failure of first clutches (New ton 1979, Greenwood and Harvey 1982, Haug et al. 1993, Ronan 2002, Catlin 2004, Rosenberg and Haley 2004).

### 9.3.3 Phenology

The burrowing owl arrives in Colorado in late March or early April (Jones 1998). Pair formation, nest selections, and breeding occur within a few weeks (Grant 1965, Butts 1973, CDOW 2003). Egg incubation period is approximately 30 days (Plumpton and Lutz 1993), with young appearing above ground approximately two weeks after hatching. Colorado's second Breeding Bird Atlas documented active nests from April 8 through August 27 (Wickersham 2016). Females incubate the eggs in underground burrows while males provide almost all of the female's food requirements until the end of brooding (Haug et al. 1993). Burrowing owls are short-lived, breeding only once or twice in their lifetime (Haug et al. 1993, Wellicome 1997). Though burrowing owls generally leave Colorado in September (Jones 1998), they have been observed on PCMS as late as December (M. Blake, pers. comm.).

King and Belthoff's (2001) study in southwestern Idaho found that radio-tagged juveniles moved from their natal burrows when they were about 5 weeks old, and had permanently abandoned their natal burrows by 6 weeks old. The average date of dispersal to be 27 July (range: 15 July to 22 August), which was approximately 4 weeks after fledging. The average date of their last observation of radio-tagged juveniles was 13 August; almost all juveniles had departed the study area by early September. Mean departure dates in Davies and Restani's (2006) study area in North Dakota were August 24 to September 2, when juveniles were about 12 weeks old. Caitlin and Rosenberg (2014) found that the timing of fledging was related both to independence and to distance moved, with birds that fledged early in the season remaining closer to their nests for a longer period of time compared to those that fledged later.

## 9.4 Threats

The primary factors implicated as causes for burrowing owl population declines are habitat alteration and fragmentation, prairie dog eradication efforts, predation, and prey limitation. Fragmentation has reportedly increased populations of species that prey on burrowing owls in Canada (Wellicome and Haug 1995). Black-tailed prairie dogs, which provide important nesting habitat, have experienced as estimated 98% decline as well as a reduction in range, attributed to a combination of habitat loss and sylvatic plague (Sheffield 1997a, Kotliar et al. 1999, Hoogland 2006, Alverson and Dinsmore 2014). However, across most of its range, burrowing owls are able to successfully inhabit highly altered landscapes. Thus, the interplay of potential sources of stress and their impacts on burrowing owls are open to debate.

### 9.4.1 Residential / Commercial Development and Incompatible Agriculture

Across the range of the burrowing owl, habitat has undergone extensive conversion, particularly to urban development and crop agriculture. In Colorado, approximately 48% of the shortgrass prairie ecosystem, by far the most important system in the state for burrowing owls, has been converted to other uses (Neely et al. 2006). Shortgrass prairie is the most altered of Colorado's major ecological systems, and only a small portion of it is legally protected from conversion (Rondeau et al. 2011).

Aside from outright loss of habitat through permanent conversion, urban development and incompatible agriculture fragment remaining habitat, and often go hand in hand with elimination of prairie dog colonies, the burrowing owl's preferred habitat. Direct and indirect effects on burrowing owls from development and agricultural production have been variable. In addition to the discussion in the following sections, refer also to Section 9.4.1 for additional information on burrowing owl use of urban and agricultural landscapes.

***Urban Development***

Urban development is a significant source of habitat loss in many portions of the burrowing owl's range. Some individuals are able to live in urbanized landscapes, while others are not. Thus, the impacts of urbanization on this species are complex. For example, along the Front Range of Colorado, burrowing owls and other shortgrass prairie birds have declined or disappeared from previously occupied habitat (Jones and Bock 2002). In contrast, Chipman et al. (2008) found that urban and rural burrowing owls in Texas had comparable activity budgets and hunting success, but a high degree of variation between individuals within each land use type. They cited other studies suggesting trade-offs between urban and rural habitats, including higher mortality but also higher nesting success in urban sites in New Mexico (Botelho and Arrowood 1996), higher nest density and nesting success in agricultural sites than urban sites in Washington, but higher natal recruitment and adult return rate at urban locations (Conway et al. 2006). Also see Section 9.4.2 Transportation and Service Corridors.

***Incompatible Agriculture***

Like urban development, the effects of agriculture on burrowing owl are mixed. For example, Desmond (1991) reported higher fledgling success for owls nesting in croplands compared to rangelands in Nebraska. On the other hand, Clayton and Schmutz (1997) found higher post-fledging loss due to vehicle collisions in cultivated landscapes compared to unfragmented rangeland. Burrowing owls are able to successfully breed along roadsides and irrigation systems in agricultural landscapes. Bartock and Conway (2010) note that the Imperial Valley of California, an area heavily used for crop agriculture, is one of the few areas in the U.S. where Burrowing Owl populations increased significantly during the past 35 years (citing Sauer et al. 2008).

Livestock grazing is generally compatible with Burrowing Owls so long as the presence of burrowing rodents are tolerated. Many studies have shown that moderate to heaving grazing can create or improve burrowing owl habitat by reducing vegetation height and attracting burrowing rodents (Butts 1973, Wedgwood 1979, Kantrud 1981, Kantrud and Kologiski 1982, Faanes and Lingle 1995, Clayton 1997, Murphy et al. 2001).

McDonald et al.'s (2004) summary of information on the effects of agricultural production (both grazing and cultivation) suggests that a mix of rangeland and cropland may offer preferred nesting habitat in spring and increased foraging habitat in summer (citing Leptich 1994), with cultivated lands increasing abundance of prey as well as home range size (i.e., foraging distances) (citing Haug 1985, Belthoff and King 2002, and Rosenberg and Haley in press).

## 9.4.2 Transportation and Service Corridors

Roadways sometimes attract burrowing owls, but are also a potentially significant source of mortality. Burrowing owls often fly close to the ground, making them susceptible to vehicle collisions (Klute et al. 2003). Urban owls experience high rates of vehicle collisions (Boal and Mannan 1999, Millsap 2002, Roth et al. 2005, Hager 2009). Bayless and Beier (2011) found that dirt roads with low traffic volumes in their Arizona study area offered opportunities for rodent hunting, and successful own nests closer to roads than unsuccessful nests. Other studies note that the tendency to roost and hunt along roads increases potential for collision as well as predation by larger raptors also foraging along roads (Glazener 1963, Konrad and Gilmer 1984, Haug and Oliphant 1987, Clayton and Schmutz 1999, Millsap 2002, Ramsden 2003 Williford et al. 2009).

### 9.4.3 Biological Resource Use (including persecution)

A number of authors have identified rodent control programs (e.g., prairie dogs, ground squirrels) as a primary factor in declines of burrowing owl populations (Butts and Lewis 1982; Pezzolesi 1994; Desmond and Savidge 1996, 1998, 1999; Toombs 1997; Dechant et al. 1999; Desmond et al. 2000; Murphy et al. 2001, Klute et al. 2003). In addition to the loss of habitat that results from control of burrowing rodents, insecticides and rodenticides can reduce food supply and may be toxic to owls (Ratcliff 1986, James and Fox 1987, James et al. 1990, Baril 1993, PMRA 1995, Hjertaas 1997, Sheffield 1997b). Examples include: lowered owl body weight and breeding success in pastures treated with strychnine-coated grain (James et al. 1990), a 71% decline in breeding population of owls within one year of pesticide application in prairie dog colony (Butts 1973), and potential for direct mortality from ingestion of rodents poisoned with anticoagulants (Sheffield 1997b). James and Fox (1987) found the number of young in nests that experienced spraying of carbofuran within 50m of burrows were reduced by 54%; brood size and nesting success were reduced by >80% with direct overspray of nest burrows.

### 9.4.4 Invasive and Other Problematic Species

Burrowing owls can be negatively impacted by outbreaks of sylvatic plague that reduce prairie dog numbers colonies. Collapse of prairie dogs colonies after a plague episode may, at least temporarily, reduce or eliminate local burrowing owls. However, Alverson and Dinsmore (2014) found that plague history was not an important predictor of occupancy by burrowing owls (though colony size was). They noted that protecting prairie dogs from plague may be beneficial to owls, but outright protection of prairie dogs and their connectivity was more important.

Plague is fairly common within prairie dog colonies at Fort Carson (Clawges 2014) and at PCMS (D. Rodriguez, pers. comm.). A decrease in number of burrowing owls observed in prairie dog colonies has been documented at Fort Carson following plague events (Clawges 2014). After a possible plague outbreak between 2015 and 2017 at PCMS, there was a 94% decline in prairie dogs (M. Blake, pers. comm.). Dusting prairie dogs with deltamethrin, an insecticide to control fleas that infect prairie dogs with the plague bacterium, has been used at Fort Carson at select sites successfully according to site managers (Clawges 2014; INRMP 2014). Due to cost and personnel limitations, it is impractical to dust all active colonies at Fort Carson. Dusting was done on one prairie dog colony on PCMS. This colony is one of a handful of colonies that has survived the recent plague outbreak, possibly a result of the dusting (M. Blake, pers. comm.).

### 9.4.5 Climate Change

Some authors consider climate change to be a major threat to burrowing owl populations (Audubon Society 2015; Cruz-McDonnell and Wolf 2016). The National Audubon Society considers the burrowing owl to be “Climate Endangered.” According to their modeling, up to 77% of burrowing owl breeding habitat could be lost by 2080 (Figure 65). The model estimated that only 33% of its current winter range would remain intact, with the other 67% shifting to new locations but an overall increase in winter range of 29% (Audubon Society 2015). Cruz-McDonnell and Wolf (2016) documented a decline of 98% in a breeding population in New Mexico over a 16 year period, which was strongly associated with decreased precipitation and increased air temperature. These climate variables affected arrival on breeding grounds, pair formation, nest initiation, hatch dates, and body mass (Cruz-McDonnell and Wolf 2016).

Warming temperatures are projected throughout the shortgrass prairie ecological system (see Section 8.4.9). Winter and spring precipitation is projected to increase, while summer precipitation is expected to decrease. It is unknown how these potential shifts in climate may impact the prey base for burrowing owl, but some authors suggest that winter and spring precipitation are important predictors of prey availability for burrowing owl (Cruz-McDonnell and Wolfe 2016). Therefore, if Fort Carson and PCMS experience extreme drought conditions across winter, spring, and summer, this could result in declines in burrowing owl populations. Reports from Fort Carson indicate that drought may be a major factor in declines observed throughout the installation (Clawges 2014), but it is unknown how if drought conditions caused prey limitation.

To help us better understand relative vulnerability of the burrowing owl to climate change, we evaluated 21 direct and indirect factors related to species distribution, habitat connectivity, and life history using NatureServe's Climate Change Vulnerability Index tool (CCVI) (see Appendices B and C, respectively, for CCVI results for details on the CCVI tool). We considered the burrowing owl's distribution across the western U.S. as well as its distribution in Colorado, and found that the species ranked "Moderately Vulnerable" in Colorado but "Highly Vulnerable" in the western U.S. The primary factors driving vulnerability in our assessment were dependence on a few species for generation of habitat, and those species are expected to be adversely impacted by climate change, low levels of genetic diversity, and predicted loss of current breeding range (National Audubon Society 2015).

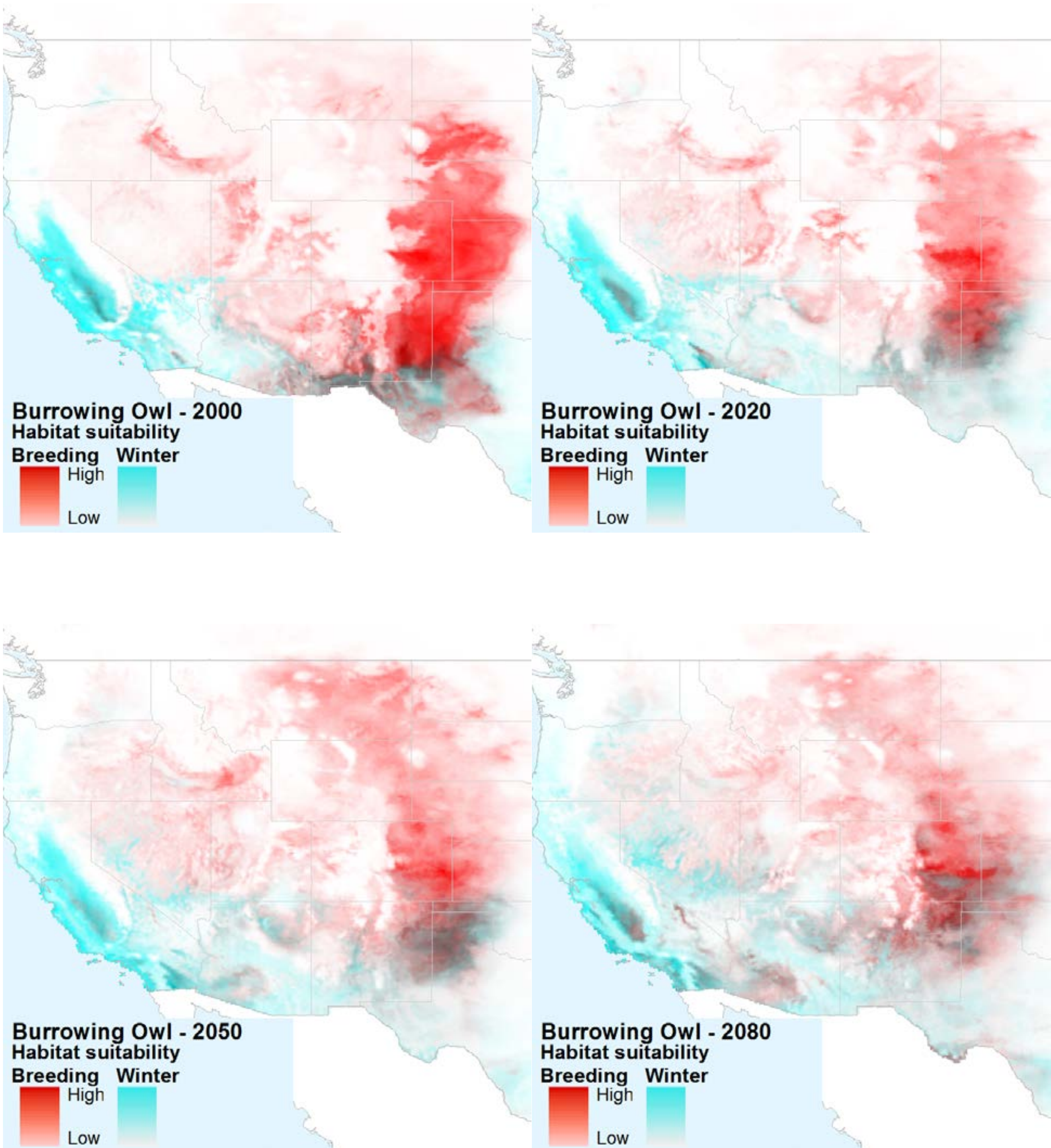



**Figure 65. Predicted current (2000) and future (2020, 2050, and 2080) habitat suitability.** Source: National Audubon Society 2013. Underlying models for summer and winter distribution can be found at http://climate.audubon.org/birds/burowl/burrowing-owl.

## 9.4.6 Threats on DoD Installations

Training activities can damage shortgrass prairie, resulting in the loss or degradation of nesting and foraging habitat for burrowing owl. Burrowing owls are more likely to be resilient to the direct effects of military training than other species due to spending much of their time underground as well as being more likely to nest in sites with shorter grass and more bare ground, as previously discussed.

Human intrusion and disturbance is an ongoing issue. According to Clawges (2014), bivouacs are commonly seen within prairie dog colonies on Fort Carson, despite environmental class instruction to avoid exposure. This is probably due to the fact that prairie dog areas are flat and have cropped vegetation, which provides an appealing setting for encampments. Site inspections and corrective action by Range Control staff may be the best way to deter soldiers from using these areas.

Although not a primary threat, burrowing owls are sometimes struck and killed by aircraft at Fort Carson and PCMS. The installations have created a plan to help avoid wildlife aircraft collisions called the Butts Army Airfield Wildlife Aircraft Strike Hazard Plan (Directorate of Public Works 2013). The plan recommends removing prairie dogs from airfields using poison gas and shooting to lower the likelihood of burrowing owl use and nest establishment in the prairie dog colonies. The plan also recommends that surveys should be conducted for burrowing owls prior to using poison gas for prairie dog control. For more information on burrowing owl and prairie dog control guidelines in the airfields at PCMS and Fort Carson, see the WASH Plan (2013) and the upcoming Prairie Dog Management Plan (anticipated release date is 2017).

***Fort Carson***

The best available data on the location and magnitude of training activities at Fort Carson is from data obtained from the installations regarding training occurring from 2004 to 2008. These data show that very little training occurred in Training Areas 34 and 52, where the majority of burrowing owl sightings have occurred.

Most military training within shortgrass prairie habitat was concentrated in Training Areas 29, 30, and 31 (Figure 3). The impact area in the eastern portion of Fort Carson is also shortgrass prairie habitat. Due to lack of access, species counts are not conducted in this area and populations are largely unknown. The majority of use came from the 3rd Battalion, 29th Field Artillery unit of the 3rd Armored Brigade Combat Team discussed in Chapter 2. This training occurred mostly during March and April, 2005 in preparation for their deployment to Operation Iraqi Freedom in November, 2005. This unit consists of three firing batteries of M109 Howitzer tanks, as well as numerous support vehicles and personnel. The training impact was likely highly intense, but short lived. As previously stated, the heaviest use was in Training Areas 29, 30, and 31 which form a small pocket of shortgrass prairie habitat within the mostly pinyon juniper habitat in the southwest region of the installation. Training in this habitat is sporadic in both time and space, however, it is highly impactful when training does occur in these areas. Due to the potential for high intensity training and the lack of data from the large patch of shortgrass habitat in the impact area, the burrowing owl is moderately vulnerable to potential military training activities at Fort Carson.

***PCMS***

The majority of acreage at the PCMS is shortgrass prairie habitat (Figure 17). As described in section 2.3.4, the majority of military training is conducted in the corridor formed by Training

Areas 7 & 10, within the core of this habitat type. Although the training occurring in this habitat type is intense, it is short-lived and most likely attenuated by the underground nature of this species. Due to these factors, the burrowing owl is moderately vulnerable to military training activities at the PCMS.

## 9.5 Management Recommendations

A variety of authors and researchers have offered recommendations for management of burrowing owl habitat. These include:

1. **Collaborate with partners to manage for landscape scale heterogeneity** (McDonald et al. 2004, Conway et al. 2010)
    a. Promote ecosystem processes that produce natural variation within native shortgrass to ensure that suitable habitat is available despite fluctuations in prairie dog populations. Include both strategic land/easement acquisition and partnerships with willing partners to meet land-management goals over a broad scale to achieve successful results (Tipton et al. 2007).

2. **Maintain populations of prairie dogs and other fossorial mammals to provide habitat and prey** (Wellicome and Holroyd 2001, Poulin et al. 2011, Conrey 2010, Conway et al. 2010, Alverson and Dinsmore 2014).
    a. Manage for larger prairie dog towns, at least 20-35 ha (Pezzolesi 1994, Desmond et al. 1995, Dechant et al. 1999, Latta et al. 1999, Klute et al. 2003),
    b. Maintain large, well-connected, active colonies (McDonald et al. 2004)
    c. Refrain from spraying pesticides within 400-600 m of owl nest burrows during the breeding season (Haug 1985, Haug and Oliphant 1990, James and Fox 1987).

3. **Conduct regular monitoring to document status of breeding populations.**
    a. Begin surveys for burrowing owls in mid-April; continue until mid-July to overlap the prelaying through prefledging stages of the nesting cycle. Visit nests at least every 7 days to improve accuracy of idenfitying critical dates (e.g., first egg laid, first fledged nestling, nest failure (Lantz and Conway 2010). This level of monitoring is more intensive than that currently undertaken at Fort Carson (Clawges 2014), so additional monitoring would be advisable when resources allow.
    b. Observation periods of 60 minutes are recommended; half-hour periods have been known to underestimate brood size (Bayless and Beier 2011).

Additional recommendations specific to Fort Carson and PCMS are based on Conway et al. (2010), who identified the importance of healthy dispersal rates across the burrowing owl's range, and the need to collaborate with partners (especially those in areas providing immigrant birds). They emphasized the potential for installation-level management to have regional population implications, and provided the following suggestions to guide regional management of burrowing owls across and among DoD installations and their partners:

1. Adopt and implement standardized monitoring protocols to identify conflicts between burrowing owl populations and the military mission early. As noted under 9.6.1, recommended monitoring intensity is greater than that currently employed at Fort Carson.
2. Work with local and regional partners to develop site-specific management plans for an area larger than the installation to support the extensive connectivity among burrowing owl populations.
3. Maintain low grasses adjacent to burrowing owl breeding sites.
4. Maintain burrowing mammals to provide nesting and roosting burrows and prey.
5. Develop site-specific plans that support maintenance of owl and rodent populations consistent with WASH safety needs.

## 9.6 Information Needs

A monitoring effort to document impacts of drought on prey species would improve forecasting of potential climate change impacts to burrowing owls.

# Cliffs, Canyons, and Outcrops Ecosystem and Golden Eagle

# 10 Cliffs, Canyons, and Outcrops (incl. Pine Barrens)

## 10.1 Origins, Distribution, and Composition

### 10.1.1 Origins

Cliff, canyon, and outcrop habitat is largely the product of weathering and erosion. Five to ten million years ago, the western Great Plains were a gentle eastward-sloping depositional plain. Remnants of this surface form the current High Plains, extending from northern Nebraska through the Texas Panhandle and are characterized by relatively low topographic relief (Figure 14). In some places streams with their headwaters in the High Plains surface (most notably the Republican, Arikaree and Smoky Hill rivers) have eroded modest valley systems several hundred feet deep where limestones and sandstones of the Ogallala Formation form small bluffs and outcrops.
At the northern edge of Colorado, a scarp cut in the calcium carbonate-cemented sands and silts of the upper Ogallala Formation of the High Plains forms the Chalk Bluffs (Scott 1978). Rimrock and erosional remnants of the High Plains escarpment stretch for many miles north of the South Platte River. The Pawnee Buttes are two of the more conspicuous outliers of High Plains rocks near the scarp. Far to the south, in eastern New Mexico and the Texas panhandle, the bounding escarpments of the Llano estacado are also formed in the Ogalalla Caprock (called the Mescalero Ridge to the west and the Caprock escarpment on the east). Topography at the edges of the High Plains ranges from steep rocky bluffs below the escarpments and buttes with intervening swales or gullies to smaller breaks and barrens with gentle slopes. The Ogallala, Arikaree, and White River Formations are the most common cliff and outcrop forming substrates, consisting primarily of sandstones of varying hardness, and often interspersed with limestone, ashy claystone, or volcanic tuff (Tweto 1979).

As regional uplift developed to the west, streams that had formerly deposited sediments on the nearly level plains for millions of years began to cut down through the sediment layers instead. The action of the South Platte River and its tributaries to the north, and the Arkansas and Canadian rivers and their tributaties to the south have removed great volumes of Tertiary (65- to 2-million-year-old) sedimentary rock layers of the Great Plains, leaving remnants of higher ground as well as bluffs and badlands throughout the piedmont of Colorado and northeastern New Mexico (Trimble 1980). North of Fort Morgan, Colorado, tributaries of the South Platte have formed rough, steep valley walls in the Cretaceous age Fox Hills formation (Scott 1978). On the opposite bank of the South Platte, Reardon Hills and Fremont Butte are remnants of Ogallala Formation sitting above badlands formed in White River siltstones. To the southeast, the Ogallala –White River boundary forms lines of rocky breaks northwest of Akron, Colorado.

Along the mountain front the layers of older sedimentary rock have been sharply upturned by the rise of the Rocky Mountains. These differentially eroded layers form conspicuous hogback ridges of hard sandstone and limestone that are prominent from the vicinity of Pikes Peak north into Wyoming. Near the Palmer divide north of Colorado Springs, outcrops are formed by caprock of resistant Oligocene Castle Rock Conglomerate on mesas and buttes. Shale barrens of the Niobrara Formation are also found near the mountain front. These and other outcrops of the Great Plains are exceptional in having escaped the nearly continuous mantle of windblown sand and silt that softens much of the rest of the Colorado Piedmont (Trimble 1980).

Extensive Tertiary volcanism in the Raton Section in southeastern Colorado, northeastern New Mexico, and the Oklahoma panhandle formed basalt-topped mesas and peaks with steeply sloping sides rising above the comparativel flat surrounding area. Cliffs of the Mesa de Maya region are formed in slowly eroding basalt near mesa tops, with more gentle slopes below formed in the softer underlying upper Cretaceous sediments (Scott 1968), and cliffs formed in the more resilient lower Cretaceous Dakota sandstone (Rogers 1953). Below the dissected mesas, the Pugatoire River and its tributaries have excavated an extensive canyon system reaching down into strata of Permian and Triassic age. Jurassic strata of the Morrison formation are above these, including the extensive Picketwire Canyonlands dinosaur trackway exposed in the main canyon of the Purgatoire. Canyon walls of the Apishapa, Purgatoire and their tributaries are largely formed in members of the Cretaceous Purgatoire Formation topped by Dakota sandstone.

With increasing distance from the canyon system, younger Cretaceous layers of the Carlile Shale, Greenhorn Limestone and Graneros Shale cover extensive areas in southeastern Colorado and northeastern New Mexico. These in turn are overlain by breaks and hills of gray shale and limestone belonging to the Niobrara Formation. Where softer formations are protected by less erodible overlying layers, breaks or cliffs may form. Shale breaks and pine barrens in southeastern Colorado are largely defined by the boundary between the Niobrara shale and the underlying Cretaceous strata. These habitats are most often found on Cretaceous bedrock of the Middle and Upper Chalk members of the Smoky Hills Member of the Niobrara Formation.

### 10.1.2 Distribution

Cliffs, outcrops, breaks, and barrens are scattered throughout most of the western Great Plains, in areas where windblown sediment does not mask underlying bedrock. In the northern portion of the region, occurrences include rimrock and erosional remnants of the High Plains escarpment stretching for many miles north of the South Platte River, as well as other isolated buttes and outcrops to the south. To the southwest, shale outcrop occurrences are most often found Cretaceous bedrock of the Middle and Upper Chalk members of the Smoky Hills Member of the Niobrara Formation. The area between Pueblo and Cañon City contains the highest frequency of such shale barrens in southeastern Colorado (Kelso 1999). Outcrops supporting open woodlands of primarily juniper ("pine barrens") are common on shale exposures in southeastern Colorado in an area ranging east from Pueblo to La Junta, and south to the New Mexico border in the vicinity of Trinchera.

Cliff habitats are most extensive along the mountain front, and on the steep edges of the basalt mesas that form dominant landmarks near the intersection of Colorado, New Mexico, and the Oklahoma panhandle. However, widespread dissected dry canyonlands of southeastern Colorado and northeastern New Mexico also provide extensive, if narrow, bands of potential cliff and outcrop habitat.

The small, scattered, and often vertical nature of these habitats makes it difficult to give an accurate estimate of total acreage. However, there are at least 125,000 acres of shale barrens in southwestern Colorado. Fort Carson, PCMS, and the Air Force Academy all have cliffs, canyons, and outcrops.

### 10.1.3 Composition – Soils

Substrates are variable, depending on underlying bedrock and action of geologic processes, and can include basalt, sandstone, limestone, clay, siltstone, and shale. Soils of cliffs and canyon walls are typically poorly developed and highly localized, since the accumulation of organic debris occurs only on ledges and in cracks or crevices, and rockfall can eliminate these deposits in an instant (Larson et al. 2000). Mineral components are derived from weathering of the component bedrock. Outcrops and barrens with less precipitous slopes are still subject to the continual movement of substrate under the influence of gravity.

Soils of limestone and shale breaks and barrens in southeastern Colorado are primarily classified in the Penrose series, consisting of shallow, well and somewhat excessively drained, moderate to slowly permeable soils formed in thin, calcareous, loamy materials weathered in place from limestone and interbedded limy materials (NRCS 2006). Penrose soils are on hills, plains, ridges, hogbacks, cuestas, and mesa tops. Slope angles range from flat on summits to moderately steep on side slopes, and exposures are variable, depending on how uplift, regional erosion, or downcutting has occurred (Kelso 1999). Sites feature highly weathered bedrock on the surface, consisting of small flat pieces less than four centimeters long that form a thin surface layer with shallow mineral soil underneath (Kelso et al. 2003). Soils belong to the Penrose series and are typically shallow and fine-grained, with about 60 percent of the particles composed of silts and clays. Soil pH tends to be alkaline with a range from 7.4 to 8.3 (Kelso et al. 2003). Summit flats have shallower soils than slopes, with slope bottoms generally deeper than slope tops (Kelso 1999).

Barrens are generally found on shales, soft limestone (chalk), or shale-derived soils, and are characterized by a high percentage of open, rocky ground between the low-growing shrubs and herbaceous cover. Some occurrences have an overstory of sparse juniper, and may include scattered larger shrubs and bunchgrasses. Shale substrates often form a rocky “pavement” between plants. In the Central Shortgrass Prairie ecoregion, this system may provide suitable habitats for northward range extension of species that are more typical further south (Kelso 1999). Little is known about biogeochemistry and nutrient cycling in these habitats. Productivity is generally low; both soil nutrients and moisture are probably limiting. These areas are dominated by the few species that can utilize barren areas with limited soil development.

Soils of the Mesa de Maya / Black Mesa region are formed in a variety of materials generally derived from basalt or underlying bedrock. Mesa-top soils are generally poorly developed, with a significant portion of weathered basalt, while deeper soils of the lower mesa slopes develop from the erosional debris that naturally collects at the base of slopes (colluvium), as well as material weathered from underlying sedimentary layers (Rogers 1953, 1954).

### 10.1.4 Composition – Vegetation

Vegetation patterns are controlled both by regional climatic variation and by site-specific environmental factors. Cliffs, canyons, and outcrops support a variety of plant communities, depending on the steepness, exposure, soil conditions of the site, and adjacent vegetation.

***Cliffs***

Vegetation of cliffs and rocky outcrops is typically sparse, and often restricted to shelves, cracks and crevices in the rock, or other areas where soil accumulation allows growth. Nevertheless, these microsites do provide limited habitat for both plants and animals.

On the plains, the tops of bluffs and escarpments are often dominated by the adjacent shortgrass or mixedgrass prairie communities. The lack of vegetation on many sites protects them from fire, and in a few instances the rocky cliffs support disjunct populations of foothills species such as ponderosa pine (*Pinus ponderosa*), Rocky Mountain juniper (*Juniperus scopulorum*), limber pine (*Pinus flexilis*), and mountain mahogany (*Cercocarpus montanus*). Sheltered areas on bluff slopes typically support sparse shrub cover of skunkbush sumac (*Rhus trilobata*), chokecherry (*Prunus virginiana*), currants (*Ribes* spp.), sand sagebrush (*Artemisia filifolia*), snakeweed (*Gutierrezia sarothrae*), pricklypear cactus (*Opuntia polyacantha*), and soapweed yucca (*Yucca glauca*). Prairie grasses from adjacent areas, including blue grama (*Bouteloua gracilis*), sideoats grama (*B.curtipendula*), prairie sandreed (*Calamovilfa longifolia*), and needle and thread (*Hesperostipa comata*) are typical components.

Cliff habitats of the mountain front typically include small patches of dense vegetation and scattered trees and/or shrubs. Characteristic trees includes Douglas fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*), and limber pine (*Pinus flexilis*), or pinyon (*Pinus edulis*) and juniper (*Juniperus* spp.) at lower elevations. Scattered shrubs may be present, including fivepetal cliffbush (*Jamesia americana*), creeping barberry (*Mahonia repens*), skunkbush sumac (*Rhus trilobata*), mountain mahogany (*Cercocarpus montanus*), rockspirea (*Holodiscus dumosus*), and currants (*Ribes* spp.).

***Canyons***

Open to moderately dense pinyon and juniper woodlands often occupy canyonland slopes. Scattered pinyon trees may occur within these woodlands but are never dominant. A mosaic of shrub species is characteristic of canyon walls and slopes, and varies with substrate and moisture availability. Common species include Bigelow sage (*Artemisia bigelovii*), mountain mahogany (*Cercocarpus montanus*), skunkbush sumac (*Rhus trilobata*), currants (*Ribes* spp.), common hoptree

(*Ptelea trifoliata*), littleleaf mockorange (*Philadelphus microphyllus*), and soapweed yucca (*Yucca glauca*). James' seaheath (*Frankenia jamesii*) and spiny greasebush (*Glossopetalon spinescens* var. *meionandrum* or *Forsellesia meionandra)* form a community restricted to gypsiferous and calciferous soils. Canyon floors, gravelly river benches and the bases of mesa slopes often support a degraded shrubby grassland of rubber rabbitbrush (*Ericameria* nauseosa) and tree cholla (*Cylindropuntia imbricata*) with an understory of blue grama (*Bouteloua gracilis*) and James' galleta (*Pleuraphis jamesii*). Rock outcrops with very sparse vegetation are also common.

Occasional seeps and springs of the canyon walls provide habitat for regionally rare ferns (Table 15). For the most part, these species represent xeric-adapted ferns that are rare in the western Great Plains but more widely distributed in more temperate parts of North America and beyond. With the exception of *Argyrochosma fendleri*, which ranges northward along the mountain front, these species are generally confined to the cliffs and outcrops of the Mesa de Maya and adjacent canyons.

**Table 15. Habitat and range of canyon ferns.**

| Species | Common Name | Habitat and Range (FNA 1993) |
|---|---|---|
| *Adiantum capillus-veneris* | Southern Maidenhair Fern | Moist calcareous cliffs, banks, and ledges along streams and rivers, walls of lime sinks, canyon walls (in the American southwest), around foundations, on mortar of storm drains; 0--2500 m; Lower 48 generally south of 40th parallel, disjunct in SD. Mexico; West Indies; Central America; South America in Venezuela, Peru; tropical to warm temperate regions in Eurasia and Africa. |
| *Argyrochosma fendleri* | Fendler Cloak-fern | Rocky slopes and cliffs; usually on granitic or volcanic substrates; 1700-3000 m; West central North America from Sonora in Mexico to WY. |
| *Asplenium platyneuron* | Ebony Spleenwort | An ecological generalist, particularly characteristic of disturbed woodlands. Tropical Africa, United States, West Indies. |
| *Asplenium resiliens* | Black-stem Spleenwort | Cliffs, sinkholes, on limestone or other basic rocks; 100-1500 m; Lower tier of states from NV to PA, south to FL; Mexico; West Indies in Hispaniola, Jamaica; Central America in Guatemala; South America. |
| *Astrolepis cochisensis* | Scaly Cloak Fern | Rocky slopes and cliffs; favoring limestone and other calcareous substrates; 400--2100 m; Southwestern U.S., CA to TX; n Mexico. |
| *Cheilanthes eatonii* | Eaton's Lipfern | Rocky slopes and ledges, found on a variety of substrates including limestone and granite; 300-3000 m; Southwestern U.S. UT/AZ., to TX/AR., disjunct from VA, WV; Mexico; Central America in Costa Rica. |
| *Notholaena standleyi (Cheilanthes standleyi)* | Star Cloakfern | Rocky slopes and cliffs, on a variety of substrates including granite and limestone; 300-2100 m; South central US: AZ, CO, NM, OK, TX; Mexico. |
| *Cheilanthes wootonii* | Wooton's Lacefern | Rocky slopes and ledges, usually on igneous substrates; 8002900 m; Southwestern U.S, CA to OK, TX; n Mexico. |

| Species | Common Name | Habitat and Range (FNA 1993) |
|---|---|---|
| *Pellaea atropurpurea* | Purple-stem Cliffbrake | Calcareous cliffs and rocky slopes, usually on limestone; 100-2500 m; widespread in eastern and central U.S. west to NV, WY and SD; Eastern Canada; Mexico; Central America in Guatemala. |
| *Pellaea glabella* ssp. *simplex* *(Pellaea suksdorfiana)* | Smooth Cliffbrake | Calcareous cliffs and ledges, usually on limestone; 900-3000 m; Western North America not including OR and CA. |
| *Pellaea wrightiana* | Wright's Cliffbrake | Cliffs and rocky slopes, on a variety of acidic to mildly basic substrates; 300-2900 m; Southwest and southcentral U.S. to northern Mexico. AZ, CO, NM, OK, TX, UT; disjunct from NC. |
| *Woodsia neomexicana* | New Mexico Cliff Fern | Cliffs and rocky slopes; usually on sandstone or igneous substrates; 300-3500 m; AZ, CO, NM, OK, SD, TX. |
| *Woodsia plummerae* | Plummer Woodsia | Cliffs and rocky slopes; usually on granite or volcanic substrates; 700-3100 m; AZ, CA, CO, NM, OK, TX; n Mexico. |

***Outcrops and barrens***

Claystone and limestone layers form gravelly barrens that support a characteristic "cushion plant" community that typically includes Hooker's sandwort (*Arenaria hookeri*), tufted evening primrose (*Oenothera caespitosa*), spiny phlox (*Phlox hoodii*), stemless four-nerve daisy (*Tetraneuris acaulis*), silky milkvetch (*Astragalus sericoleucus*), along with species typical of the nearby grasslands. These barrens are also home to the regionally rare plants Nuttall's biscuitroot (*Lomatium nuttallii*), mountain cryptantha (*Cryptantha cana*), and alpine feverfew (*Parthenium alpinum*).

In the southwestern portion of the region, cushion plant vegetation is characterized by cover less than 25%, and often much lower. Some occurrences ("pine barrens") may support a sparse overstory of one-seed juniper (*Juniperus monosperma*). Typical shrub species are James' seaheath (*Frankenia jamesii*), spiny greasebush (*Glossopetalon spinescens* var. *meionandrum*), fourwing saltbush (*Atriplex canescens*), and Bigelow sage *(Artemisia bigelovii*). Perennial low-growing forbs and sub-shrubs include stemless four-nerve daisy (*Tetraneuris acaulis*), buckwheat (*Eriogonum* spp.), Fendler's bladderpod (*Lesquerella fendleri*), ribseed sandmat (*Chamaesyce glyptosperma*), Hooker's Townsend daisy (*Townsendia hookeri*), plains blackfoot (*Melampodium leucanthum*), and Rocky Mountain zinnia (*Zinnia grandiflora*). Occurrences may include low cover of bunchgrasses such as New Mexico feathergrass (*Hesperostipa neomexicana*), Indian ricegrass *(Achnatherum hymenoides*), purple threeawn (*Aristida purpurea*), and grama grasses (*Bouteloua* spp.). Along with the substrate, wind appears to be an important factor shaping the appearance of these outcrops. As this community grades into adjacent communities in more sheltered areas below ridgetops, cover and plant height increases.

Shale or "chalk" barrens, either with or without an overstory, often support populations of narrowly endemic species, such as the Colorado endemics roundleaf four o'clock (*Mirabilis rotundifolius*), Pueblo goldenweed (*Oonopsis puebloensis*), and golden blazingstar (*Mentzelia chrysantha*). Kelso et al. (2003) found that plants endemic to the Niobrara chalk barrens in Colorado's Arkansas River Valley did not require the specialized chemistry of the chalk substrate, but rather were functionally adapted to survive in these habitats that exclude many species. Many of the barrens species have woody rhizomes or roots that are able to penetrate the thin, moisture-retentive chalk strata, allowing the plants to access limited soil moisture, and making them resistant to disturbance (Kelso et al. 2003).

## 10.2 Primary Ecological Processes

### 10.2.1 Weathering and Erosion

Cliffs, outcrops, breaks and barrens are all the result of erosional processes. The breakdown of substrate rocks (weathering) into soil is influenced by climate, vegetation and other biota, topography, parent material, and the passage of time. Erosion of weathered particles by wind, water, and the force of gravity is the primary natural disturbance process in these environments. Physical weathering includes the downward movement of rock and soil under the influence of gravity (mass wasting), including larger slips, slides and rockfalls, shrinking/swelling in response to changes in water content (mostly in shales and mudstones), direct pressure effects from the formation of ice and mineral crystals, thermal stress, and frost action (Larson et al. 2000). Chemical weathering in these environments is directly controlled by precipitation amount and chemistry, rock temperature, and the chemical composition of the rock. Chemical weathering is most prevalent under conditions of higher temperature and high precipitation, whereas physical weathering is more important at lower temperatures (Larson et al. 2000). The rate of erosion and the size of eroded rock particles have a strong influence over which organisms occur on cliffs, talus, and other outcrop sites (Larson et al. 2000).

***Cliffs***

Cliff environments are shaped by the parent rock type and strength, climate, aspect, and the weathering patterns produced by physical and chemical processes. Larson et al. (2000) define three basic parts of a cliff habitat: 1) the relatively level plateau at the top, 2) the vertical or near-vertical cliff face, and 3) the pediment or talus at the bottom of the face. These three elements share some physical characteristics, are linked by similar ecological processes, and often support the same plants and animals (Larson et al. 2000). Within the larger cliff habitat, steep slopes, small terraces ledges, overhangs, cracks and crevices often form a mosaic of microhabitat types that appears to be the primary factor contributing to cliff biodiversity (Graham and Knight 2004). In addition, the cliff rim is often windier than the surrounding plateau, providing a distinct microhabitat that differs from the nearby flatter areas. At cliff faces there is less hydraulic pressure retaining water within the rock, so liquid water is more consistently found than in the surrounding habitat types (Larson et al. 2000). Many, but not all, cliff environments in the region are found in canyons.

***Canyons***

Canyons of the Southern Rocky Mountains open onto the Great Plains. Additionally, in northeastern New Mexico and southeastern Colorado a combination of geologic uplift and fluvial processes have resulted in the formation of bedrock canyons on some reaches of the Canadian River in New Mexico, and the Purgatoire River in Colorado. Such landforms are the result of the interaction between tectonic activity, climate, and local topography (Venditti et al. 2014). Canyon incision through bedrock erosion is due to a combination of processes such as abrasion by sediment loads, plucking of rock blocks from the banks or river bed, cavitation, debris-flow scour, and weathering (Whipple et al. 2013).

***Outcrops and barrens***

Permanent flowing water is rare in the Western Great Plains. The action of major rivers and their generally ephemeral tributary networks in eastern Colorado (the South Platte and Arkansas drainages) and in eastern New Mexico (the Canadian and Pecos drainages) has excavated large volumes of sediment that once formed the High Plains surface just east of the mountain front. Although these large drainage networks may exhibit scattered rocky outcrops, most reaches consist of dry arroyos, gully networks with intervening shale badlands, and low river terraces that are not properly described as canyons, although some reaches may exhibit relatively steep sidewalls. Channel incision in these areas is largely driven by summer precipitation events, and flash flooding may play an important role in the evolution of these reaches (Tucker et al. 2006, DeLong et al. 2014). In general, outcrops and barrens are the result of differential resistance to erosion of underlying substrates.

## 10.2.2 Drought

Effects of drought on these sparsely vegetated habitats are little known, but Tucker et al. (2006) propose a mechanism whereby alternating episodes of drought that eliminates or weakens erosion-preventing vegetation, and intense summer storm activity producing high volume flows can lead to increased incision under drought conditions. In areas where trees are present (i.e., “pine barrens”), extended drought may result in extensive local mortality of woody vegetation.

## 10.2.3 Fire

Cliffs, outcrops, and barrens often serve as refugia for endemic species adapted to the particular environmental conditions of the site. Although fire can be an important element that slows and prevents tree establishment in many of these habitats, or removes established trees from pine barrens, the shallow soils over bedrock, and extremes of climate or microclimate, are important factors as well (Anderson et al. 1999). For rock outcrop communities with extensive exposed bedrock, fire is typically not an important disturbance factor. Differences in microhabitat between rock outcrop sites and the surrounding habitats with deeper soils produce distinctive vegetation of these sites.

## 10.2.4 Disturbance

Little is known about the system-level effects of disturbance, natural or anthropogenic in this ecosystem. Kelso et al. (2003) found no significant effect of disturbance by cattle grazing, camping, road proximity, motorcycle racing, or tracked vehicle maneuvers on the presence of *Mirabilis rotundifolius* in southeastern Colorado shale barrens. Some barrens species are not well adapted to disturbance, so moderate disturbance produces distinctive plant communities dominated by species that tolerate these activities (Kelso et al. 1999, 2003). Natural disturbance by wind and water erosion may have similar effects, leading to the differentiation of plant communities according to microsite characteristics. These communities are closely tied to edaphic conditions, so minor breaks or small barriers due to changes in substrate are part of the natural distribution and variability. If the breaks are larger, barriers may exist for some species.

## 10.3 Associated Species of Conservation Concern

In Colorado, cliffs and canyons support 18 Species of Greatest Conservation Need (CPW 2015) (Table 16). Of these, one species is federally listed (Mexican spotted owl), and almost all (14) are considered vulnerable, imperiled, or critically imperiled by NatureServe or the Colorado Natural Heritage Program. Of Colorado species inhabiting cliffs and canyons, this habitat type is *the* primary, or *a* primary habitat for 13 species. Two species have been named by DoD PIF as Mission-Sensitive Priority Bird Species: golden eagle and prairie falcon. Additional information on the golden eagle can be found in Section 11 of this report.

**Table 16. Colorado Species of Greatest Conservation Need that occur in cliff and canyon habitats (CPW 2015).** Table codes: **Federal listing status** – E=endangered; T=threatened. **Colorado listing status** – E=endangered; T=threatened; SC=Special Consern. **NatureServe Global Status Rank** and **Colorado Status Rank** – 1=Critically Imperiled; 2=Imperiled; 3=Vulnerable; 4=Presumed Secure; 5=Demonstrably Secure; B=breeding; N=non-breeding; T=subspecies; NR=not ranked; X=extirpated. * = species is on the Partners in Flight National Watchlist.

| Common Name | Scientific Name | Cliffs, Canyon, Outcrop is primary habitat? | Federal Listing Status | Colorado Listing Statis | Other State Listings | Colorado SGCN Tier | Other State SGCN | Colorado Trend | NatureServe Global Status Rank | NatureServe Colorado Status Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| Canyon tree frog | *Hyla arenicolor* | | | | | 2 | | Unknown | G5 | S2 |
| | | | | | | | | | | |
| American peregrine falcon | *Falco peregrinus anatum* | X | | C | TX | 2 | | Increasing | G4T4 | S2B |
| Black swift | *Cypseloides niger* | X | | | | 2 | NM | Stable* | G4 | S3B |
| Ferruginous hawk | *Buteo regalis* | | | C | | 2 | NM, OK, TX | Stable | G4 | S3B,S4N |
| Golden eagle | *Aquila chrysaetos* | X | | | | 1 | NM, OK, TX | Unknown | G5 | S3S4B,S4N |
| Mexican spotted owl | *Strix occidentalis lucida* | X | T | T | TX | 2 | NM, TX | Unknown | G3G4T3T4 | S1B,SUN |
| Prairie falcon | *Falco mexicanus* | X | | | | 2 | OK | Unknown | G5 | S4B,S4N |
| | | | | | | | | | | |
| A lampshade spider | *Hypochilus bonneti* | X | | | | 2 | | | GNR | |
| Colorado blue | *Euphilotes rita coloradensis* | X | | | | 2 | | | G3G4T2T3 | S2 |
| | | | | | | | | | | |
| Allen's big-eared bat | *Idionycteris phyllotis* | | | | | 2 | NM | Unknown | G4 | |
| Big free-tailed bat | *Nyctinomops macrotis* | X | | | | 2 | TX | Unknown | G5 | S1 |

| Common Name | Scientific Name | Cliffs, Canyon, Outcrop is primary habitat? | Federal Listing Status | Colorado Listing Statis | Other State Listings | Colorado SGCN Tier | Other State SGCN | Colorado Trend | NatureServe Global Status Rank | NatureServe Colorado Status Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| Bighorn sheep | *Ovis canadensis* | X | See footnote[21] | | | 2 | NM | Stable | G4 | S4 |
| Fringed myotis | *Myotis thysanodes* | X | | | | 1 | TX | Unknown | G4 | S3 |
| Little brown myotis | *Myotis lucifugus* | | | | | 1 | TX | Unknown | G3 | S3 |
| Spotted bat | *Euderma maculatum* | X | | | NM, TX | 1 | NM, TX | Stable | G4 | S2 |
| Townsend's big-eared bat ssp. | *Corynorhinus townsendii pallescens* | | | C | | 1 | TX | Unknown | G2G4T3T4 | S2 |
| | | | | | | | | | | |
| Midget faded rattlesnake | *Crotalus oreganus concolor* | X | | | | 2 | | Unknown | G5T4 | S3? |
| Colorado checkered whiptail | *Aspidoscelis neotesselata* | X | | | | 1 | | Stable | G2G3 | S2 |

[21] Peninsular Bighorn Sheep (*Ovis canadensis nelsoni*) = E, Sierra Nevada Bighorn Sheep (*Ovis canadensis sierrae*) = E

## 10.4 Incompatible Land Uses and Other Stresses

Cliff, canyon, and outcrop habitats in the region are somewhat impacted by anthropogenic disturbance, primarily that associated with energy production (especially wind turbine farms), transportation development, and in some areas, military maneuvers. Continued gradual habitat fragmentation and degradation is likely to have the greatest impact on rare or endemic species and plant communities. Warmer future conditions, coupled with a potential for increased frequency of severe storm events, may change the structure and distribution of these habitats considerably. Installations with cliff, canyon, and outcrop habitat present are primarily affected by development, depending on their size and location. Energy development is prevalent in the vicinity of several installations, but generally not those with cliff, canyon, and outcrop habitat. Roads of all sizes are generally present at low to moderate levels in the surroundings of all installations.

From a landscape-scale aerial mapping standpoint, the footprint of this system is often deceptively small. On the plains, this system is more significant than its footprint would suggest, due to the generally high topographic relief that is quite different from the surrounding landscape matrix in which it occurs. With the exception of some low-relief outcrops and barrens, this system does not readily lend itself to permanent human development or infrastructure. In terms of the mappable land uses that we analyzed, the greatest source of potential stress on cliffs, canyons, and outcrops is roads (Table 17).

**Table 17. Acres of potential impact from incompatible land uses in the cliff, canyon, and outcrop system.**

| Cliffs, Canyons, and Outcrops<br>Total acres: 325,816 | | |
|---|---|---|
| **Threat** | **Acres Vulnerable** | **% of total** |
| Development - High Intensity | 63,350 | 19% |
| Development - Low Intensity | 46,458 | 14% |
| Agriculture (crops) | 26,746 | 8% |
| Energy - Oil and Gas | 19,883 | 6% |
| Energy - Wind | 3,185 | 1% |
| Transportation – Major Roads (interstates, state highways, roads with four or more lanes) | 43,968 | 13% |
| Transportation – Minor Roads (local roads with fewer than four lanes) | 255,891 | 79% |
| **Total Acres *Not* within one mile of a mappable threat** | **25,957** | **8%** |

### 10.4.1 Residential and Commercial Development

Land use between and adjacent to cliff and outcrop areas can fragment the landscape and reduce connectivity between patches and between outcrops and the surrounding landscape. This fragmentation can adversely affect the movement of surface/ groundwater, nutrients, and dispersal of plants and animals. In areas near the larger population centers, some of these habitats are in areas that are highly desirable for suburban development, roads, or recreational infrastructure.

However, land use changes are most likely to convert areas of previously low intensity development into higher intensity development, contributing to increased fragmentation, but with little complete loss of habitat.

Within the region, about 63,000 acres of this habitat are within one mile of industrial or commercial (high intensity) development, and about 46,000 acres are within one mile of low urban or suburban (low intensity) development (Figure 66). The majority of developed acres in the vicinity of cliff and canyon habitats occur along the Rocky Mountain Front around the southern boundary of Fort Carson. Though much of the area around Fort Carson and the Air Force Academy is intensely developed, cliffs and canyons do not occur in those places. Forecasts of future residential development (urban, suburban, exurban, and rural) indicate slight increases (generally less than 1%) in exurban and rural development near these habitats over the coming century (EPA 2010).

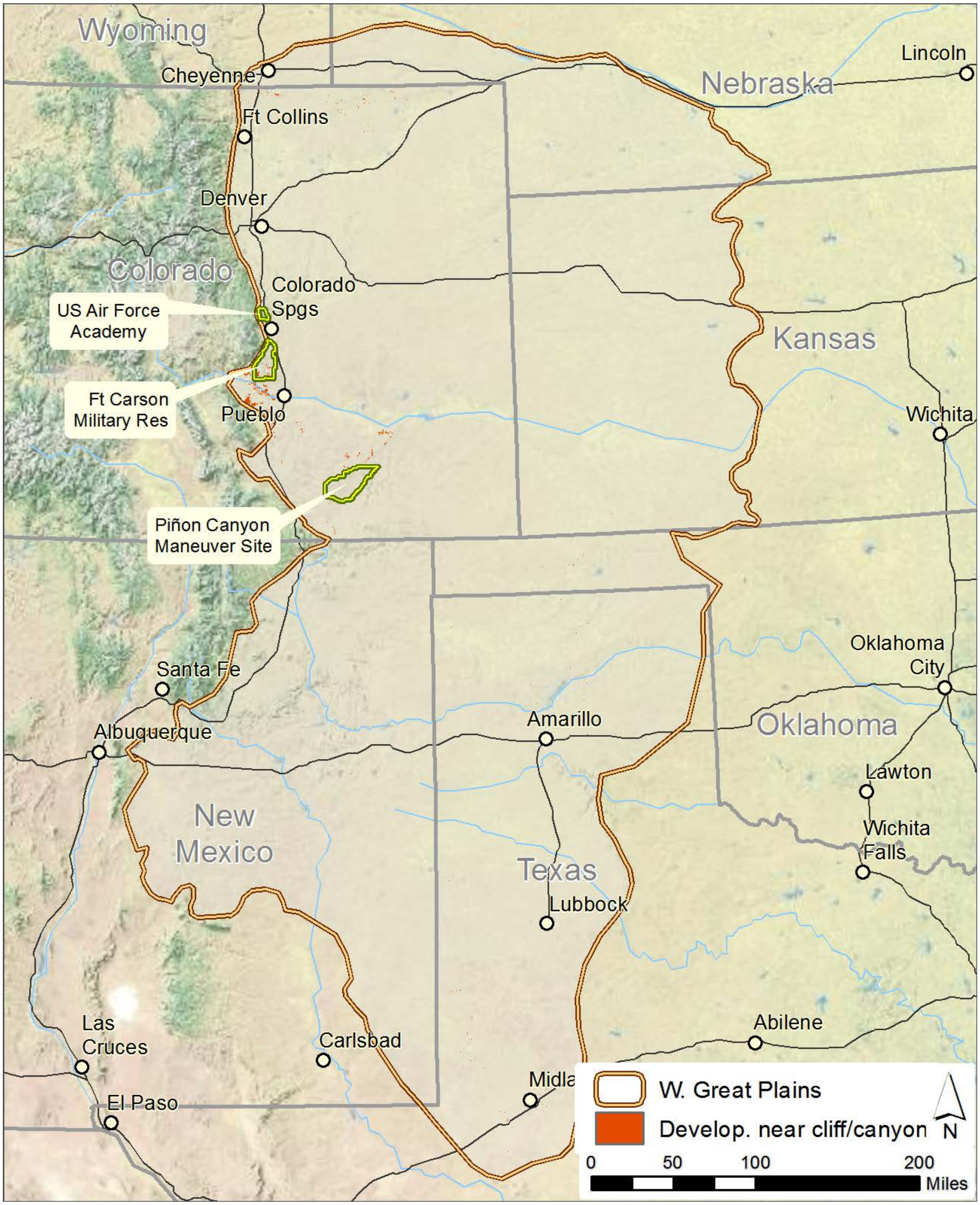



**Figure 66. Distribution of cliff and canyon habitat within one mile of residential and commercial development (low and high intensity combined).** Note that this map shows only development in the vicinity of cliffs and canyons, as opposed to all existing development.

### 10.4.2 Incompatible Agriculture

These habitats are not subject to conversion to cropland, but outcrops may be grazed by domestic livestock in some areas. Conversion of surrounding areas to cropped agriculture may eventually impact the biodiversity of outcrops. Within the region, more than 25,000 acres of this habitat are within one mile of agricultural land. These acres are widely scattered across the Western Great Plains region, and occur in very small patches that are not detectable on a letter-size map. Very little of this potential impact occurs in the vicinity of Fort Carson, PCMS, or the Air Force Academy.

### 10.4.3 Energy Production and Mining

Oil and gas development, with associated roads, pipeline corridors, and infrastructure, is an ongoing source of disturbance and fragmentation for a few areas. Fragmentation, disturbance, and loss of habitat from renewable energy production facilities is primarily due to the concentration of wind turbines at the edges of the High Plains escarpment (e.g., Caprock in eastern New Mexico; Cedar Breaks and Peetz Table in eastern Colorado). Outcrops of shale, sandstone, limestone, and granite are quarried for a variety of local or regional uses. This type of mining activity causes localized habitat destruction. We were unable to locate spatial data to represent the regional distribution of quarry mines, and thus were unable to calculate acres of impact. However, within the region, nearly 20,000 acres of cliffs, canyons, and outcrops are within one mile of oil and gas development, and about 3,000 acres are within one mile of a wind turbine facility. These locations are widespread but patchily distributed across the Western Great Plains, but mappable footprints are so small as to be undetectable on a letter-size map. The majority of oil and gas sites are clustered in northeastern Colorado and Texas, though there are a few small sites in the general vicinity of Fort Carson and PCMS. Most wind turbine sites within the region are on the eastern plains of Colorado, farther out from the mountain front than these installations.

### 10.4.4 Transportation and Service Corridors

Cliffs, outcrops and barrens are relatively free of direct transportation use themselves, but canyons where such habitats occur are rarely without roads. Impacts from road construction and maintenance, including rockfall mitigation, are generally limited to areas immediately adjacent to transportation corridors. Where roads occur near cliff and canyon rims rather than floors, additional impacts may include altered runoff rates and erosion, as well as direct impacts to sensitive wildlife species (e.g., raptors) and cliff vegetation. Within the region, more than 40,000 acres are within a mile of a major road, while more than 250,000 acres of this habitat are within one mile of a minor road. Major roads near cliffs, canyons, and outcrops are quite limited in distribution, but the majority of those that occur are clustered in the general vicinity of Fort Carson and PCMS (Figure 67). Minor roads are widespread across the Western Great Plains. Though it is common to find roads within or adjacent to cliffs, canyons, and outcrops, the comparatively limited and patchy distribution of this system makes these areas of impact difficult to detect on a letter-size map, where many intersections are a single pixel. However, like major roads, the most significant areas of potential impact are clustered along the mountain front in the general vicinity of Fort Carson and PCMS (Figure 68).


**Figure 67. Distribution of cliffs, canyons, and outcrops within one mile of major roads.**


**Figure 68. Distribution of cliffs, canyons, and outcrops within one mile of minor roads.**

### 10.4.5 Human Intrusions and Disturbance

Anthropogenic surface disturbance due to military training activities or recreational use can change soil or vegetation structure in outcrop habitats. Tracked vehicles are exceptional in their ability to dramatically change soil structure in a single pass, but any vehicular activity can affect soil and vegetation under certain conditions. Fine-textured soils are generally most susceptible to damage by vehicular disturbance (Milchunas et al. 1999). Species composition in outcrop communities is likely to be changed by occasional heavy disturbance during tracked vehicle maneuvers (Milchunas et al. 2000), but the long term effects of such use are unknown. At least some of the outcrop and pine barren occurrences at Fort Carson and Piñon Canyon Maneuver Site are likely to be exposed to disturbance by tracked vehicles during training maneuvers, especially if frequency of use increases. Cliff and canyon habitats are not likely to be impacted by training maneuvers since steep slopes would be avoided due to danger of rollover. Recreational use (e.g., climbing) of cliff and canyon habitats on public (open space) lands can be a local source of disturbance.

### 10.4.6 Natural System Modifications

Water storage construction projects (dams and reservoirs) are often sited in or near cliff and canyon habitats, and reservoir filling inundates these areas. Water storage can change groundwater flow patterns in adjacent cliff habitats, which may in turn change vegetation composition or persistence.

### 10.4.7 Invasive and Other Problematic Species and Genes

In some occurrences of this ecosystem, invasive species are considered only a low threat because the limited soil development and extreme edaphic conditions render the substrate less habitable for both native and exotic species. Nonetheless, exotic or invasive species reported from Niobrara outcrops along the Colorado Front Range include smooth brome (*Bromus inermis*), Japanese brome (*B. japonicas*), thisle species (*Cirsium* spp.), leafy spurge (*Euphorbia esula*), sweet clover (*Melilotus* spp.) (Supples 2001), diffuse knapweed (*Acosta diffusa*), bindweed (*Convolvulus arvensis*), and yello alyssum (*Alyssum alyssoides*) (Carpenter 1997).

### 10.4.8 Climate Change and Severe Weather

The climate projections discussed in Section 8.4.9 for shortgrass prairie are also relevant for cliffs, canyons, and outcrops in the western Great Plains. If changing climate conditions result in an increased frequency of extreme storm events, patterns of runoff and erosion may change, with the potential to impact cliff, canyon and outcrop habitats. Drought conditions may also contribute to increased erosion in some instances if soil-holding vegetation is depleted.

# 11 Golden Eagle (*Aquila chrysaetos*)

**Golden eagle.**
Photo: Dick Daniels (www.carolinabirds.org)

## 11.1 Range, Distribution, and Abundance

Golden eagles range across the Northern Hemisphere, and are found throughout Europe, Asia, and parts of northern Africa, in addition to North America, including the U.S., Canada, and Mexico (Figure 69). In North America, golden eagles are wide-ranging across the western portion of the continent, but rare in the east (Figure 70). Breeding distribution includes western and northern Alaska eastward through Northwest Territories to Labrador, and south to northern Mexico, Texas, western Oklahoma, and western Kansas (NatureServe 2015). Breeding is sporadic and rare in northeastern North America, but has been reported. Lee and Spofford (1990) note that reported nesting records south of the Adirondacks are doubtful. North American winter range extends from south-central British Columbia into Mexico; breeding range and winter range overlap across the majority of the western coterminous U.S. (Kochert et al. 2002). In Colorado the golden eagle occurs statewide.

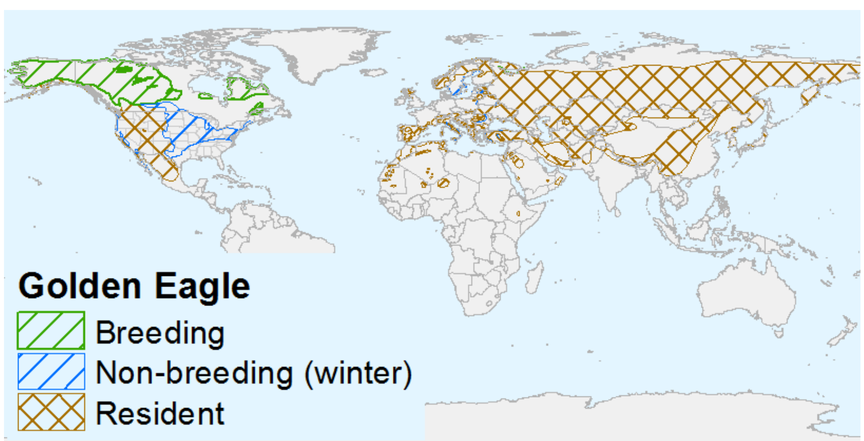



**Figure 69. Worldwide distribution of golden eagles.** Source: Source: Birdlife International and NatureServe 2015.

In 2009, the U.S. Fish and Wildlife Service estimated just over 30,000 golden eagles in the coterminous U.S. Other estimates covering the majority of the eagle's coterimous U.S. range fell between ~22,000 – 28,000 (Nielson et al. 2014, Millsap et al. 2013). The 2016 Partners in Flight Landbird Conservation Plan estimates the U.S./Canada population at 57,000 birds (Rosenberg et al. 2016). Abundance is evenly distributed (Figure 71). The USFWS 2016 status assessment for golden eagle estimated an average late summer population of averaging 31,000 in the U.S. over the past decade (USFWS 2016).

In Colorado, golden eagles occur statewide (Figure 72). Overall distribution was unchanged from the first Colorado Breeding Bird Atlas (BBA) (Kingery 1998) to the newly revised BBA (Figure 73), but this species was detected in 16% fewer blocks in BBAII, and the number of confirmed priority blocks declined by 22% (Wickersham 2016). Because nesting attempts can fluctuate widely depending on prey availability from year to year, the decline in BBA detections of breeding birds may not be indicative of an actual Colorado trend (Wickersham 2016).

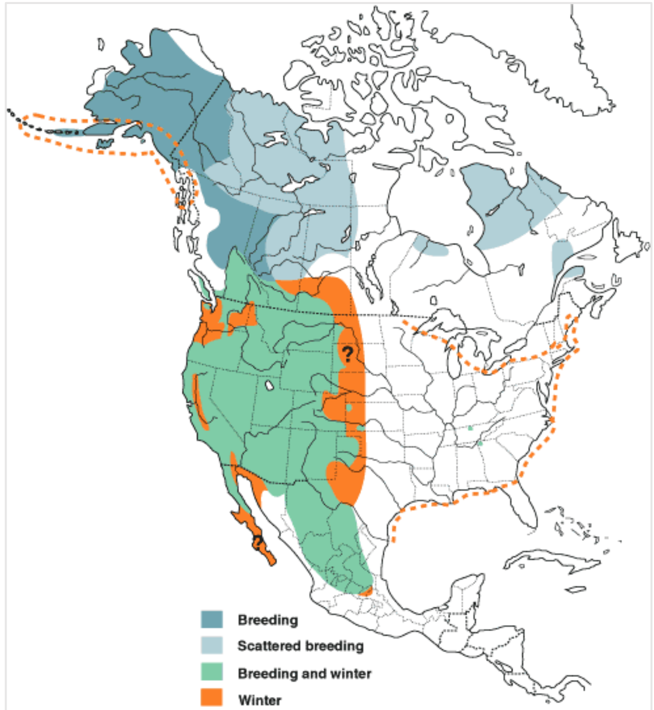



**Figure 70. Distribution of the golden eagle in North America** (adapted from Kochert et al. 2002).

Golden eagles are known to occur at Fort Carson, and have also been documented PCMS and the Air Force Academy. On Fort Carson, 19 known or suspected eagle nests have been documented, and additional nests have been identified in the foothills west of the post. Detailed information on nesting sites and breeding activity on Fort Carson can be found in Clawges (2015). In summary, there have been three intermittently active eyries on Fort Carson between 2007 and 2015 (Figure 74).

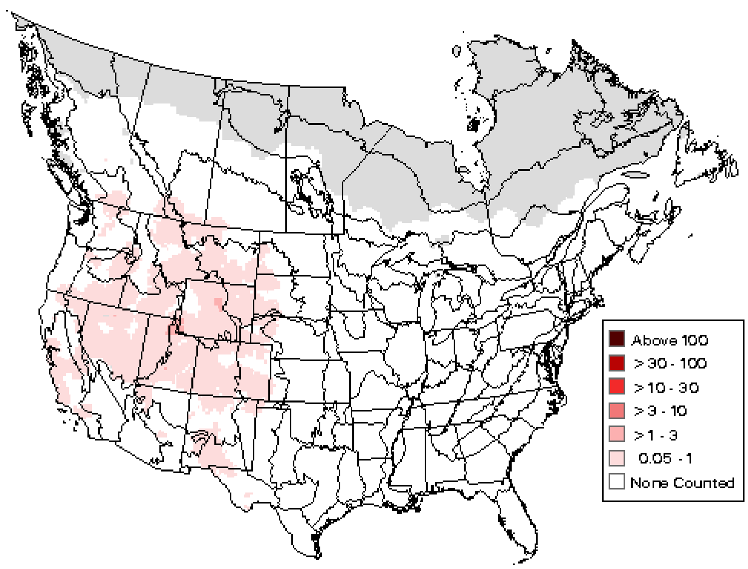



**Figure 71. Golden eagle BBS summer distribution 2007 - 2013.** This map is a simple summary of relative abundance based on raw BBS data, using average counts of golden eagles observed on each route over the time interval (https://www.mbr-pwrc.usgs.gov/bbs/ra2013/ra03490.htm).

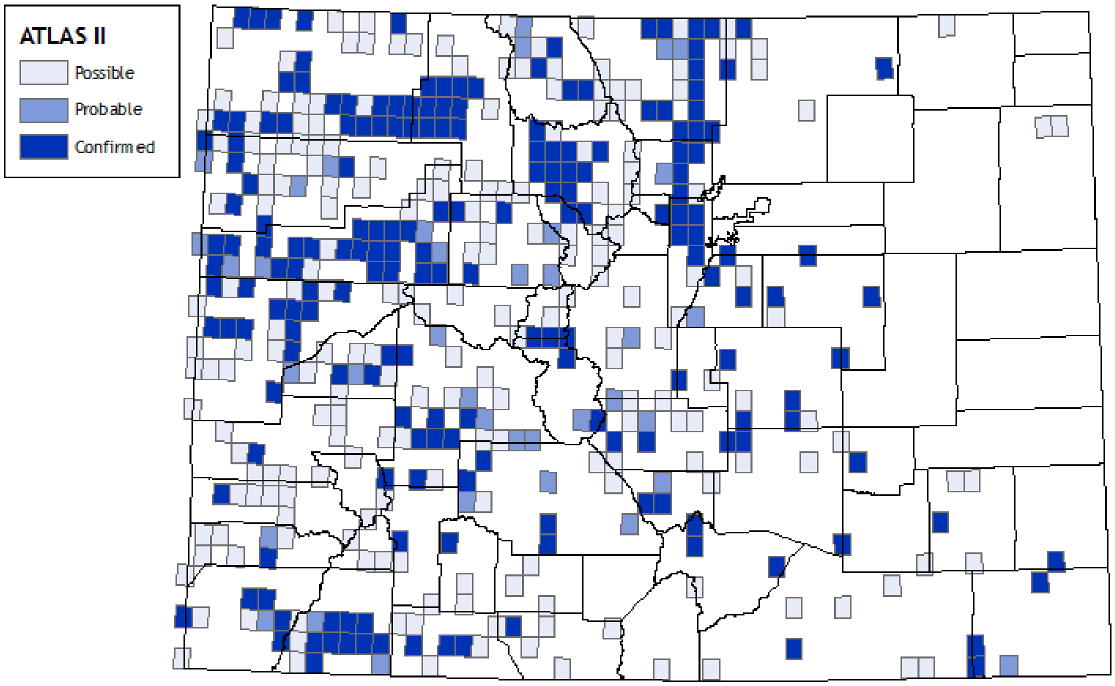



**Figure 72. Golden eagle breeding distribution in Colorado.** Source: Wickersham 2016.

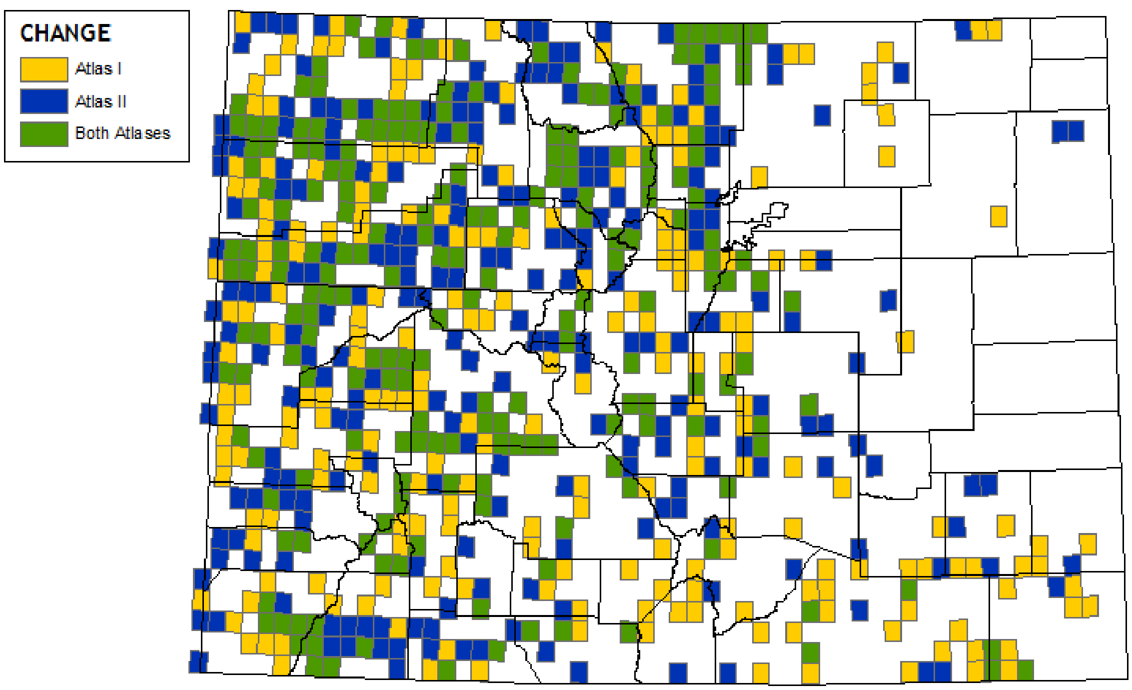



**Figure 73. Change in golden eagle breeding distribution in Colorado from Breeding Bird Atlas I to Breeding Bird Atlas II.** Source: Wickersham 2016.

The southernmost eyrie consists of seven nests, two of which are off-installation just to the south. Golden eagle nesting has been documented within training areas 32, 52, and 56 at Fort Carson during breeding surveys conducted from 2008 to 2015. Additional eyries are known to exist in training areas 33, 38, 39, 41, 45, 51, 123 and 145, but nest activity was not observed at any of these eyries between 2008 and 2015. The highest concentrations of eagle sightings occur in training areas 24, 31, 40, 43, 53, and 54 near prairie dog colonies. Golden eagles that breed on Fort Carson stay in their territories year-round. Eagles of all ages have been observed between August and December (non-breeding season) at Fort Carson; some of these birds are probably migratory adults from other breeding locations.

Detailed occurrence information is not available for PCMS. Golden eagles are uncommon on the Air Force Academy.

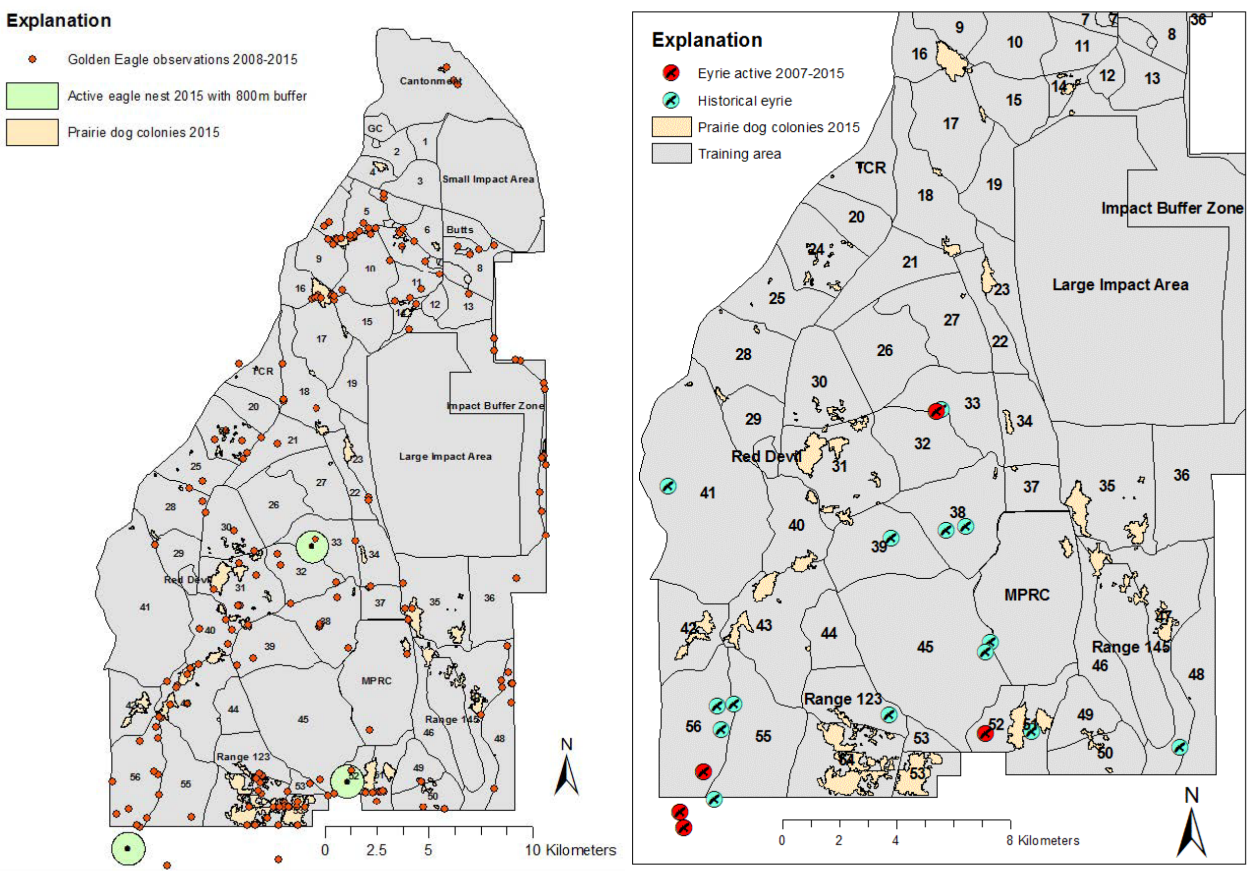



**Figure 74. Golden eagle observation locations and active nests with buffers (left), active and historical eyries and prairie dog colonies (right) at Fort Carson, 2007-2015**. Source: Clawges 2015.

## 11.2 Conservation status

The current status of golden eagles is rather a conundrum. Golden eagle populations in North America experienced declines in the mid-1900s, reportedly due to development-related habitat loss and concomitant declines in prey abundance, accidents, and disturbance (Kochert and Steenhof 2012), and eradication campaigns based on the belief that eagles were major livestock predators (NatureServe 2015).

Debate is ongoing regarding the current status of the continental population. In its 2009 Final Environmental Assessment for take rules under the Bald and Golden Eagle Protection Act, the USFWS tentatively concluded that the golden eagle was declining (USFWS 2009). Other recent estimates of population trends for golden eagles are mixed, with stable or slightly increasing populations in the northern portion of its western North American range, slightly declining in southern portions of its western range, and increasing in the east (Farmer et al. 2008, Millsap et al. 2013). However, Millsap determined that the golden eagle population in the western U.S. was stable overall from 2006-2010. Nielsen et al. (2014) estimated abundance and trend in 2006 and 2012 for the four BCRs that collectively contain approximately 80% of the golden eagle's range in the coterminous U.S. They found declines in numbers of juveniles in the Northern Rockies and Southern Rockies/Colorado Plateau BCRs, but no decline in total abundance across the western U.S. Nielsen et al. went on to caution that their analysis was based on a limited number of years' data. Breeding Bird Survey data from 1966 – 2013 also present a mixed picture of trend for golden eagle, with increases in some places and decreases in others (Figure 75). PIF's 2016 Landbird Conservation Plan shows an overall 6% increase from 1970-2014 for the U.S. and Canada (Rosenberg et al. 2016). Some authors note problems with BBS data (e.g., Thogmartin et al. 2006), but Millsap et al. (2013) compared their results to BBS data and determined that the BBS was useful in providing trend information. A 2016 status update for Bald and Golden Eagle Protection Act determined that status is still somewhat equivocal, with count data suggesting a stable population, but demographic data forecasting a slight decline (Millsap et al. 2016). Paprocki et al. (2014) cautioned that local scale (e.g., BCRs) may not accurately reflect trends if climate change is altering distribution patterns.

The golden eagle is federally protected under the Bald and Golden Eagle Protection Act and the Migratory Bird Treaty Act, and is identified as a species of conservation concern on the following lists:

***International***

- Convention on International Trade in Endangered Species (CITES) Appendix II species (not necessarily threatened with extinction, but trade must be controlled in order to avoid utilization incompatible with survival)

***National***

- U.S. Fish and Wildlife Service Birds of Conservation Concern (BCRs 9, 16, 17, 18, and 33)
- DoD PIF Mission-Sensitive Priority Bird Species (i.e., determined to have greatest potential impact on military mission if listed)
- U.S. Migratory Bird Program Focal Species

- Bureau of Land Management Sensitive Species in Arizona, California, Colorado, and Montana

***State***

- Species of Greatest Conservation Need in western states: Arizona, California, Colorado (Tier 1), Idaho, Kansas, Montana, Nebraska, Nevada, North Dakota, Texas, Utah, Washington, and Wyoming
- Natural Heritage Program conservation status ranked Critically Imperiled in Kansas, Imperiled in Oklahoma, and Vulnerable in California, Colorado, Montana, Nebraska, New Mexico, North Dakota, Oregon, South Dakota, Texas, and Washington.

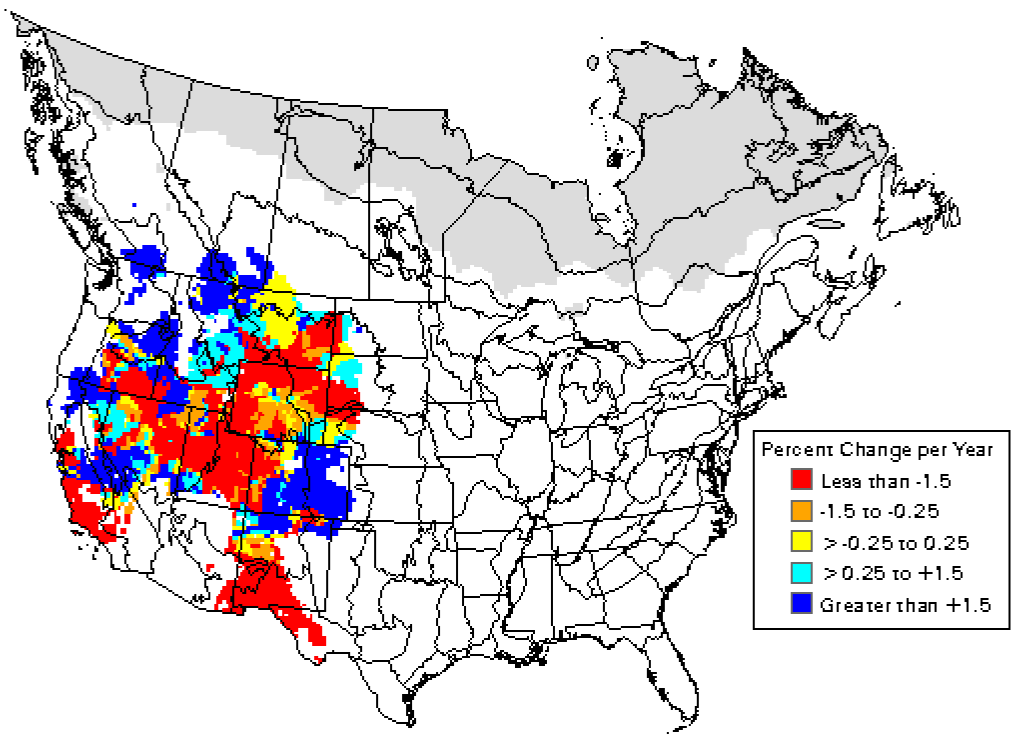



**Figure 75. Golden eagle trend based on BBS data from 1966-2013.** Source: Sauer et al. 2014 (https://www.mbr-pwrc.usgs.gov/bbs/tr2013/tr03490.htm).

## 11.3 Species Requirements

### 11.3.1 Habitat

Golden eagles occupy a wide range of habitats, most commonly where cliffs occur near open spaces that support abundant prey populations (Kochert et al. 2002). They prefer open to semi-open habitats such as grasslands, savannas, shrublands, woodland and forest edges, deserts, tundra, and both interior and coastal waterways, and are found across elevations ranging from sea level to 11,900 feet (Kochert 1986, Kochert et al. 2002). In Colorado, golden eagles are documented most frequently in cliff habitats, but also use pinyon-juniper, ponderosa pine and other coniferous woodlands, grasslands from alpine to prairies, shrublands (especially sagebrush), riparian, and rural agricultural areas (Wickersham 2016).

***Breeding Habitat***

This bird is a wide-ranging habitat generalist, and thus descriptions of breeding habitat include a variety of open and semi-open habitats. These include tundra, shrublands (sagebrush), grasslands (including prairie and desert grasslands and chaparral), woodlands (oak) and coniferous forests, and riparian habitats (Kochert 1972, Menkens and Anderson 1987, Peterson 1988, Bates and Moretti 1994, Kochert et al. 2002). Heavily forested areas are avoided. Golden eagles are primarily found in areas of mountain cliffs or canyons with rimrock terrain, adjacent to open shrubland or grassland. Use of agricultural fields has been documented in some places (Kochert 1972, Menkens and Anderson 1987), but is avoided in others (e.g., Colorado, Olendorf 1973; Wyoming, Phillips et al. 1984).

Nests are most commonly located on cliffs, but have also been documented in the upper third of deciduous and coniferous trees, on the ground or on human made structures (e.g., windmills, electricity transmission towers, artificial nesting platforms) (Phillips and Beske 1990, Kochert et al. 2002, Pagel et al. 2010). In Boeker and Ray's (1971) and Kochert et al.'s (2002) study areas, eagles nested almost entirely on cliffs. According to Kochert et al., preferred nest sites often afford a wide view of surrounding area or are on prominent escarpments, usually in close proximity to foraging grounds. The majority (80%) of nests in their study area were inaccessible to humans and mammalian predators.

Territories often have multiple nests, usually two or three, but Kochert and Steenhof (2012) documented use of up to 18 nests within a territory (mean 7). Their number of alternate nests documented was higher than previous studies (citing Dixon 1937, McGahan 1968, Kochert et al. 2002, Watson 2010); they attributed this difference to the fact that the years covered by their study was more than twice that of previous studies, suggesting that shorter-term monitoring may underestimate the number of nests in a territory.

Nests may be reused over long periods of time. Some pairs use the same nest yearly but keep alternate nests repaired until eggs are laid. Other pairs use different alternate nests from year to year. Reuse or switching of nests does not appear to be related to success of the previous year (Boeker and Ray 1971, Kochert et al. 2002), but often occurs after loss of a mate (Kochert and Steenhof 2012). Kochert and Steenhof documented reuse of individual nests from 1 to 26 times over 45 years, with years between incidents of reuse ranging from 1 to 39 years. They determined that the 10-yr protection period for unused Golden Eagle nests proposed by the USFWS (Pagel et al. 2010) would have protected only 66% (198) out of 300 nests that were reused during their study. The 102 nests, representing 255 nestings and at least 274 fledged young, that would not have been protected (i.e., had not been used for more than 10 previous years) were in 56 different territories (85% of all study territories) (Kochert and Steenhof 2012).

***Foraging Habitat***

In the interior west, open grasslands and shrublands appear to be particularly important for foraging golden eagles, especially in areas of abundant prey. Primary prey include rabbits, hares, ground squirrels, prairie dogs, and marmots (Kochert et al. 2002), but golden eagles will also take birds, reptiles, and fish (Olendorff 1976), as well as large animals (e.g., seals, ungulates, domestic livestock) and carrion (Kochert et al. 2002). Eagles will disproportionately select shrub habitats when available compared to adjacent grasslands (Marzluff et al. 1997). Agricultural areas are avoided (Steenhof et al. 1997). Desert shrublands including big sagebrush (*Artemisia tridentate*) / green rabbitbrush (*Chrysothamnus viscidifiorus*), winterfat (*Ceratoides lanata*), and salt-desert shrubs (*Atriplex confertifolia, A. canescens, Sarcobatus vermiculatus*), grasslands, and water are all habitats important for golden eagles and their prey (Knick and Dyer 1997, Knick et al. 1997). On Fort Carson golden eagles are most commonly sighted in association with prairie dog complexes (Clawges 2015).

***Wintering Habitat***

In the western U. S., wintering golden eagles are found in open habitats of native vegetation. They prefer sagebrush communities, riparian areas, grasslands, and rolling oak savanna (Knight et al. 1979, Millsap 1981, Fischer et al. 1984, Hayden 1984, Craig et al. 1986, Estep and Sculley 1989, Marzluff et al. 1997), but avoid urban, agricultural, and forested landscapes (Millsap 1981, Fischer et al. 1984, Craig et al. 1986, Marzluff et al. 1997, Kochert et al. 2002). They are common near water (e.g., reservoirs with winter waterfowl concentrations, Wingfield 1991), and tend to avoid harsh, dry areas that experience less than 10 inches of annual rainfall (e.g., Sonoran Desert, central Nevada) (Kochert et al. 2002). Wintering eagles tend to be associated with steep river valleys, reservoirs, and marshes in inland areas; estuarine marshlands, barrier islands, managed wetlands, sounds, and mouths of major river systems in coastal areas (Kochert et al. 2002). In Colorado, golden eagles may either stay within their breeding grounds or migrate from the western half of the state onto the plains of eastern Colorado.

***Migration Habitat***

Golden eagles migrate from breeding sites in Alaska and northern Canada to winter in southern Canada, the coterminous U. S., and central Mexico. These birds may travel more than 5,000km during migration (Kochert et al. 2002). Birds that breed further south may not migrate. During migration, eagles use a wide variety of open to semi-open habitat very similar to breeding habitats, including grasslands, savanna, shrublands, woodland and forest edges, deserts, tundra, and both interior and coastal waterways (Kochert et al. 2002, Melcher et al. 2015). Migration pathways tend to follow mountain chains and other topographic features to take advantage of strong thermals (Kochert et al. 2002). In Colorado, Golden eagles are year round residents (Barrett 1998) and tend to remain within striking distance of their breeding territories throughout the year. Populations in Colorado breeding at higher elevation may migrate to lower elevations on the eastern plains during winter.

## 11.4 Spacing and Movement

Golden eagles do not usually tolerate other individuals within 2m (Halley and Gjershaug 1998), but will gather at carcasses and sometimes roost together (Kochert et al. 2002).

Home range size is highly variable. In the western U.S., foraging range averages around 2,000 – 3,300 ha during the breeding season. Year-round home range sizes are approximately 1,500 – 6,100 ha. Along the Snake River in Idaho (i.e., in linear habitat), documented ranges were ~200 – 8,300 ha. Winter ranges may be much smaller – e.g., in Wyoming, ~1,360 ha in winter, 2,400 ha breeding; in Idaho, 890 ha in winter, 3,200 breeding). During breeding, documented distances between occupied nests in western U.S. and Canada range from 0.5 to 16km, though even in optimal habitat pairs are seldom less than 1km distant. Home ranges may overlap in winter (Kochert et al. 2002).

Within nesting territories, distances between alternative nests are probably related to terrain and proximity of other nesting pairs (Boeker and Ray 1971). McGahan (1968) reported separation distances between alternate nests from <1km to >5km. Kochert and Steenhof (2012) documented distances between nearest alternative nests within territories ranging from 1 to 1,822 m, though the majority (90%) were ~500m. They did not observe large separation (4.8 – 6.1km) between alternative nests asreported by McGahan (1968) and Lockie and Ratcliffe (1964), possibly, they thought, because golden eagles in their study area nest at relatively high densities in a linear setting along the Snake River. Thus, their results may not be comparable to distances in nonlinear habitats.

## 11.5 Phenology

The golden eagle breeding timeline is very long, extending from a minimum of 4 months to up to 5.5 months. Golden eagles nest from late March through August, depending on location (Kochert et al. 2002). The courtship and nest-building phases last for longer than a month. The commencement of egg laying varies according to latitude, but can be initiated as early as February in Texas and parts of California and as late as April in Alaska. The incubation period is extensive, lasting from 43-45 days and is performed mainly by the female. Young can fly at about 60-77 days of age, and remain under parental care for an additional 30+ days.

In Colorado, courtship may begin as early as December, with nest building and incubation occurring in mid-February or early March. Field surveys for the 2016 Colorado Breeding Bird Atlas documented occupied nests from early February through early July. Fledged young were observed from early June through mid-August (Wickersham 2016).

A survey of golden eagle breeding on Fort Carson in 2015 documented breeding activity beginning in early January and ending in late July, with two young fledged from each of two nests (Rule Canyon and Teller Reservoir), and one juvenile observed at a nest on Beaver Creek south of the installation (Clawges 2015).

Fall migration from Alaskan breeding territories begins in September. Peak flights at raptor migration count sites in southern Canada and the northern U.S. occur in October, but continue through December. In the spring, birds from most wintering areas depart for breeding grounds in March. Routes are not well-known. In the western U.S. migration corridors follow north-south mountains, particularly the Rocky Mountains into western Montana and Alberta, but further south also include Sandia and Manzano Mountains in New Mexico, and the Cascades in the Pacific Northwest (Kochert et al. 2002).

## 11.6 Threats

### 11.6.1 Rangewide Threats and Current Habitat Condition

The threats facing golden eagles are related to changes in ecological processes (e.g., increases in wildfire due to climate change), as well as human-induced fragmentation of large landscapes, and human activities that directly affect eagles. With no natural predators, impacts from interactions with humans is the most severe direct threat golden eagles face and the main cause of their mortality. Collisions with cars, electrical lines or wind turbines and electrocution from landing on power poles causes mortality or injury to many eagles (Phillips 1986, Hunt et al. 1999, Erickson et al. 2005, and Lehman et al. 2007). Eagles may encounter dangerous toxins such as lead as a result of human activities (e.g., hunting) (Kochert et al. 2002, Wendell et al. 2002, Erickson et al. 2005). Franson et al. (1995) identified the main causes of golden eagle mortality as collisions with vehicles, power lines, or other structures (27%); electrocution (25%); gunshot (15%); and poisoning (6%).

The expansion of urban and exurban development has resulted in the loss of breeding habitat in California and along Colorado's Front Range (Boeker 1974, Scott 1985). Additionally, agricultural development can render areas once used as wintering habitat as unsuitable for Golden Eagles (Craig et al. 1986).

Large-scale activities that have the potential to impact the landscape for golden eagles and for their habitat include (Kochert et al. 2002, Holroyd et al. 2010, Johnston et al. 2013, Katzner et al. 2012, Melcher et al. 2015):

- Fire (wildland and human-caused),
- Urban, rural, and agricultural development,
- Motorized vehicle travel,
- Livestock grazing (e.g., sheep and cattle), and
- Energy development
    - o Renewable energy (wind, solar, and geothermal)
    - o Conventional energy (oil, gas, and coal)
    - o Associated right-of-ways (roads, pipelines, transmission/distribution lines).

### 11.6.2 Energy Production and Mining

Research at the Altamont Pass Wind Resource Area documented 54 golden eagle fatalities attributable to wind turbines and used predictive modeling to estimate annual turbine-caused fatalities for golden eagles at 67 (Smallwood and Thelander 2008). They referenced another overlapping study (Hunt 2002), which concluded that the local golden eagle population was stable in spite of turbine-related mortality, and that the majority of mortalities were local birds.

Smallwood and Thelander were unable to rule out non-resident birds, and noted that the turbine-related mortality may not alter the number of local pairs if there is recruitment from other populations. A summary of reported bald and golden eagle mortalities at wind energy facilities across 10 states over a 15-year period documented 79 golden eagle fatalities (93% of all eagle mortalities), with more golden eagle collisions during March through June than other months (Pagel et al. 2013). They noted that the majority of eagle remains were discovered incidentally and reporting was voluntary, suggesting that the actual numbers of eagles killed is higher than their study documented.

According to the U.S. Fish and Wildlife Service (2013), golden eagles are at greater risk for mortality from wind turbines than other raptors due to:

- the interaction of topographic features, season, and wind currents that create favorable conditions for slope soaring or kiting (stationary or near-stationary hovering) in the vicinity of turbines;
- behavior that distracts eagles and presumably makes them less vigilant (e.g., active foraging or inter- and intra-specific interactions);
- resident status (resident birds are less vulnerable; dispersers and migrants are more so). This latter point should not be taken to undercut the potential severity of the risk to breeding adult eagles and their young, as losses from these segments of the population, especially breeding adults, can have serious consequences to populations.

However, Johnston et al. (2014) determined that eagles can detect and avoid turbines during migration. They monitored three fall migration seasons, one pre-construction and two post-construction, at a wind development site in British Columbia, and then used GIS to analyze flight tracks. Along the eastern front of the Rocky Mountains, the orographic lift used by golden eagles in migration and relationship between topography and prevailing winds often co-occur in places suitable for wind development. Johnston et al.'s results documented a similar number of ridge-top crossings prior to and after construction, but a significantly smaller proportion of flights crossing the risk zone (rotor-swept height) in post-construction years compared to pre-construction. Eagles avoided turbines by slight adjustments in altitude rather than flying around turbines. Johnston et al. did not observe a decline in eagle abundance after construction, suggesting that birds are not avoiding the wind development site, perhaps because eagles' visual acuity allows them to detect and avoid the development.

Additionally, disturbance from pre-construction, construction, or operation and maintenance activities at wind developments could disturb eagles at concentration sites or result in loss of productivity at nearby nests, resulting in permanent loss of nesting territory (USFWS 2013a). The degree to which nesting territories may be displaced by wind development facilities is not well known. Hunt and Hunt (2006) found that 58 occupied territories near a large wind facility in California were still active after five years. Johnson et al. (2006) documented a golden eagle nest successfully fledging young within a mile of a wind facility in southern Wyoming. The sighting of wind turbine complexes within the migratory pathways of Canadian and Alaskan populations that move between their northern breeding grounds and wintering areas in the western continental U.S. and northern Mexico is also a concern (Johnston et al. 2013).

### 11.6.3 Transportation and Service Corridors

The electrocution of golden eagles from power lines is an ongoing problem, but scientifically collected data on the rates of electrocution from across North American are lacking. Reports on electrocution for all birds from utilities, wildlife rehabilitators, and falconers between 1986 and 1996 documented 1,450 raptor electrocutions representing 16 species, with the golden eagle accounting for the largest percent of mortalities (Erickson et al. 2005). Collision with power lines is another major source of mortality for golden eagles. Benson (1982) identified that 83% of the 416 deaths from collision with power lines in six western states were golden eagles. The Avian Powerline Interaction Committee's (2012) synthesis of studies on this risk indicate that extrapolation of study results is very difficult due to the significant influence of site-specific factors.

### 11.6.4 Natural Systems Modifications

The recent increase in the incidence of catastrophic wildfire in the intermountain West, including Colorado, has the potential to disrupt the breeding biology of golden eagles. Nesting success at burned territories in Snake River Canyon declined after major fires with abandoned territories being subsumed by neighboring pairs, resulting in a decreased number of nesting pairs (Kochert et al. 1999). Fire effects are mediated through declines in abundance of eagle prey (e.g., loss of lagomorphs from shrub habitats) (Kochert et al. 1999). Changes in precipitation and temperature predicted for the Rocky Mountain region over the next 50 years suggest the observed increase in wildfires recently witnessed in region may persist (Westerling et al. 2006, Melillo et al. 2014).

### 11.6.5 Human Intrusions and Disturbance

Along with urbanization comes increased recreational activity that can cause disturbance to golden eagles. Human activity near nests can cause breeding failures, but most evidence is anecdotal or correlative (Kochert et al. 2002). Colorado Parks and Wildlife recommends no surface occupancy within ¼ mile of active golden eagle nests beyond what already occurs, and restriction of human activity to within ½ mile of active nests from December 15 through July 15 (CPW 2008). Additionally, researchers can cause disturbance at nests, resulting in nest abandonment, nest mortality due to excessive egg cooling or heating during periods when the researcher is at the nest and brooding adults are away, or cause young to fledge prematurely (Kochert et al. 2002). Such disturbance can be avoided if proper protocols and precautions are developed and followed by researchers.

### 11.6.6 Pollution

Golden eagles appear to be less susceptible to chemical pollution than other raptors (Kochert et al 2002), but secondary poisoning can occur when eagles consume carrion killed by exposure to chemicals used on crops. Raptors in the U. S., Canada, France and Great Britain have been killed by consuming rodents poisoned with rodenticides (Stone et al. 2003, Walker et al. 2008, Albert et al. 2010), and this problem is exacerbated by the fact that raptors show an increased sensitivity to anticoagulants (Rattner et al. 2011).

Lead poisoning in golden eagles is a significant issue over wide regions of the U.S. (Stauber et al. 2010). Harmata and Restani (1995) documented lead in the blood of 85% of spring migrating golden eagles (n-86) captured in Montana. In southern California, Pattee et al. (1990) found evidence of lead exposure in 36% of free-ranging golden eagles (n=162). Ingestion of bullet fragments from hunter-killed animal carcasses and gut piles left in the field can cause toxicity in golden eagles (Fisher et al. 2006). Retrospective studies at a university veterinary hospital in the Pacific Northwest examined the cause of mortality in golden eagles and identified lead toxicity as the most frequent cause of death, accounting for over 60% of mortalities (Stauber et al. 2010, Franson and Russel 2014). They found lead poisoning to be a major problem between October and March (i.e., elk and deer hunting seasons in the autumn, followed coyote hunting over winter). Game carcasses and entrails left in the field expose winter scavenging golden eagles to high risk of acute lead poisoning (Stauber et al. 2010, Golden et al. 2015). An even greater risk comes from animals shot with varmint bullets (which fully disintegrate in the body) because the whole animal is available for consumption (Stauber et al. 2010). Pauli and Buskirk (2007) determined that the lead in a single prairie dog shot with an expanding bullet was enough to poison scavengers. They suggested that, since recreational prairie dog hunters often use expanding bullets and rarely remove carcasses, this is as an important source of lead in wildlife food chains. Bans on lead ammunition are known to have positive effects on incidence of lead poisoning in eagles (Kramer and Redig 1997, Hunt et al. 2006, Kelly et al. 2011). The threat from pollutants is probably limited in its scale and scope in Colorado, but information is lacking.

### 11.6.7 Climate

The Audubon Society considers the golden eagle “Climate Endangered.” According to their models, this species is projected to lose 41% of its breeding range and 16% of its winter range by 2080 (Figure 76) (http://climate.audubon.org/birds/goleag/golden-eagle). Paprocki et al. (2014) investigated latitudinal center of abundance using Christmas Bird Count data from 1975 – 2011, and found a significant poleward range shift for six raptor species. Of these, the golden eagle had one of the fastest rates of change at 7.74 km. per year. Van Buskirk’s (2012) study of migration phenology at Hawkwatch sites on Lake Superior found that Golden Eagle exhibited very strong shifts in phenology, with an increase of approximately 30 days in the time between spring and autumn migrations since 1970. Chamberlain and Pearce-Higgins (2013) suggested that impacts from climate change may manifest more through effects on prey availability rather than through direct effects on birds per se, as shown for golden eagle by Watson et al. (2003). They noted that the issue appeared to be less a problem of mismatched phenology so much as alterations in prey populations and prey availability. Our assessments of vulnerability using NatureServe’s Climate Change Vulnerability Index indicate that the golden eagle would be considered moderately vulnerable across its western U.S. distribution, but less vulnerable in Colorado (see Appendix B for details).

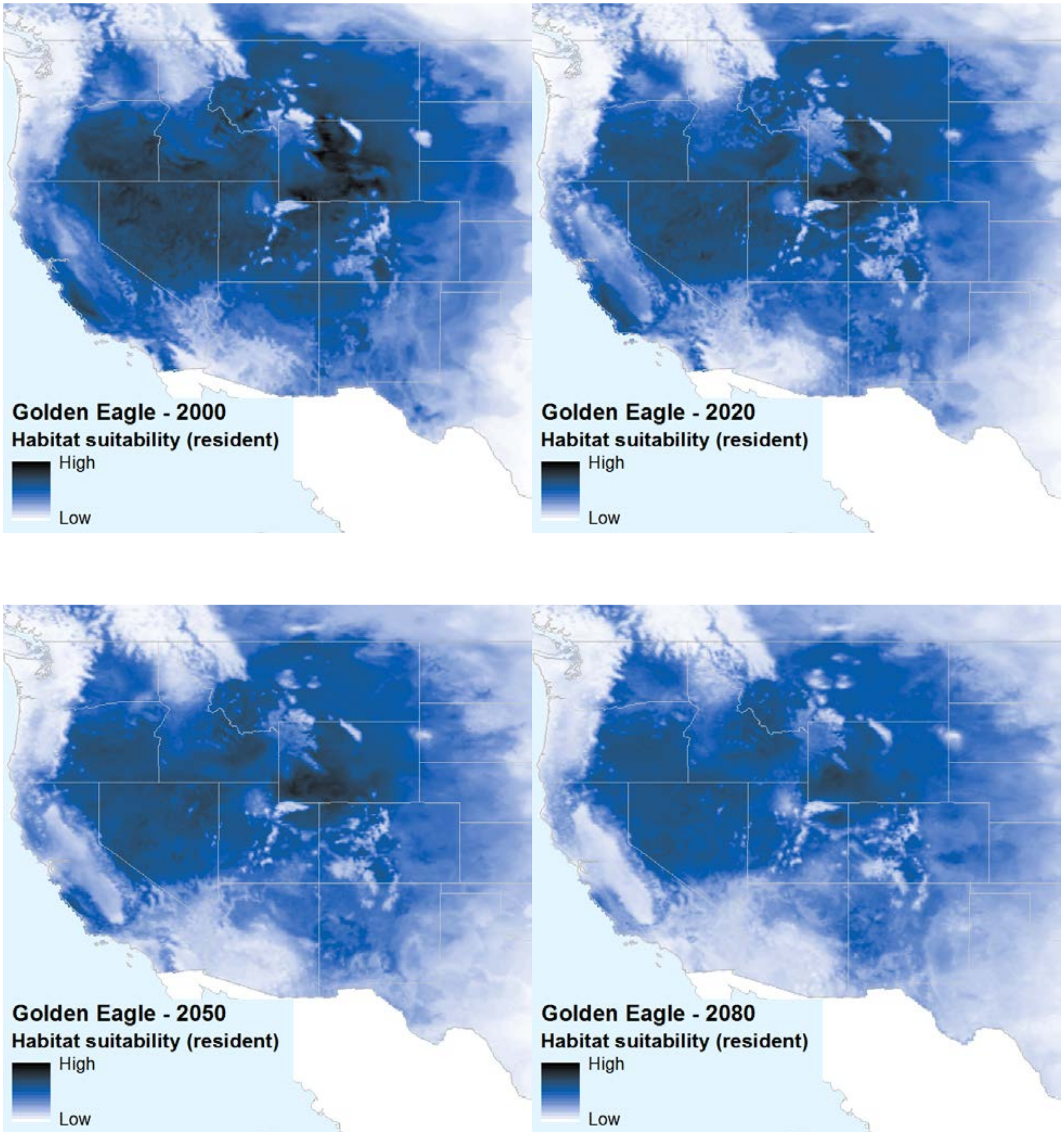



**Figure 76. Predicted current (2000) and future (2020, 2050, and 2080) habitat suitability.** Source: National Audubon Society 2013. Underlying models for summer and winter distribution can be found at http://climate.audubon.org/birds/goleag/golden-eagle.

### 11.6.8 Threats on DoD Installations

The unique requirements associated with military training exercises, including use of large vehicles, large numbers of troops, use of live ammunition, the need for large training landscapes, and the infrastructure (airstrips, buildings, roads and utility lines) have some potential to negatively impact golden eagles. Fort Carson and PCMS have addressed many of these issues in their management plans (Piñon Canyon EA 2011, U.S. Army 2011, DPW 2015). Table 18 lists the potential threats and management considerations for the golden eagle associated with training operations at these installations.

Although military training activities have the potential to degrade golden eagle habitat, ultimately training activities have little impact on cliff and canyon ecosystems due to their inherent landscape characteristics. Vehicle maneuvers are mostly impossible due to the steepness and roughness of the terrain, and foot traffic is limited due to these same factors. Most cliff and canyon systems are either off-limits to training, or have heavy restrictions on the types of training conducted within them, though collision with aircraft is possible. Due to these factors, coupled with the measures taken by the installation mentioned in Table 18 to protect the nesting areas of the golden eagle, the vulnerability of this species to military training at Fort Carson and PCMS is currently low.

## 11.7 Management Recommendations

Provisions for golden eagle management in the Fort Carson/PCMS INRMP and WASH plans (summarized in Table 18) are consistent with recommendations provided elsewhere in the golden eagle literature. Key priorities are minimization of human disturbance, collision hazards (both utility lines and aircraft) and management of prey species (particularly prairie dogs).

The existing management actions detailed in the INRMP and WASH plans are comprehensive and well thought out insofar as on-installation management options are concerned. In addition to these, we would recommend:

1. Implementation of a long-term monitoring strategy to detect impacts from climate change, including both eagle phenology and prey availability components.
2. Increased emphasis on inter-agency and cross-jurisdictional information sharing, the better to advance all parties' understanding of the status of local and regional golden eagle populations and early detection of evolving management needs (particularly with regard to climate change).

**Table 18. Threats to golden eagles from military training at military installations in the western U. S. and the management considerations associated with each threat.**

| Threat | Management Consideration |
|---|---|
| *Human Disturbance* | |
| • Troop maneuvers | • Temporarily restrict vehicle and foot travel within a 0.5 mile radius (800 meters) of active nests (CPW 2008). |
| • Aerial flyovers | • Temporarily restrict aircraft flights within distances specified in installation management plans[22]. |

[22] 2500 – 500 ft. AGL; determined by installation biologists based on aviation tolerance of individual nests.

| Threat | Management Consideration |
|---|---|
| • Live ammunition – aerial and ground resulting in accidental or purposeful death of eagles<br>• Demolitions<br>• Installation infrastructure | • Troop training and education on the need to prevent mortality of eagles and the legal ramifications of eagle "take." No tolerance enforcement of temporary restrictions at nest sites.<br>• Blasting and other activities that produce extremely loud noises should be avoided within 0.5 miles (800 meters) of active golden eagle nests (Potomac-Hudson Engineering 2014).<br>• Avoid construction of buildings, roads, trails, or power lines within a 0.5 mile radius (800 meters) of any known eagle eyrie (U. S. Army 2011). |
| *Electrocution*<br>• Utility poles and lines | • Perform a continuous assessment of risk of electrocution of hawks, eagles, and owls at Fort Carson, to include identification and mitigation of high-risk poles (DPW 2015).<br>• Perform post-assessment recommendations to retrofit problematic utility poles. |
| *Collisions*[23]<br>• Utility lines<br>• Aircraft<br>• Vehicle | • Avoid construction of power lines within a 0.5 mile radius (800 meters) of any known eagle eyrie and at high forage concentration areas, including prairie dog complexes. New power lines should be built to raptor-safe construction standards (Kochert et al. 2002 and APLIC 2012).<br>• Manage flight paths on training areas in high eagle forage concentrations areas, including prairie dog complexes, to avoid conflict with eagles. Control prairie dog populations at airstrips.<br>• Manage vehicle speed and use in high eagle forage concentrations areas, including prairie dog complexes, to avoid conflict with eagles. |
| *Prey Population Dynamics*<br>• Secondary poisoning associated with prairie dog control<br>• Plague resulting in prairie dog population decline | • Informally consult with the USFWS regarding the limited use of poison grain for lethal control of prairie dogs (DECAM 2015).<br>• Dust prairie dog populations for control of the flea vector responsible for plaque transmission (DECAM 2015).<br>• Manage fuel loads in shrub habitats supporting lagomorphs, an important alternative prey species, especially when prairie dog abundance is reduced by plague outbreaks. |

[23] The Avian Powerline Interaction Committee (APIC 2012) offers a wealth of information on understanding and reducing powerline collisions and electrocutions, including details on options for line marking (to increase line visibility), management of surrounding landscapes (to influence bird behavior), and design on monitoring studies. Considerations and suggestions include: marking of problematic lines (or segments of lines) with spheres, spirals, suspended devices, or lighting (see Chapter 6 of APIC 2012 for details); management of roads (e.g., signage) and other means of reducing human access in problem areas to prevent flushing of birds into lines; monitoring of collisions to identify potential causes and mitigation options (see Appendix B of APIC 2012 for details); use of standardized survey procedures to allow comparison of results with other studies.

# Preble's Meadow Jumping Mouse at the U.S. Air Force Academy

## 12 Preble's Meadow Jumping Mouse

### 12.1 Management Summary

The only Colorado military installation which supports a population of Preble's meadow jumping mouse (*Zapus hudsonius preblei*) (PMJM) is the U.S. Air Force Academy (Academy). The most significant issue for PMJM management on the Academy is increased riparian habitat erosion caused by elevated storm water runoff from urban development. This impacts the population of PMJM at the Academy and jeopardizes the conservation of PMJM in the southern part of its range. Since 1998, when PMJM was listed as a threatened subspecies under the Endangered Species Act, the lands east of the Academy have experienced a dramatic increase in urban development (Kuby et al. 2007), and the increase in impervious surface has increased the frequency, rate, and volume of storm water runoff and the degree of flooding that occurs on the Academy.

### 12.2 Range, Distribution, and Critical Habitat

The PMJM is found from southeastern Wyoming southward along the Front Range of Colorado to Colorado Springs (Figure 77). Historically, PMJM occupied creeks in the Denver and Colorado Springs metropolitan areas, but is now believed to be extirpated from these areas (Ryon 1996, USFWS 2004). It is found at elevations ranging from approximately 4,650 to 7,600 feet. In Colorado, the eastern extent of its range is marked by shortgrass prairie where riparian corridors with the density of vegetation needed by PMJM are limited (Beauvais 2001). At higher elevations, the distribution of PMJM overlaps with that of the western jumping mouse (*Zapus princeps*) in places. In Colorado, this occurs in the Cache La Poudre, Big Thompson, and Upper South Platte drainages well north of the Academy (Meaney et al. 2002, King et al. 2006a & b in recovery plan, Bohon et al. 2005, Schorr et al. 2009), and has not been documented in drainages in El Paso County (USFWS 2015).

Critical habitat designated by the U.S. Fish and Wildlife Service includes riparian corridors along rivers and streams, adjacent uplands, and areas that provide connectivity between and within populations in Boulder, Broomfield, Douglas, El Paso, Jefferson, Larimer, and Teller Counties. Other habitat identified as essential to the conservation of the species are not included in the critical habitat designation because they are covered by approved Habitat Conservation Plans that provide greater benefits than designation would. In addition, approximately 3,300 acres of Department of Defense lands are not included in the final critical habitat designation because they are covered by approved Integrated Natural Resource Management Plans.

## 12.3 Conservation Status

The PMJM is listed as threatened by the U.S. Fish and Wildlife Service (USFWS 1998). The Colorado Natural Heritage Program considers PMJM to be a globally-imperiled subspecies and critically-imperiled subspecies with the state (CNHP 2016). Colorado Parks and Wildlife has identified PMJM as a state threatened species and a Tier 1 Species of Greatest Conservation Need. The PMJM is also listed as a Species of Greatest Conservation need in Wyoming.

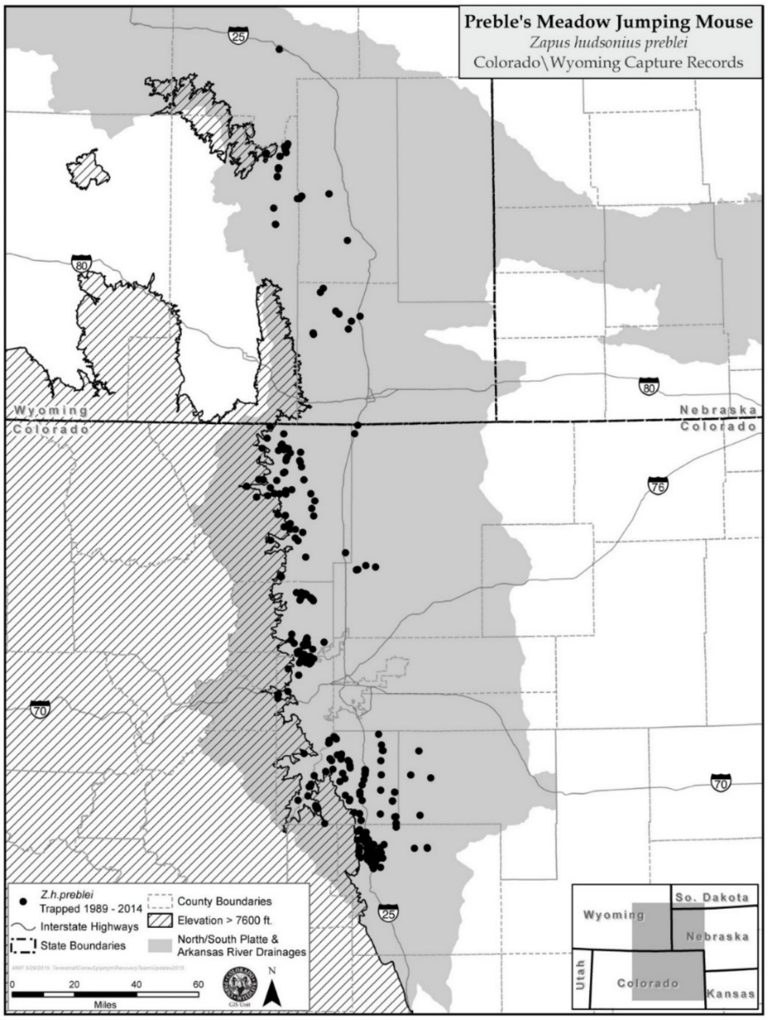



**Figure 77. Distribution of known Preble's meadow jumping mouse (*Zapus hudsonius preblei*) occurrence.** This map reflects successful trapping locations; it should not be interpreted as representing abundance. Source: USFWS 2015.

### 12.3.1 USAFA's Level of Responsibility and Value of Conserving and Managing the Academy's PMJM Population and Habitat

The PMJM is found in two major river drainages in Colorado: the South Platte River and the Arkansas River drainages. The Monument Creek population of PMJM, which includes the associated tributaries, is the largest PMJM population in the Arkansas River drainage. With much of Monument Creek and the viable PMJM habitat being found on the Academy, the Academy's PMJM population is the most valuable conservation priority for PMJM recovery in the Arkansas River drainage. Additionally, because there are only a handful of medium and large PMJM populations targeted for conservation in the PMJM Recovery Plan (USFWS 2015), the Academy PMJM population is invaluable for rangewide recovery of the subspecies. Finally, the PMJM habitat and population at the Academy is the most important in its contribution to our understanding of PMJM ecology. Since 1994, on-going studies of the Academy's PMJM population have contributed greatly to our understanding of PMJM habitat use, movement patterns, population dynamics, physiology, genetics, predators, parasites, and distribution.

## 12.4 Species Requirements

### 12.4.1 Habitat

The PMJM is a riparian-obligate that lives in dense, lush vegetation consisting of shrubs and grass and forb ground cover, sometimes with a tree overstory, along creeks, rivers, and other associated waterbodies (Bakeman 1997, Trainor et al. 2007). Within the range of PMJM, most streams quickly transition from high to low gradient, with an attendant decrease in flow velocity. The seasonal influence of snowmelt and runoff on stream hydrograph and temperature that is typical of montane streams persists for some distance from the mountain front. The piedmont zone also gives rise to spring-fed streams that can support riparian habitat suitable for PMJM, even in occasionally intermittently flowing reaches. The smaller streams with riparian habitat used by PMJM are largely supported by groundwater inflow with occasional large precipitation events. These streams are characterized by intermittent flooding and a seasonally high water table, but may be dry in some reaches for part of the year. Waterbodies that support riparian habitats include large rivers (e.g., South Platte), perennial streams and creeks, and ephemeral drainages. PMJM have also been found in low, moist areas, dry gulches, agricultural ditches, and wet meadows and seeps near streams (USFWS 2015).

The shrub layer in PMJM habitat is most commonly willow (*Salix* spp.), but many other shrubs and tall trees may also be present. These include snowberry (*Symphoricarpus* sp.), chokecherry (*Prunus virginiana*), hawthorn (*Crataegus* sp.), Gambel's oak (*Quercus gambelli*), alder (*Alnus incana*), river birch (*Betula fontinalis*), skunkbrush (*Rhus trilobata*), wild plum (*Prunus americana*), lead plant (*Amorpha fruticosa*), and dogwood (*Cornus sericea*) (Bakeman 1997; Shenk and Eussen 1998), as well as spruce (*Picea pungens*) and aspen (*Populus tremuloides*) at higher elevations (Ruggles et al. 2001). Sites close to creeks with a greater percentage of shrubs, grasses, and woody debris are more likely to be used (Trainor et al. 2007). At the Academy, PMJM densities are positively correlated with, and show greater survival with, increasing density of vertical vegetation and total grass cover (Schorr 2001, Schorr and Mihlbachler in review).

Primarily an herbivore, the PMJM eats forb and grass seeds, but ingests some invertebrate and fungal material as well. Documented food sources include both native and non-native plants: willow (*Salix* spp.), lamb's quarters (*Chenopodium* sp.), sunflowers (*Helianthus* spp.), sedge (*Carex* spp.), grasses (*Festuca, Sporobolus* and *Agropyron* spp., *Bromus* spp., *Poa* spp.), bladderpod (*Lesquerella* sp.), Russian thistle (*Salsola* sp.), mullein (*Verbascum* sp.),and rushes (*Equisetum* sp.) (Shenk and Eussen 1998; Shenk and Sivert 1999).

In the summer (late May – mid-September), the PMJM spends most of its time in the dense riparian vegetation, and sometimes ventures into the surrounding uplands to feed. The uplands where PMJM have been observed are highly variable, and range from open grasslands to woodlands (USFWS 2015). Prior to hibernation, PMJM spend time in uplands fattening for the 7-8 months of hibernation. Also, PMJM venture into uplands to hibernate in underground burrows at the base of trees and shrubs, including cottonwood (*Populus* spp.), Gambel's oak (*Quercus gambelii*), willow (*Salix* spp.), chokecherry (*Prunus virginiana*), snowberry (*Symphoricarpos albus*), skunkbrush (*Rhus trilobata*), and sumac (*Rhus* spp.), as well as herbaceous vegetation such as clematis (*Clematis* spp.), thistle (*Cirsium* spp.), and alyssum (*Alyssum* spp.) (Shenk and Sivert 1999). Hibernacula are usually north-facing (Schorr 2001). All documented hibernacula have been found between 3.3 and 335 feet of a perennial stream or intermittent tributary (Shenk and Sivert 1999; Schorr 2001; Ruggles et al. 2004; T. Ryon, Greystone Consultants., pers. comm.).

## 12.4.2 Spacing and Movement

The PMJM is primarily nocturnal, but can be seen during daytime when disturbed from day nests (Shenk 1998, Schorr 2001). During evening hours, most individuals remain within a smaller patch of riparian habitat, but then may move longer distances during twilight hours (Schorr, unpublished data). Individuals can move in excess of 4 km along riparian corridors where they live. Telemetry studies, in which short-lived (3-4 week) telemeters are attached to PMJM, have documented relatively small home ranges. For example, the mean maximum distance traveled by PMJM was 232 m (range: 90 – 470 m) and 362 m (13 – 968 m), during two studies at the Academy (Schorr 2001, 2003). Not surprisingly, PMJM had relatively constrained home range estimates of 0.53 ha (± 0.39 ha) and 1.41 ha (± 1.31 ha) during these respective studies (Schorr 2001, 2003). Yet, a few individuals showed the capacity for long-distance movement during these short-term studies, demonstrating dispersal of 934 m and 968 m (Schorr 2003). True long-distance dispersal was best observed not using telemetry, but through trapping records, when 22 PMJM were documented traveling > 500 m, and several were documented traveling > 4.3 km (Schorr 2003). These movements were made along the riparian corridor and not away from the riparian corridor.
Ryon (1999) documented similar long-distance movements at the Rocky Flats Environmental Technology Site. Using radio telemetry, Ryon found one individual that moved greater than 1600 m within a 30-day period. Over two consecutive nights, one individual moved greater than 1000 m. As Ryon pointed out, many of these longer forays were restricted to seep wetland and riparian corridors within the research area. The maximum distance from a stream channel for a collared

jumping mouse was 245 m. Shenk and Sivert (1999) used radio telemetry to determine meadow jumping mouse movement patterns. Like Ryon, they documented movement of greater than 1600 m. They also found long-distance movements along intermittent and perennial waterways and they documented seasonal movements of jumping mice. Shenk and Sivert described multiple movements of jumping mice greater than 100 meters away from waterways, extending well into the uplands. They also documented some of the most extensive use of upland communities to date.

Because the PMJM is a riparian-obligate, individuals do not venture far from the associated dense, mesic habitat unless via drainages or cover (Schorr 2001). Maximum distances from Monument Creek for telemetered individuals over 3 years (1997 – 1999) was 144 m (Schorr 2001). At other study sites along the Front Range, PMJM have been documented traveling greater than 100 m from the creek (Shenk and Sivert 1999). Some of the longest movements for PMJM away from the creek occur in fall as PMJM are looking for hibernacula outside of the flooding zones of their primary habitat (Schorr 2001).

Bakeman (Ensight 1999) used mark-recapture-trapping studies in and around an interstate overpass to determine what physical features limit meadow jumping mouse movement. Bakeman was also able to document movements through man-made structures, including metal and cement culverts.

Movement under the nearly 100-m long, cement overpass may have been facilitated by the presence of artificial cover. Artificial willow-shrub mimics built of perforated plastic boxes and willow sprigs were placed at regular intervals within the culvert. Similarly, PMJM at the Academy have been documented moving through short (23 m) culverts and long (92 m) trail underpasses (Schorr, unpublished data).

Similar to field studies at the Academy, Bakeman documented frequent creek crossings. Meadow jumping mouse swimming ability has long been documented (Hamilton 1935, Preble 1944, Quimby 1951, Sutton 1955) and creeks should not be considered a barrier to dispersal.

Understanding PMJM movement is critical for developing effective conservation strategies at the Academy and elsewhere throughout the range. The long-distance movements that have been documented using mark-recapture techniques likely underestimate the full dispersal capacity of PMJM because they are limited to where traps are placed. Even more limiting is the use of telemetry to understand these movement patterns because the battery life and potential behavioral bias of attaching telemeters. A better mechanism, which is being tested at the Academy, is the use of landscape genetic analysis. Using genetic tissue from PMJM along most of the Academy's PMJM habitat, researchers from CNHP and the U.S. Geological Survey are determining the dispersal pathways and potential isolation of PMJM populations at and near the Academy. This type of analysis is limited to the locations where PMJM have been captured, but can elucidate long-term population structure that is influenced by PMJM dispersal capacity, and the habitat disruptions that may limit it.

### 12.4.3 Phenology

Male PMJM typically emerge from hibernation in May, with females emerging sometimes 3 weeks later (Schorr et al. 2009). Males likely are fattening after a long season of fasting and preparing for reproduction. Other subspecies of meadow jumping mice generally have two litters per year, with early litters born in June (Quimby 1951). Hibernation typically begins in early fall (September – October) and extends through late spring (May – June). Adults begin hibernation earlier (~third week of August) than young-of-the-year, who usually enter hibernation in September or October, due to the ability or adults to acquire sufficient fat stores before young are able to do so (Wunder and Harrington 1996, Meaney et al. 2002).

## 12.5 Threats

The information in the following sections are summarized from the draft federal recovery plan for PMJM (USFWS 2015). The primary reason for PMJM decline is associated with habitat loss along and near riparian corridors throughout its range (USFWS 2015). Loss and fragmentation of habitat is attributed to urban development, construction of highways and bridges, water development, increased runoff and flood control, mining (sand, gravel), and overgrazing. These activities destroy habitat features necessary for cover, nests, food, hibernation, and movement.

### 12.5.1 Residential and Commercial Development

Development can remove and alter riparian and surrounding upland habitat, making it unsuitable for PMJM. Private land ownership typically follows valley bottoms, thus disproportionately impacting areas favored by PMJM (Theobald et al. 2001, Kuby et al. 2007). The indirect effects of human settlement have resulted in reduced native tree and shrub diversity and abundance, increased canopy closure, an increase in non-native predators and competitors, and a more open understory with reduced ground cover (Miller et al. 2003), which does not favor PMJM. These habitat impacts fragment PMJM habitat, limiting the extent and size of PMJM populations by disrupting movement throughout the habitat. Maintenance of dispersal corridors between PMJM populations may be critical to the subspecies' conservation (Shenk 1998).

Introduced animals associated with human development may displace, prey upon, or compete with PMJM. Feral cats and house mice (*Mus musculus*) were common in and adjacent to historic capture sites where PMJM are no longer found (Ryon 1996), and domestic cats prey on PMJM (Shenk and Sivert 1999). The PMJM was 13 times less likely to be found at sites where house mice were present (Clippinger 2002).

Based on many unsuccessful surveys, researchers believe PMJM are extirpated from sites around Denver and Colorado Springs. Bock et al. (1998) found that numbers of small mammals decrease with proximity to urban environments. Clippinger (2002) determined that residential developments (low density and high density) within 690 feet of trapping sites decreased the likelihood of capturing PMJM. See Section 12.6 for additional information on specific impacts to PMJM at the U.S. Air Force Academy from urban development.

## 12.5.2 Agriculture

The PMJM uses native grass and hayfields that are in or adjacent to suitable riparian habitat. Despite PMJM using adjacent hayfields, mowing of hay may directly kill or injure PMJM, reduce food supply, and remove cover (USFWS 2013b). Also, hay production near floodplains may limit growth of willows and other shrubs that are important habitat components for PMJM. Conversion of grasslands to farms and livestock grazing is believed to have adversely impacted PMJM (Compton and Hugie 1993). The Academy is bounded to the west by National Forest Service lands, and to the east and south by urban development, so crop agriculture is not a relevant management issue.

Incompatible livestock management impacts riparian habitat by altering stream channels (downcutting, trampling of banks, increased erosion), water flow (increased flow and velocity, decreased late-season flow), and vegetation (loss to grazing, trampling, altered hydrology) (Kauffman and Krueger 1984). Such impacts are known to jeopardize meadow jumping mice (Giuliano and Homyack 2004, Frey 2005), and Ryon (1996) cited livestock grazing as a contributor to the lack of structural habitat diversity at historical PMJM sites. Alternatively, grazing and haying, when used as land management tools on City of Boulder Open Space, showed no adverse effects on abundance of PMJM (Meaney et al. 2002), so grazing can be compatible with PMJM when timing and intensity are appropriately managed (Bakeman 1997).

## 12.5.3 Energy Production and Mining

Energy development has the potential to alter and fragment PMJM habitat through exploration for and extraction of oil, natural gas, and minerals. Oil and gas extraction potential is variable throughout PMJM range, but it is also widespread (Copeland et al. 2009). Current oil and gas areas are only slightly impacting PMJM habitat, but the increasing demand for natural resources is likely to lead to increased production. We do not have detailed information on locations of oil and gas reserves, but according to a generalized map for Colorado, there is low to medium potential for oil and gas development near the state distribution of PMJM (Rondeau et al. 2011).

Alluvial aggregate extraction may produce long-term changes to PMJM habitat by altering hydrology and removing vegetation. Restoration of riparian vegetation is precluded if mines are developed with impervious liners and converted to reservoirs after aggregate is removed, as is oftehn the case. It has been suggested that mining impacts the deposits of alluvial sands and gravels that may be important hibernation locations for PMJM (USFWS 2015).

## 12.5.4 Transportation and Service Corridors

Transportation corridors and utility right-of-ways (sewer, water, power, communications lines, and associated ditches) frequently cross PMJM habitat. Maintenance on existing roads and construction of new roads can destroy and fragment PMJM habitat, forming partial or complete barriers to dispersal (USFWS 1998). Right-of-ways have similar construction and maintenance concerns, though these are generally short-term disturbances due to permitting processes put in place since the 1998 listing. See Section 12.5.4 for additional impacts related to transportation corridors.

## 12.5.5 Human Intrusions and Disturbance

Trail systems frequently parallel or intersect riparian communities within Colorado, and they may modify both riparian and upland habitats, as well as introduce disturbances that alter activity and feeding patterns (Meaney et al. 2002). Meaney et al. (2002) found fewer mice at sites with trails than on those without. Trails at the Academy both parallel some creeks and cross the riparian areas. At areas, like along Lehman Run near the Academy campus, installation of a maintained hiking trail only temporarily disrupted a small segment of the riparian habitat. Along the southern section of Monument Creek, the Santa Fe Trail parallels the creek and is typically outside the floodplain limiting the impacts to the system. However, it is unclear how the amount of traffic on the Santa Fe Trail impacts PMJM travel into upland habitat.

## 12.5.6 Natural Systems Modifications

***Hydrology***

Riparian communities are established and maintained by the interactions between surface water dynamics, groundwater, and river channel processes (Busch and Scott 1995), including flooding and sediment transport. Changes in the timing and abundance of water that maintains riparian habitat may be detrimental to PMJM persistence. The two most prevalent causes of altered hydrology within the range of PMJM are disruption of natural flow regimes below dams and diversions, and excessively high runoff cycles that result from increased area of paved or hardened surfaces (e.g., urban areas, roadways) (Schorr 2012). Introducing impervious surfaces and destroying vegetation changes the frequency and severity of floods, and also prevents the re-establishment of vegetation (Schorr 2012). Extreme flooding can incise floodplains, create cutbanks, and thus lower the water table. Increasing the severity of floods could extirpate small, isolated PMJM populations. When altered flooding regimes are combined with drought, results can include dessicated soil, lower stream flows, and degraded or lost riparian vegetation.

Similarly, groundwater depletion via wells and water diversion impacts PMJM habitat by replacing riparian vegetation with more xeric plant communities. Bank stabilization, channelization, and other methods of hardening stream banks can increase the rate of stream flow, narrow riparian areas, and destroy riparian vegetation. All of the above hydrologic changes, often associated with urbanization and associated roads and water use infrastructure (Lazaro 1990), impact PMJM habitat and are threats to PMJM populations (Schorr 2012, Schorr and Mihlbachler in review).

***Wildfire***

Fire is a natural component of many western ecosystems, and has a direct influence on PMJM habitat. As an ecological process, fire has a role in maintaining the transition and upland habitats that PMJM uses, and does not normally have any adverse population level impacts on PMJM (Kaufman et al. 1990, B. Mihlbachler, pers. comm.). However, recent history has seen significant effort to suppress fires for human safety and the protection of valuable infrastructure. The result of this is overly dense vegetation and build-up of fuels, with a consequent increased risk of catastrophic wildfire. Severe fires can result in destroyed vegetation, inability of vegetation to regenerate due to sterilized soils, and much greater erosion and sedimentation in creeks. Such a setting would be very risky for PMJM persistence.

## 12.5.7 Climate and Extreme Weather Events

Because projected warmer and drier conditions are expected to decrease the quality and quantity of riparian habitats, PMJM is especially vulnerable when faced with a changing climate (USFWS 2015).

***Climate Projections***

Climate projections for mid-century within the range of PMJM generally indicate warmer and drier conditions, although precipitation change is more uncertain in direction and magnitude for areas with more complex topography such as the Front Range (Lukas et al. 2014). Hydrologic modeling for river basins on both eastern and western slopes indicates that as a generalized rule-of-thumb, for each 1.8°F (1°C) of warming, an approximate 5% increase in precipitation would be required for runoff levels to remain more-or-less unchanged (Nash and Gleick 1993, Poiani et al. 1995, Woodbury et al. 2012). Although many models project a slight increase in precipitation (averaging 5% increase or less annually) for the PMJM range by mid-century, a simultaneous temperature increase of 4°F or more means that no areas in the current PMJM range will receive sufficient compensatory precipitation to maintain current runoff patterns (Figure 78). Hence, future conditions for PMJM habitat are likely to be effectively drier.

Warming-induced changes in snowpack and snowmelt timing include earlier onset of spring snowmelt, a shift towards precipitation falling as rain instead of snow in spring and fall, and increased sublimation from the snowpack even during the winter. Thus, changes in the hydrologic cycle are expected to include shifting runoff and peak flows to earlier in the spring (potentially by as much as a month to six weeks under the most extreme conditions), and reducing late summer-early autumn flows (Rood et al. 2008, Deems et al. 2013, Lukas et al. 2014, Gordon and Ojima 2015). Riparian vegetation is in part determined by flow levels (Auble et al. 1994). Reduced summer flows are predicted to result in more frequent drought stress for riparian habitats, with a resulting loss or contraction of the habitat (Rood et al. 2008). Such changes are expected to have the most impact at lower elevations (Lukas et al. 2014), potentially including some areas toward the lower elevational limit of PMJM occurrence.

These conditions are not limited to transition streams on the Front Range. A statewide climate change vulnerability assessment for Colorado's recently revised State Wildlife Action plan shows that predicted temperature and precipitation are outside of historic means for wetland and riparian habitats across all elevational gradients (Figure 79, Decker and Fink 2014). This means that – if projections hold true – water providers and users could be competing with ecosystem instream flow needs across the state, and depending on how regional precipitation patterns play out, they could be doing so simultaneously. Future climate projections for downstream water compact states are similarly problematic (Palmer et al. 2009).

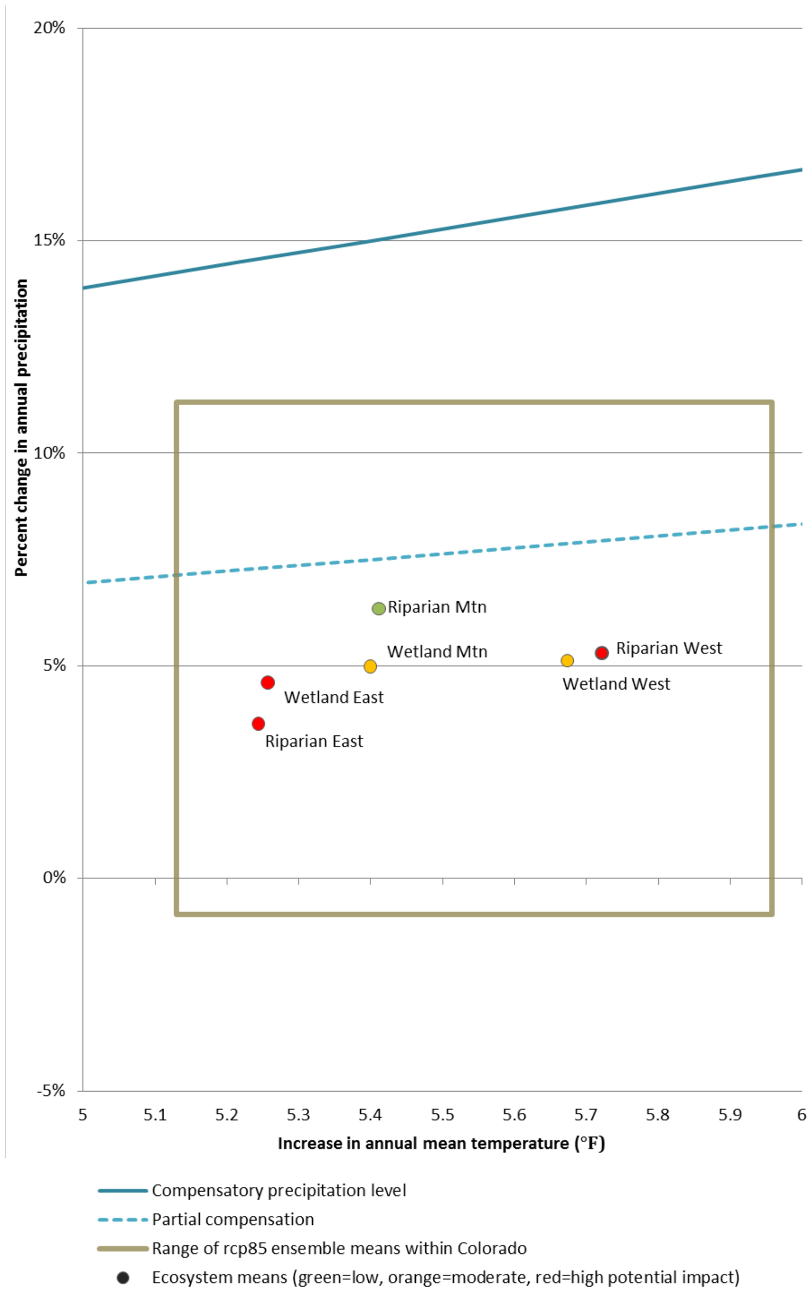



**Figure 78. Projected annual change in Colorado for wetland and riparian ecosystems.** Ecosystem means are colored to indicate the degree to which the ecosystem is projected to experience conditions that are out of range of those in its current statewide distribution. Source: Colorado Natural Heritage Program 2015.

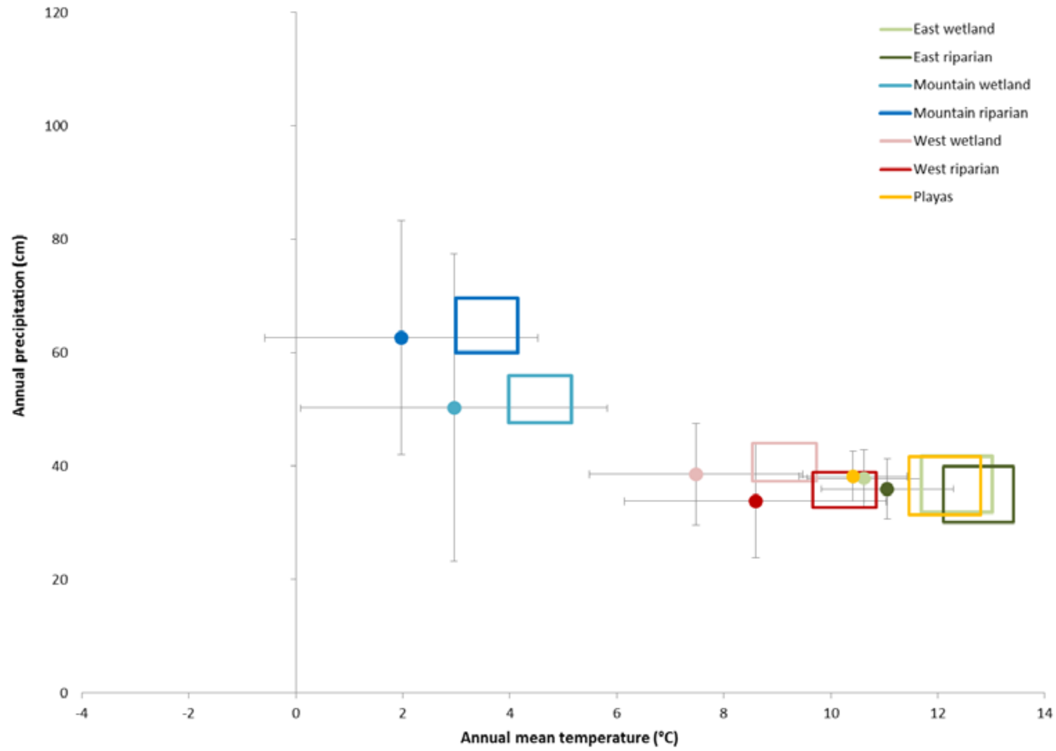



**Figure 79. Current Colorado annual mean temperature and precipitation and projected mid-century region of change for wetland and riparian habitats.** Circles represent historic means with error bars representing one std. dev. Squares represent the middle 80% percent of the range of projected mid-century change based on a moderate emissions scenario (RCP6). Source: Decker and Fink 2014.

***Potential Impacts***

Dominant riparian species (e.g., willow and cottonwood) are often dependent on periodic flood disturbance for dispersal and regeneration. The hydrology of PMJM habitat has already been altered by dams, diversions, and groundwater pumping, and these modifications may interact with warming temperatures and changes in precipitation pattern to alter fluvial regimes. Such changes can increase vulnerability of riparian habitats to invasion by exotic species, especially after extreme events (Capon et al. 2013). Climate change in upstream areas as well as in adjacent habitats could have significant impact on riparian habitats, potentially reducing vegetative cover, and altering species composition.

In addition, the interactions of added plant growth due to increased $CO_2$ concentration and warming-induced drought and heat-stress, with potentially reduced stream flows, are likely to affect riparian community structure and composition (Perry et al. 2012). To our knowledge, there are no published studies of how this might occur specific to the transition streams along Colorado's Front Range. Recent studies in Arizona determined that reduced base flows and water tables and increased stream intermittency would cause riparian vegetation to shift from hydric species such as cottonwood and willow to more mesic species (e.g., tamarisk), with corresponding decrease in canopy cover and canopy height, and that annual herbaceous species would increase while perennials decrease (Stromberg et al. 2007, 2010). That same study showed that increased intensity in floods would shift the riparian community to younger trees (i.e., increased woody stem density but decreased basal area), expand xeric shrubs, and replace perennials with annuals. Shifts in plant communities associated with increased flood intensity translates to reduced ability to stabilize sediments (e.g., loss of perennial plants). These studies focused on a different kind of riparian system (Sonoran desert) than that on the Academy, so how relevant these results are is unknown. However, note that the majority of herbaceous species documented in the PMJM diet are perennials.

Reduced flows in summer are expected to coincide with increased demand for water from both agricultural and municipal users. Conflicting goals between instream flow needs for ecosystems and the agricultural sector seems especially likely. Agriculture accounts for the great majority of Colorado's water consumption (~89%, State of Colorado 2015). Warming temperatures are expected to lead to longer growing seasons, increased evapotranspiration, and therefore increased irrigation requirements during summer and early fall months when stream flows will be at their lowest. In addition, warmer, drier conditions and more frequent and extreme droughts are expected to increase stress on forested uplands, with a consequent increase in longer fire seasons and severity of wildfires. While wildfires can occur during any season, severe fires are most likely during the hottest, driest part of the summer. Finally, climatic change will lead to increased municipal consumption of energy (e.g., air conditioning) and water demands (e.g., landscape irrigation), potentially further reducing water availability for riparian habitat.

## 12.6 Management Recommendations

Implications and strategies for the highest priority conservation issues for PMJM at the Academy are discussed in the following sections. These include erosion related to surrounding urban development and cross-boundary collaboration to increase the resiliency of riparian systems to impacts from climate change and other stressors.

### 12.6.1 Increased Erosion and Habitat Degradation from Urban Development

The most immediate PMJM conservation concern for the Academy is the maintenance of riparian habitat that is being lost along the eastern boundary and along Monument Creek. The increased runoff caused by land use changes east of the Academy has created erosion issues that jeopardize the PMJM population. For example, from 2000 to 2005 more than 5,000 single-homes were permitted for construction annually in Colorado Springs, with a peak in 2004 and 2005 of nearly 7,000 per year (USHUD 2015). This transformed the areas east of the Academy from large rural ranches to high-density housing reduced the acreage of native and farmed grasslands, and increased the acreage of impervious surfaces that generate more runoff volume and transport runoff much more quickly. One of the tributaries, Monument Branch, in 2003 was a small meandering creek that fed Monument Creek, with riparian vegetation on either side. After repeated flooding in 2006 and 2007, Monument Branch was denuded of riparian vegetation (Figure 80).

Flooding has occurred periodically in the Colorado Springs area, such as the flood in late April and early May of 1999, but without the erosive impacts as those that began after the development intensity east of the Academy. The increased erosive effects of urban-induced flooding are not new

**Figure 80. Monument Branch at the confluence with Monument Creek in April 2003 (left) and November 2006 (right). Notice the loss of riparian willow that used to exist along Monument Branch in 2003.**

(Leopold 1968, Hollis 1975). As impervious surface area increases with urban development, both the discharge volume and frequency of flooding increase (Figure 81). Urban development increases the peak discharge and frequency of floods, exposing communities and ecosystems to flood hazards (Konrad 2003). It has been estimated that in areas where impervious-surface cover exceeds 10% of the watershed runoff increases 200-500% over historic levels (Paul and Meyer 2001). The increased area of impervious surfaces adjacent to the Academy have reduced infiltration, increased runoff, and exacerbated streambank erosion (Stogner 2000, Armstrong and Stevens 2002). Much of the risks associated with urbanization-induced flooding risk have focused on human property and safety; however, these impacts have repercussions for nearby natural systems (Poff et al. 1997). In particular, the loss of riparian habitat can have detrimental impacts to the plant and animal communities (White and Greer 2006). For PMJM, the loss of riparian habitat due to erosion can have implications for survival and recruitment (Schorr 2012, Schorr and Mihlbachler in review). Even after urbanization-induced impacts to riparian systems, successful restoration of riparian habitat is possible, albeit challenging (Kus 2002, Bernhardt and Palmer 2007).

Bakeman (2005) found that the installation of check dams can mitigate the impacts of urbanization on PMJM habitat. In particular, groundwater elevations were raised to allow the growth of riparian vegetation after repeated flooding incised the stream banks and lowered the water table (Bakeman 2005). The increase in PMJM abundance was attributed to increased graminoid cover at treatment plots. On the Academy, PMJM habitat was restored along Black Forest Creek after moderate construction impacts (B. Mihlbachler, pers. comm.). Unfortunately, the scale and frequency of flooding, along with the highway construction that has occurred along Interstate 25, have not allowed the riparian habitat on the eastern boundary of the Academy to recover.

***Guidance for erosion control from storm water runoff and riparian habitat conservation***

There are a host of initiatives that prioritize the conservation of water resources, but few that target the conservation of riparian vegetation and habitats (Knopf et al. 1988). For the Academy, there are several federal legislative orders and acts that support the conservation of PMJM habitat indirectly. Executive Order 11988 (1977) Floodplain Management requires federal agencies to minimize adverse impacts to floodplains, avoiding floodplain development when practical alternatives can be identified. Executive Order 11990 (1977) Protection of Wetlands mandates that federal agencies "shall provide leadership and shall take action to minimize the destruction, loss or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands". The National Environmental Policy Act (NEPA) (1969) identifies adverse effects to endangered and threatened species habitat as "significant" impacts, requiring federal actions, such as issuing regulations, providing permits for private actions, funding private actions, making federal land management decisions, and constructing publicly-owned facilities to undergo NEPA review and consultation. The Federal Lands Policy and Management Act (1976) requires the management of public lands in a fashion that will "provide food and habitat for fish and wildlife," minimizing adverse impacts to the natural values, such as fish and wildlife habitat. The Fish and Wildlife Coordination Act (1964), is designed, in part, to protect fish and wildlife when federal actions result in the control or modification of a natural stream or body of water. It requires federal agencies to consider the effect projects have on fish and wildlife resources and to prevent loss or damage to these resources. The Clean Water Act (Water Pollution Control Act) (1972) and its subsequent amendments are over-arching regulatory mechanisms to protect U.S. waters from pollution. With specific erosion and sedimentation minimization requirements, the Clean Water Act has Nationwide Permits (2012) that describe allowable discharges from residential developments. In particular, discharge must not cause "loss of greater than ½-acre of non-tidal waters", including the loss of no more than 300 linear foot of streambed, "unless for intermittent and ephemeral streambeds the district engineer can demonstrate the discharge will result in "minimal adverse effects".

The piece of legislation with the most directive in preventing PMJM habitat loss, the Endangered Species Act (ESA), does not target riparian areas, but addresses conservation of habitat for endangered and threatened species. This is most clearly stated under Section 9 (Prohibited Acts) where it is unlawful to "take" any such species listed under the Endangered Species Act. The term "take" has been clarified to mean "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct", with "harm" including "significant habitat modification or degradation where [the modification] actually kills or injures wildlife [listed under ESA] by significantly impairing essential behavioral patterns, including breeding, feeding, and sheltering" (50 Code of Federal Regulations 222.102). Motivated by the listing of PMJM, the Academy developed a PMJM conservation and management plan to "secure the long-term conservation of PMJM within the [Academy]" (Grunau et al. 1999). This plan documents the offsite issues that jeopardize the long-term viability of PMJM populations on the Academy, including the need to manage the Monument Creek watershed "in a manner consistent with maintenance of existing flows, hydroperiod, and geomorphology" (Grunau et al. 1999). Interestingly, in this document from nearly 20 years ago, there was an emphasis on identifying and avoiding the offsite hydrological degradation that eliminates habitat for PMJM, "as the hydrologic function is altered and adjacent habitat degrades, the risk to the [Academy] PMJM increases, with reduced flexibility in management options for the [Academy]".

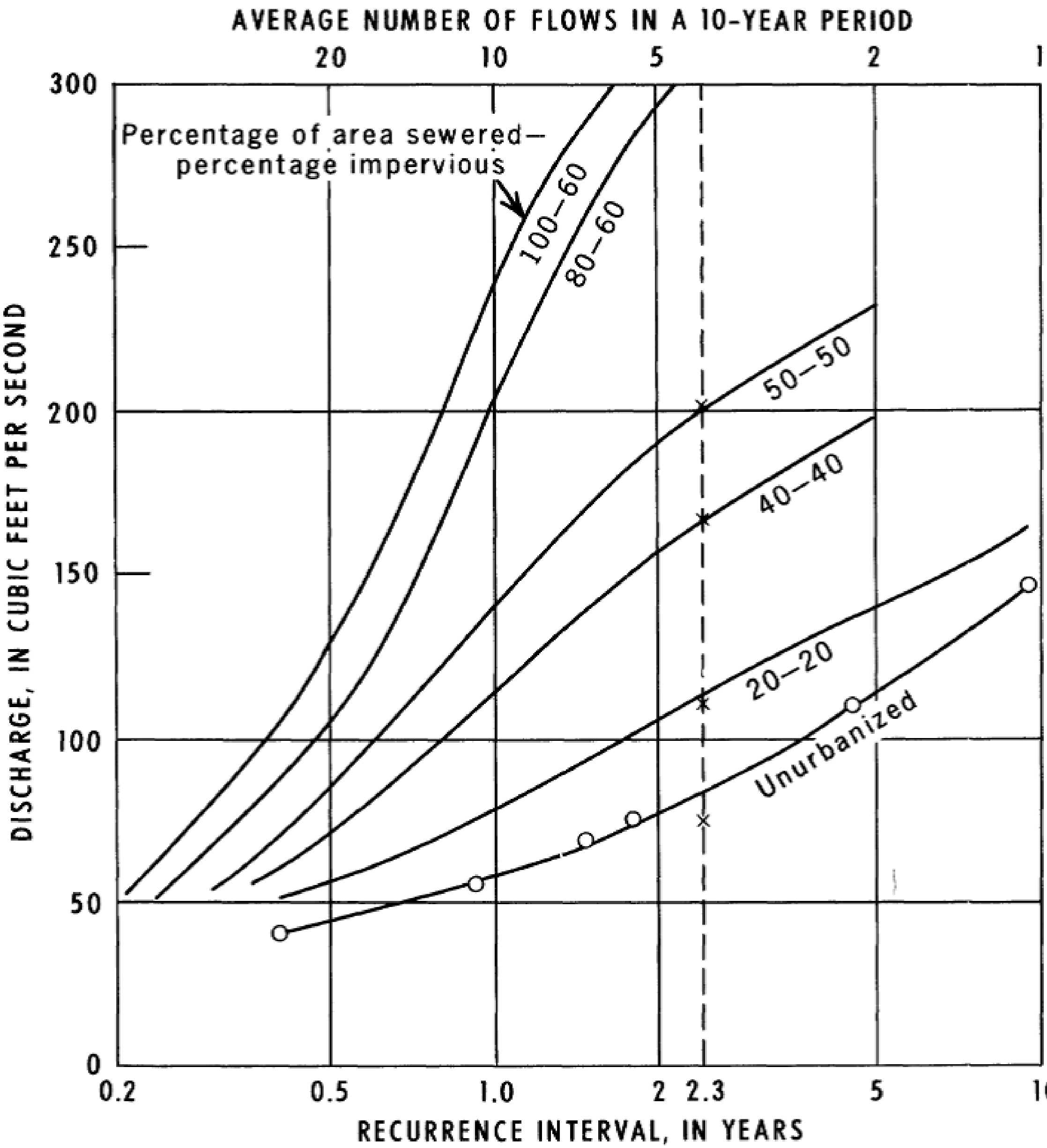



**Figure 81. Flood frequency curves for a 1-square-mile basin in various states of urbanization (Leopold 1968).**

Within the state, the agency most involved with flooding, flood control, and the subsequent erosion is the Colorado Department of Public Health and Environment. The *Urban Storm Drainage Criteria Manual Volume 3* (2010) provides best management practices on minimizing erosion from urban development, but does not address the cumulative effects of urban development on frequency and scale of flooding. There are recommendations on how to reduce impacts from urbanizations, such as runoff reduction practices, best management practices that capture volume with slow release, stream stabilization, and site-specific source-control best management practices. Chapter 2 of the Criteria Manual addresses drainage law, and it states that the owner of an upstream property "possesses a natural easement on land downstream for drainage of surface water flowing in its natural course", and that the "upstream property owner may alter drainage conditions ***so long as the water is not sent down in a manner or quantity to do more harm to the downstream land than formerly***" (from Civil Law Rule; emphasis added). Similarly, it addresses the use of natural waterways as conduits for draining overland flows, "***at least where the augmented flow will not tax the stream beyond its capacity and cause flooding of adjacent lands***" [emphasis added]. These two violations of water use stem from the "reasonable use law" of water law, in which each landowner with land abutting a surface water body is a co-owner of the right to use that water. However, courts can intervene in a riparian owners' decisions when a use by one co-owner interferes directly with a use by another co-owner (Dellapenna 2010).

The City of Colorado Springs Engineering Division's *Drainage Criteria Manual: Stormwater Quality Policies, Procedures and Best Management Practices* (2002) and *Drainage Criteria Manual* (2014) provide guidance and management practices for minimizing impacts to hydrology and floodplains. These documents recognize the value of natural floodplains for "natural attenuation of flood peaks, water quality enhancement, groundwater recharge, wildlife habitat and movement corridors, and opportunities for recreation", and changes to the natural function can have long-term consequences. The typical standard, mandated by Federal Emergency Management Act, is to implement floodplain management criteria within the "regulatory 100-year floodplain," which is the land area that will be inundated or flooded based on the storm water runoff produced by the 100-year storm event, or the rainfall event that has a 1% probability of being equaled or exceeded in any given year. Given these definitions and the frequency and peak-volume of flooding events on the eastern tributaries along Academy's border, there is evidence that the 100-year floodplain is routinely being exceeded due to off-site impacts. Additionally, this might be an issue of upstream property owners violating the Civil Law Rule, in that the "manner and quantity" of water is doing harm to the downstream property owner as demonstrated by the loss of PMJM habitat and the undue management and conservation burden applied to the Academy.

***Correcting Off-site impacts to PMJM habitat on the Academy***

Although best management practices for development (riparian buffer regulations, land-use/zoning regulations, detention areas, etc.) may play a part in mitigation of storm water runoff, such efforts are not likely to be entirely sufficient to prevent ongoing degradation of the local watershed (Booth et al. 2002). Integrated mitigation efforts that limit impervious area, preserve native vegetation cover, maintain or expand wetland and riparian buffer areas, preserve riparian corridor connectivity, and eliminate construction on unstable slopes are recommended. Effective mitigation and correction of PMJM habitat loss on the Academy from upstream storm water management will require timely collaborative planning with the City of Colorado Springs and El Paso County. Such conversations may identify where the installation of flood-mitigation features can reduce flows that reach the Academy. Holistic approaches to storm water management that maintain native habitats can be effective for limiting flooding impacts and reducing habitat loss for wildlife (Tourbier 1994). Check dams have proven successful in reducing storm water flows and erosion along East Plum Creek in Douglas County (Bakeman 2005) and may be worthwhile investments. Early consultation with storm water engineers with a history of restoring stream and wetland function in support of native ecosystems is likely to be essential for success. Additionally, conversations about how to leverage city, county, and federal funds may identify resources for maintaining PMJM habitat on the Academy and preventing further upstream storm water management violations. Because several of the drainages are subject to increased runoff and erosion after the 2013 Black Forest fire, additional resources may be available for those areas.

***Prioritizing where floodwater control is required to restore and maintain PMJM habitat***

There are numerous tributaries to Monument Creek that flow onto the Academy from the East, including (from north to south) Black Forest Creek, Smith Creek, Monument Branch, Black Squirrel Creek, Middle Tributary, Kettle Creek, and Pine Creek. Most of these have experienced increased flows over the past several decades and most have undergone some level of habitat rehabilitation (U.S. Air Force Academy Natural Resource Management - Watershed Management website: https://usafa.isportsman.net/Watershed.aspx). Monument Branch, Middle Tributary, Black Squirrel Creek, and Kettle Creek have the longest stream miles of any of the tributaries, and thus, are likely to have the most value for PMJM habitat conservation because of their potential for more habitat and PMJM. Monument Branch has undergone the most urbanization-induced erosion damage with incised banks and dramatically-increased sedimentation (Figure 82). Similarly, Kettle Creek, has undergone a dramatic drop in the water table that supports PMJM habitat, causing this area, which once hosted some of the highest densities of PMJM (Ensight Technical Services 2003), to now have no PMJM captured in 2012 (Figure 82).

**Figure 82. Increased erosion along Monument Branch (left) and incision of Kettle Creek because of flooding (right).** *Photographs by Brian Mihlbachler.*

As urbanization continues to increase storm water runoff, increasing erosion, lowering water tables, and reducing PMJM habitat on the Academy, the Academy, the City of Colorado Springs, and El Paso County municipalities will need to address the inevitable “harm” caused to PMJM under the

ESA. Currently, PMJM habitat on lands managed and permitted by the City of Colorado Springs and El Paso County has been lost due to mismanagement of flood waters (see the eroded Pine Creek canyon at Interstate 25). These issues have jeopardized PMJM populations along Smith, Monument Branch, Black Forest, and Kettle creeks on and off the Academy, and further jeopardize recovery of PMJM. The longer these issues go unaddressed the greater likelihood that the eroded soils are deposited along Monument Creek and begin to bisect the Monument Creek PMJM population. Should the Monument Creek population continue to lose habitat, and the capacity to support PMJM, this population could be demoted from a population of "medium" size to "small" size (USFWS 2015), and will make recovery and delisting of PMJM extremely difficult. Delisting PMJM is achieved when 2 "large" and 5 "medium" populations are stable or increasing (USFWS 2015). The loss of habitat and individuals along the Monument Creek population jeopardizes 1 of the 5 known "medium"-sized populations (USFWS 2015). Thus, the current inability to prevent PMJM habitat loss from mismanaged stormwater runoff is a hindrance to recovering PMJM throughout the range.

### 12.6.2 Coordination to Improve Climate Resiliency in Riparian Habitats

Given the nature of riparian and aquatic habitats and western water law, improving the resilience of PMJM habitat at USAFA will not be possible by the Academy alone. Rather, it will require collaborative efforts by a multitude of stakeholders. The vegetation required by PMJM cannot be maintained at suitable densities without adequate surface and groundwater. Though the Academy has management authority over the terrestrial vegetation within its boundaries, it does not have control over the water. The INRMP documents and supports ongoing coordination with local governments on water management and land use impacts with potential to impact on-base habitats (e.g., Academy staff have participated in development of the soon-to-be released Colorado Springs Water Resource Plan). The INRMP further describes monitoring (water quality and stormwater) and restoration efforts. These are all important and should continue. Adding a monitoring component specifically targeting health of riparian vegetation may provide early warning of decline and reduced resiliency in the habitat component most critical for PMJM.

> *Meeting 21st-century sustainability challenges…will… require planning, cooperation, and integration that surpass 20th-century efforts in terms of geographic scope, jurisdictional breadth, multisectoral engagement, and the length of planning timelines…those efforts should be undertaken with expediency (MacDonald 2010)*

As pointed out by Palmer et al. (2009), proactive adaptation strategies are preferable to reactive strategies since significant damage may occur before reactive measures can be implemented. Proactive restoration of damaged stream reaches to improve the resilience of hydrologic function and riparian vegetation is, of course, highly desirable. However, this will be of limited use if flows cannot be maintained in a compatible hydrograph. One perhaps less obvious strategy to consider is protection of land (e.g., easements) adjacent to rivers to prevent introduction of additional impervious surfaces and possibly also provide more area available for dissipating energy from floods. Flow data and modeling can help estimate the amount and location(s) of conservation easements to pursue to best mitigate increasing flooding (Palmer et al. 2009). Purchase of instream flow water rights is another potential alternative. Palmer et al. (2009) suggest dry-year option agreements with willing private partners as an option to ensure that flows during droughts remain sufficient to protect critical habitats. Ojima et al. (1999) recall collaborative efforts to respond to the 1976-78 drought:

> *Howe et al. (1980) found that many of the rural entities that supply water for irrigation in eastern Colorado and nearby towns cooperated in various ways to make efficient use of available water supplies. For example, some senior right holders agreed not to "call" for their water, and some water users pooled their available supplies in a single reservoir to reduce evaporation and provide carryover for possible continuation of the drought. However, in some places the division engineers encountered difficulties in enforcing water rights, and in Division I (Northeastern Colorado), the drought resulted in "severe drawdown of groundwater" (Howe et al., 1980:46). In addition, in Northeastern Colorado both towns and irrigators mitigated some of the impacts of the drought by trading water through active rental markets for Colorado-Big Thompson shares and ditch-company shares (Maas and Anderson, 1978; Howe et al., 1980).*

Developing adaptive capacity in a highly connected system such as aquatic and riparian will require casting a wider collaboration net than has been needed in the past. Partners should represent multiple sectors, including agricultural producers, forest managers, developers, and water providers, as well as a multitude of governmental agencies[24] (Poff et al. 2002, Arthington et al. 2006). A particular challenge to developing the adaptive capacity will likely be legal and institutional barriers (e.g., water rights, interstate water compacts, water markets, property rights, and zoning patterns, Palmer et al. 2009). In addition, as Ojima et al. (1999) point out, decisions regarding water allocation between aquatic ecosystems and human uses needs to be more clearly assessed. A better accounting of the economic value of aquatic and riparian-based ecosystem goods and services would be advantageous.

[24] These potentially include Colorado Division of Water Resources, Colorado Water Conservation Board, U.S. Bureau of Reclamation, U.S. Army Corps of Engineers, Environmental Protection Agency, Natural Resources Conservation Service (monitors snowpack and provides the Surface Water Supply Index for Colorado), National Weather Service's River Forecast Centers (streamflow monitoring and forecasting), National Integrated Drought Information System (U.S. Drought Portal) (State of Colorado 2015).

# 13 Lessons Learned and Transfer Plan

## 13.1 Lessons Learned

### 13.1.1 Incompatible Land Use Analysis

Our analysis of impacts from incompatible land uses on ecological systems was a very straight-forward overlay and calculation of acreage. As with most analyses, the greatest constraint was availability of data. Because we were interested in the entire distribution of the ecological systems (i.e., across state boundaries), we were limited to broad scale datasets (e.g., roads) for some of our inputs. These were acceptable for giving a general sense of where and how much comparatively unimpacted habitat exists relative to land uses with readily mappable footprints. However, this analysis was compromised by lack of data for some land uses that have potential for very significant impacts. This is particularly true of invasive species and grazing, neither of which lend themselves to broad scale mapping using remotely sensed data. The EDDMapS West[25] database may be useful for including invasive species in future analyses, but thus far coverage is only in select western states. Domestic livestock grazing has significant potential to influence western ecosystems, either as a threat or as a management tool for improving ecosystem health. Unfortunately, the response of vegetation to grazing pressure is closely linked to highly variable livestock management methods which are not likely to be mappable at any scale appropriate for regional analysis.

As part of our threats assessment for ecological systems, we explored the use of NatureServe's Ecological System Rank calculator[26] (specifically the Threats Assessment component). The Conservation Rank Calculator is an Excel-based tool that automates the process of evaluating the level of species or ecosystem loss. We did not find this tool to be a good fit for our analysis, and results of that effort are not included in this report. The main problem was that the cumulative threat thresholds did not appear to reflect on-the-ground conditions accurately for our study area, and rank categories were either too narrow or too broad in comparison with the range of conditions evaluated.

### 13.1.2 Climate Change Analyses

For species, we used NatureServe's Climate Change Vulnerability Index (CCVI) to get a basic sense of the relative degree of, and reasons for, vulnerability to climate change. The CCVI is useful as a starting point for distinguishing comparative vulnerability, for quickly sorting through long lists of species, and for documenting basic understanding of climate-relevant life history factors. Application of the tool is relatively rapid, and scoring categories are well-defined and well-documented. Results are readily comparable across species and geographies of interest. Note that the exposure component of the tool really only works at fairly broad scales, largely because even down-scaled climate models are still coarse estimates. At present, the CCVI tool lacks a spatial component and thus does not predict where changes in distribution might occur. However, it does

[25] https://www.eddmaps.org/mrwc/
[26] http://www.natureserve.org/conservation-tools/conservation-rank-calculator

focus attention on significant distribution and life history factors that may be important inputs into subsequent range models.

Full climate change vulnerability assessments for ecosystems fell outside of the funding priorities under which our scope of work was developed. However, threats assessments that fail to consider climate change are, by today's standards, incomplete. Thus, for this study, we relied on readily available spatial data and methods previously developed (Decker and Fink 2014, Colorado Natural Heritage Program 2015) to to estimate how severe and/or widespread changes in climatic conditions may be for ecological systems within our areas of interest. Some lessons learned from our experience in this work is included here for the potential benefit of others interested in conducting similar analyses (summarized from Decker et al. 2017). An important note in considering climate change vulnerability is that an assessment typically reports *relative* vulnerability rather than an absolute measure of risk. Results may vary based on inputs – e.g., which climate model(s), emissions scenarios, timeframes and scale are used in a given assessment. Given the nature of climate modeling and incomplete understanding of species and ecological systems, uncertainty in results is to be expected. However, sources of uncertainty should be adequately communicated to end users to avoid confusion arising from differing results. Climate projection data are constantly being refined and updated, and assessment results from the suite of possible climate model/emissions scenario combinations are highly variable, with some factors more reliably modeled than others. In particular, highly complex topography (e.g., of much of Colorado) makes precipitation predictions problematic at scales which are likely to be important to local vegetation types over the relatively short-time period typically encompassed by natural resource management plans. Incorporation of qualitative methods (i.e., expert input on species life history and ecology) is helpful in selecting some model inputs, but is also an additional source of uncertainty given our often incomplete understanding.

In some ways, military training can be similar to natural disasters – i.e., stochastic in space and time. Managing for resilience is needed within the training environment as well as within the context of changing climate and other stressors. In many cases, our understanding of exactly where the thresholds are between resilient and not resilient (e.g., the point at which some environmental variable moves from impairing to lethal) is poor. A plethora of research priorities exist, including better tracking of species distributions, phenology shifts, and changes in behavior, food preferences, and environmental tolerances. Additionally, improved means of housing, synthesizing, and sharing data and key messages continues to be needed.

## 13.2 Transfer Plan

This comprehensive technical report is the primary deliverable. The target audience for the report and additional deliverables is policy and management professionals working in DoD natural resources. No formal metrics are proposed to gauge the effectiveness or impact of the products. The following additional products will be used to disseminate results.

- Article to be developed and submitted to the DOD Natural Resources Program's *Natural Selections* newsletter in winter 2018.

- Legacy Program fact sheet (one-page summary of the overall effort) delivered with technical report.
- A webinar is being planned for the DoD Natural Resources webinar series, pending confirmation of timeline from program staff.
- A presentation of the process and results at a related conference was proposed for this project, but travel funds were not approved. We are hopeful that a technical poster can be prepared and presented at the National Military Fish and Wildlife Association Conference to be held in Norfolk, Virginia in spring 2018, if other funding sources allow.

Modern philosophies regarding management of natural resources embrace landscape scale planning, adaptive management, and cross-jurisdictional collaboration. These are lofty goals, but are difficult to put into practice at local scales. Managers are often time- and resource-constrained, with insufficient opportunity to fully evaluate the regional context within which their actions take place. The findings reported herein can help managers understand implications of potential changes to range sustainability and resiliency at broad as well as installation-specific scales. Changing climate is already altering (in some cases worsening) historic patterns of species distributions and disturbance processes, and impacts are being experienced by species and ecological systems already stressed by human use and encroachment. An improved understanding of how local management decisions fit into the big picture can help identify and prioritize proactive, longer term strategies and partnership opportunities that all parties need to be investing in now.

# 14 Discussion

## 14.1 Summary of Threats and Threat Management

Natural resources managers actively evaluate alternatives to minimize constraints to the military mission. Some temporal and/or geographic restrictions or constraints placed on training activities are driven by unavoidable mitigation needs as determined by installation staffs. Other constraints are explicitly listed or driven by requirements or commitments enumerated in compliance documents such as biological assessments, NEPA documents, and management plans, as well as non-compliance stewardship goals. Examples of training constraints driven by environmental issues include protection of Mexican spotted owl roost trees, sensitive soil areas, and riparian area restrictions. Additional discussion and examples of administrative protections are provided in Chapter 3. Threat management takes many forms, including ongoing programs to mitigate mission impacts using both proactive and reactive approaches, as well as targeted activities that address ever-changing resource management needs.

For pinyon-juniper obligates, habitat has already been degraded by a host of factors, including historic rangeland "improvements," fire suppression and increasingly large wildfires, recent drought and Ips beetle damage, past and current attitudes of many land managers (target for removal, "grind-and-go" approach to restoration), and general confusion about the many variations of pinyon-juniper (e.g., when pinyon-juniper represents encroachment v. when it represents natural succession or recovery from past extreme events) – not to mention climate change.

The current status of the gray vireo is unclear, but its future in the region may be favorable if climate projections for juniper expansion are correct. Pinyon jay, on the other hand, may be faced with increasing stress. Its populations are showing significant declines in most parts of its range. Climate projections suggest that pinyon pine might become increasingly restricted and stressed. Pinyon jays are known to breed in other systems (e.g., ponderosa pine) and eat other foods, but their tie to pinyon pine is very strong. Whether or not pinyon jays can transition to other breeding substrates and other food sources at a population-sustaining level is unknown. It is also worth noting that ponderosa pine is also fairly degraded and stressed in many places, and this is likely to continue (e.g., wildland-urban interface, altered fire regime, future climate). Fort Carson and PCMS are near the edge of the current ranges for pinyon-juniper and pinyon jays. However, if ranges and distributions change (e.g., models predict that higher quality habitat for pinyon jays maybe move north and east), higher quality habitat may be closer to these installations. On the other hand, some models show these installations potentially losing suitability for pinyon pine. Also, if range contractions occur (i.e., for the pinyon jay), that could happen at edges of the range rather than in the core, but not all species' range contractions follow that pattern (e.g., Lomolino and Channell 1995, 1998; Channell and Lomolino 2000; Calkins et al. 2012; Herrando-Pérez 2016). It could be that populations in the core would be lost, with peripheral populations remaining. In such a case, Fort Carson and PCMS could become more significant.

Similar concerns apply to the burrowing owl. Though this species is documented from a variety of habitats, it is most often closely associated with prairie dog colonies. Thus, management for thriving prairie dog colonies is the key to conservation for this owl. See additional discussion below.

Though golden eagles are a wide-ranging species with a global distribution, they are vulnerable to a number of stresses. Key among these may be impacts from a changing climate on phenology, distribution, and response of their prey base. Similarly, there is potential for increasing impacts from wind energy infrastructure commensurate with increasing interest in development of renewable energy.

As an obligate of riparian systems, Preble's meadow jumping mouse is likely to be adversely impacted by a warming climate, which is expected to result in effectively drier conditions even if precipitation increases. These stresses, combined with increasing human population growth and demand for water resources, will certainly complicate management of western water-driven ecosystems. Of all the species evaluated in this report, the PMJM is most in need of cross-boundary management for the benefit of its habitat.

## 14.2 Recommendations to Further Minimize Risks to SAR and Their Habitats

**Invest in Planning and Cross-boundary Collaboration as a Top Priority.** Even on large installations, ecosystem management at a landscape scale requires thinking beyond boundaries. The ecological systems discussed in this report provide crucial habitat functions for multiple Species at Risk. A number of these species have been identified as having potential for impacts to the military mission if they were to become federally listed (e.g., Sections 5.4, 8.3, 10.3). The management environment is complicated by an uncertain climatic future, with potential for range shifts, contractions, and expansions. In order for species to be able to adapt to changing conditions, some may require increasing ability to move between suitable habitat patches at a very large landscape scale. In all likelihood, the importance of cross-jurisdictional management by many parties will increase as well. Various models for organizing cross-jurisdictional collaboration exist. For many years, Fort Carson, PCMS, and the Air Force Academy participated in the Front Range Ecoregional Partnership. This effort appears to have stagnated, but could be revived, potentially with a larger geographic area of interest (e.g., include all installations within the range of the shortgrass prairie, pinyon-juniper system). Similarly, in past years the Lakewood, Colorado, office of the U.S. Fish and Wildlife Service expressed interest in developing a prairie dog management agreement among the Front Range installations. Though these efforts foundered at the time, the concept has merit and is worth re-considering. Cross-installation information sharing, monitoring, and other efforts focused on pinyon-juniper obligates and on riparian systems are also worthy of consideration. The U.S. Fish and Wildlife Service and the Joint Ventures (for bird species) are obvious possibilities for organizing inter-state efforts. Symposia such as the 2008 Gray Vireo Symposium, sponsored by the New Mexico Department of Game and Fish and the New Mexico Ornithological Society, is another model for convening researchers and managers. The National Military Fish and Wildlife Association could provide a venue for symposia or a forum for convening working group(s).

**Collaboration and Communication: Best Management Practices**. Although periodic meetings between Environmental staffs and ITAM staff occur, enhanced collaboration and discussion appears to be needed between these two primary management units. Coordinated discussion and evaluation of technical approaches would help optimize LRAM activities and optimize ITAM land management with respect to habitat management (within the constraints of the training mission and ITAM objectives). There is some disagreement on the best approaches for some aspects of training land management. For example, land rehabilitation activities including revegetation of areas disturbed by military training are implemented by the Land Rehabilitation and Management component of the ITAM Program. A variety of approaches and BMPs are employed by LRAM to repair training land damage. Several resource management staff members expressed concern regarding land rehabilitation practices that excessively disturb areas that have been lightly to moderately disturbed by off-road military training and are still dominated by native vegetation. Disking prior to seeding is one such practice. The concern is that intensive seeding practices including disking disturb the soil surface and soil profile in relatively intact areas can lead to germination of undesirable weed seeds that are present in the soil seed bank. Likewise, concerns were also expressed that the timing of seeding and the use of broadcast seeding were sometimes not optimized or produced low seeding success due to poor soil-seed contact or lack of adequate soil moisture following seeding. Environmental staffs advocated for increased use of rangeland seeding using a rangeland drill to minimize weed emergence and increase seeding success.

**Collaboration and Communication: Data Sharing**. There appear to be opportunities to improve data sharing among installation programs. ITAM conducts landscape-scale and smaller, site-scale monitoring regularly at PCMS and Fort Carson. The Range and Training Land Assessment (RTLA) component of ITAM monitors training land condition and collects data to help determine LRAM project locations, priorities and effectiveness. RTLA currently conducts landscape scale monitoring every 3-5 years at Fort Carson and PCMS, including detailed spatially-referenced data for land disturbance, soil erosion, vegetation composition and abundance, and invasive non-native vegetation. Environmental Division staffs are very interested in using recent sample data and examining long-term trends in vegetation, soils/watershed disturbance and training activity captured by the RTLA data. There are opportunities to enhance communication and collaboration among the forestry, wildlife and RTLA programs in ways that would mutually benefit all programs while supporting training requirements and preferences. For example, RTLA data could be used to refine concepts related to different military disturbance (e.g., off-road maneuver training) as well as other disturbances (e.g., wildland fire, drought, wildlife impacts to vegetation). Installation-wide habitat assessments for SAR could no doubt be improved through better communication, collaboration, and data sharing.

**Landscape-scale Monitoring to Support Habitat Management.** Monitoring is a critical component of an adaptive strategy; it can enable land uses to continue without exceeding the training environment's carrying capacity. Among other things, well-designed monitoring programs document baseline conditions, ranges of variability and can help evaluate and determine condition thresholds or management targets for communities and species of interest. Monitoring programs should be objective-based, structured, recurring, address attributes that are ecologically relevant and that directly inform management decisions, and regularly funded. For example a system-scale monitoring program could incorporate appropriate indicators and metrics for the following components to inform land condition, responses to training disturbance, management activities, and other drivers/stressors (e.g., fire, drought, invasives).

- Plant composition and structure (cover and/or density)
- Noxious/weedy vegetation (cover and/or density)
- Soil compaction
- Soil erosion and water movement indicators
- Litter abundance
- Exposed bare ground
- Fire regime (frequency, seasonality, size, severity)
- Training disturbance types, intensities, and frequencies.

Qualitative indicators (e.g., some rangeland health attributes) can be very informative, are less expensive that quantitative measures, and can enable better spatial coverage and higher sample sizes, which result in more precise estimates of condition and enable more effective integration with remote-sensing approaches to characterize landscape conditions.

In disturbed areas being rehabilitated or restored, objectives could be tiered to reflect knowledge of possible trajectories following disturbance and active recovery. For example, fundamental short-term objectives for success might relate to hydrologic and soil stability, and site moderation (i.e., via appropriate litter accumulation). Near–term indicators of success may be related to total vegetation cover, bare ground, weed abundance. Mid-term indicators of success will be related to presence and abundance of vegetation structural and functional groups, some species, and groundcover characteristics. Long-term success may be tied back to conceptual models for ecological sites – species level vegetation composition, structure, function.

Ecosystem monitoring using landcover analysis is recommended to identify areas undergoing stress or reduced productivity. Numerous sources of imagery are available, including automated analysis indicating drought stress or greenness (e.g., Normalized Difference Vegetation Index). For example, numerous standardized spatial data products related to vegetation and landcover are available at no cost from NASA's MODIS (Moderate Resolution Imaging Spectroradiometer) program (https://modis.gsfc.nasa.gov/about/). These data products can be used to assess vegetation abundance, land disturbance, phenology, and drought stress and assess changes in the course of a year or over multiple years. Land cover classification and analysis using relatively coarse (e.g., 10-30m pixel) imagery is a remarkable integrator for vegetation condition, but it does have limitations, most notably in the ability to distinguish species.

**Management of Prairie Dogs as a Keystone Species**. Black-tailed prairie dog (BTPD) management continues to be challenging. BTPD management has evolved over the years at Fort Carson and PCMS to reflect conservation interest in the species at state and national scales and due to recognition of the prairie dog's role as a keystone species. PCMS is currently working on a new prairie dog management plan. Soldiers are given sensitivity training to minimize damage to prairie dog colonies. Health risks, however small, to Soldiers and civilians are the primary consideration, as infected fleas present in prairie dog colonies can transmit plague to humans.

Although the BTPD is not a listed threatened or endangered species, it continues to be periodically evaluated for consideration by the USFWS. The species occupies a minute fraction of its historic range, primarily in small and isolated colonies. This decline is largely attributed to historic and current poisoning, shooting, habitat destruction/loss and sylvatic plague. BTPDs are ecosystem engineers who have a keystone role and whose presence enables other keystone species, federally and state-listed species, numerous species at risk (e.g., golden eagle, burrowing owl) and other plant and animal species to survive within the larger shortgrass and midgrass prairie ecosystem. Black-tailed prairie dogs are an obligate short to mid-grass species that require large tracts of grasslands for their survival and viability. Many associated species have become imperiled due to prairie dog declines. A notable example is the black-footed ferret, which has been re-introduced on lands adjacent to Fort Carson. Other species dependent on habitat created or maintained by the BTPD include mountain plover, ferruginous hawk, swift fox and burrowing owl.

Persistence and/or recovery of many species of concern depend on continued presence of prairie dog colonies across the landscape, and the lands managed by DoD in this ecosystem are large and relatively unfragmented, an uncommon condition in the region. Resource managers are striving to test and adopt management strategies and practices that will conserve the species locally while minimizing risk to installation users. It is hoped that management solutions that favor promotion of increased acreages and numbers of colonies will help support important habitat for a wide variety of SARs as well as other species.

**Natural Processes/System Dynamics**. Further emphasis and commitment with respect to ecological processes and system dynamics can provide the largest benefits from a habitat perspective, and may result in more resilient conditions that reflect a broader range of variability (current and historic). Primary processes include fire, herbivory by large grazers (see more on this topic below) and watershed dynamics. We recommend increased use of management-oriented, conceptual models to identify ecological thresholds, identify risks, interpret monitoring results and help guide management actions.

**Grazing as a Potential Management Tool.** Grazing has been discussed as a possible management tool to help achieve conservation goals while reducing grassland fuel loads and thus potentially making fires less likely to occur and easier to manage. This issue was examined in detail by the Army in 2008 during the period when expansion of PCMS was being assessed, and a synopsis of those findings follows. Most of the discussion and arguments would also be relevant for Fort Carson. Grazing during periods when PCMS is not being used for military purposes has not been allowed since acquisition by the Army. However, this policy for PCMS has been a topic of interest on some installations, primarily PCMS, for a number of years. Existing information from ranchers around Fort Hood, Texas, where grazing has been allowed, indicates that this alternative is not preferred by either the ranchers or the Army's training forces. Challenges range from management of all livestock within designated areas, prevention of herd intermingling, environmental impacts associated with both training vehicles and overgrazing by herbivores, as well as coordination of grazing and training schedules. Additionally, cattle grazing requires fencing to control livestock movement and segregate stock by owner. Fencing also restricts troop and vehicle movement, and can injure Soldiers and damage machinery. Livestock on open maneuver areas result in training restrictions, as areas will have to be cleared of livestock before training can begin, reducing actual training time.

The Army proposes to examine hay-making and other agricultural based operations in addition to, or as an alternative to grazing. If feasible, acceptable, and implemented, this would allow for local area ranchers to harvest hay and other agricultural products from Army owned property, in order to feed cattle during the winter months. Hay-making and other agricultural operations could be coordinated more easily with training events and could have less impact on the land than grazing. Haying operations could have both training benefits for the Army and economic benefits for residents of the surrounding area.

The feasibility and benefits of a grazing program, primarily for PCMS, were discussed with Fort Carson Natural Resources staff in the course of this project. Advantages of instituting a grazing program on PCMS could include reduced fuel loads, possible reduction of some undesirable nonnative plants (current and future), and benefits to grassland vegetation structure and watershed function. Potential disadvantages associated with managing a grazing program fall into several categories - ecological, training and administrative. Ecologically, grazing has historically been shown to impact areas near water much more than areas far from water. These high-use areas can promote weed establishment and spread and can be sources of sediment that can contaminate streams. If cattle were allowed to graze in proximity to unfenced riparian areas, negative impacts to water quality, aquatic habitats, streambanks, and native vegetation could be expected. From an administrative perspective, the management of a grazing program would require development of infrastructure, to include fences and gates, cattle guards, corrals, and possibly additional upland water sources. Cattle present on or near training ranges may also require extra management and coordination with Range control and range users to avoid injuring livestock, thus creating a potential training constraint. Lastly, proper implementation of grazing contracts would require the use of herders, which would increase the cost of management. Although most staff agreed that there could be some ecological benefits to a properly managed grazing program, it seems to be considered an infeasible undertaking that may not be administratively viable.

**Managing for Periodic Drought and Climate Change (Warmer and Drier).** Periodic droughts are characteristic of the region, affecting important SAR habitats and training lands. Droughts are anticipated to increase in frequency and severity under climate change and these changes are already documented over the past 10 years. Changing climate is anticipated to impact Great Plains grasslands in a number of ways, and is likely to compound the effects of existing stressors and increase the vulnerability of grasslands to pests, invasive species and loss of native species (NFWPCAP 2012). Species ranges and ecological dynamics are already responding to recent climate shifts, and current land management units may be unable to support all species, communities and ecosystems (Heller and Zavaleta 2009). Some of the key anticipated ecological impacts include decreased plant productivity in the southern Great Plains (Morgan et al. 2008), increases in invasive exotic plants (Morgan et al. 2008), reduced water availability (Karl et al. 2009) and altered surface water dynamics (Bagne et al. 2013), more frequent extreme events such as heat waves and droughts (Karl et al. 2009), limited ability for species and communities to adapt in the plains due to generally open and flat terrain (Bagne et al. 2013), and the potential for increases in woody plants in grasslands as atmospheric CO2 rises (IPCC 2007).

In a synthesis assessing mitigation and adaptation strategies for climate change in North American Rangelands, Joyce et al. (2013) identify some specific climate change adaptation options for grazing management that may be relevant for managing Front Range military lands. These recommendations have been modified from their original emphasis on grazing management to emphasize the military training context (Table 19). Many of the adaptation options are described as "no regrets" strategies that promote ecosystem resilience and can be justified without emphasis on pending climate change. Anticipatory strategies occur when climate-change impacts are acknowledged as likely. Adaptive responses are planned but not implemented until climate change occurs (Joyce et al. 2013). Front Range installations are already implementing some of these strategies to varying degrees.

**Table 19. Some specific management adaptation options identified by Joyce et al. (2013) and modified for military land applications.**

**Degree of Adaptation**

| "No Regrets" | Anticipatory | Adaptive/Planned |
|---|---|---|
| • Enhance invasive species monitoring and control<br>• Enhance drought management<br>• Evaluate short-term weather forecasting to support training land allocation location and training load decisions<br>• Conservation stocking (conservative use allocation),coupled with active rehabilitation<br>• Consider plant phenology to minimize training effects on grasses<br>• Evaluate fire management: fuel management and prescribed burning | • Evaluate environmental risks in prairie resources associated with current management plan<br>• Evaluate the use of drought-resistant species in revegetation<br>• Enhance drought planning to include military mission types, resiliency associated with different ecological sites, and strategies for distributing training disturbance<br>• Consider sacrifice areas managed to contain adverse effects | • Facilitate engagement among scientists and managers to enhance the usability of climate change scientific information for rangeland management |

It is increasingly clear that given significant shifts in climatic variables, adaptation efforts will need to emphasize managing for inevitable ecological changes and concurrently adjusting some management objectives or targets (Stein et al. 2013). In a review of articles examining biodiversity conservation recommendations in response to climate change, Heller and Zavaleta (2009) found that most recommendations offer general principles for climate change adaptation but lack specificity needed for implementation. Specific adaptation tools and approaches will undoubtedly help park managers with these challenges. Adaptation approaches need to be intentional, context-specific and based on a deliberative process, rather than selected from a generic menu of options (Stein et al. 2014).

## 14.3 Knowledge and Data Gaps

Potential technical knowledge gaps identified in the course of the project include the following:

- Military land-use data, such as spatially located, actual (vs. planned) usage data for a limited number of descriptors (e.g., unit type, size, numbers and types of vehicles, estimated proportion of on-road maneuvers vs. off-road maneuvers (for motorized and mechanized units), duration of training). This database would fill a significant gap with respect to off-road training disturbance. Most record-keeping by Range Operations tends to capture live-fire troop and ammunition data extremely well, but live-fire training generally occurs on developed ranges and is not causing significant widespread environmental impacts. By capturing basic data regarding off-road vehicles by motorized and mechanized vehicles, managers would be better able to understand and estimate thresholds of use or damage to different parts of the training landscape.

- Characterization of different ecosystem trajectories for both natural and assisted recovery (refining models), and the role of recovery time and other uncertainties in state-transition models.

- Climate change is anticipated to increase the frequency and severity of droughts. Increased knowledge regarding anticipated changes in habitats and site-specific adaptations strategies and techniques are needed to support installation management. Adaptation needs include general strategies and specific, technical approaches that go beyond conventional rangeland drought-adaptation approach and are not livestock-centric. Examples of specific areas for developing knowledge include fire regime effects, use of different restoration techniques and seed mixes, and knowledge of ecological tipping points. Information needs to help manage resources and understand the repercussions of climate change on training landscapes include: 1) more specific, applied examples of adaptation principles that are consistent with uncertainty about the future; 2) a practical adaptation planning process to guide selection and integration of recommendations into existing policies and programs; and 3) greater integration of social science and extension of adaptation approaches beyond management unit/administrative boundaries (Heller and Zavaleta 2009).

- Effects of climate change on land condition in general and SAR habitats in particular.

- Refinement of land repair and restoration approaches under current condition and under future anticipated conditions/climates. Focus areas include soil amendments and site preparation techniques, seasonality of seeding, seeding methods, and innovative seed mixes.

- Sampling designs and methods to measure indicators of condition at site scales for restoration and rare habitats, as well as landscape scales.

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# Appendix A: Classification of Threats

Source: Salafsky, N., D. Salzer, A.J. Stattersfield, C. Hilton-Taylor, R. Neugarten, S.H.M. Butchart, B. Collen, N. Cox, L.L. Master, S. O'Connor, and D. Wilkie. 2008. A Standard Lexicon for Biodiversity Conservation: Unified Classifications of Threats and Actions. Conservation Biology, 22: 897–911. doi: 10.1111/j.1523-1739.2008.00937.x

| Level 1 | Level 2 | Level 3 – illustrative examples |
|---|---|---|
| **1 Residential & Commercial Development**<br>Threats from human settlements or other non-agricultural land uses with a substantial footprint | **1.1 Housing & Urban Areas**<br>Human cities, towns, and settlements including non-housing development typically integrated with housing (e.g., shopping areas, offices, schools, hospitals) | • Housing, urban, and ex-urban development<br>• Hobby livestock – domestic sheep and goats associated with exurban development |
| | **1.2 Commercial & Industrial Areas**<br>Factories and other commercial centers (e.g., manufacturing plants, military bases, power plants, train yards, airports) | |
| | **1.3 Tourism & Recreation Areas**<br>Tourism and recreation sites with a substantial footprint (e.g., ski areas, golf courses, county parks, campgrounds) | • Recreation area developments |
| **2 Agriculture & Aquaculture**<br>Threats from farming and ranching as a result of agricultural expansion and intensification, including silviculture and aquaculture | **2.1 Annual & Perennial Non-Timber Crops**<br>Crops planted for food, fodder, fiber, fuel, or other uses (e.g., farms, plantations, orchards, vineyards, mixed agroforestry systems) | • Conversion to cropland<br>• Early/often pasture and hayfield cutting (nest destruction)<br>• Intensive agricultural operations<br>• Loss of compatible CRP lands<br>• Poor quality CRP lands |
| | **2.2 Wood & Pulp Plantations**<br>Stands of trees planted for timber or fiber outside of natural forests, often with non-native species (e.g., silviculture, Christmas tree farms) | |

| Level 1 | Level 2 | Level 3 – illustrative examples |
|---|---|---|
| | **2.3 Livestock Farming & Ranching** Domestic terrestrial animals raised in one location on farmed or non-local resources (farming); also domestic or semi-domesticated animals allowed to roam in the wild and supported by natural habitats (ranching) (e.g., cattle feed lots, dairy farms, cattle ranching, chicken farms) | • Altered native vegetation<br>• Decreased water quality (nutrient load from cattle)<br>• Degradation of alpine habitats from sheep grazing & disturbance by guard dogs<br>• Incompatible timing, intensity, duration of grazing<br>• Range improvement operations<br>• Reduced grass and forb diversity<br>• Transmission of pathogens |
| | **2.4 Marine & Freshwater Aquaculture** Aquatic animals raised in one location on farmed or non-local resources; also hatchery fish allowed to roam in the wild | |
| **3 Energy Production & Mining** Threats from production of non-biological resources | **3.1 Oil & Gas Drilling** Exploring for, developing, and producing petroleum and other liquid hydrocarbons (e.g., oil wells, natural gas drilling) | • Altered native vegetation<br>• Behavioral avoidance of oil/gas development & associated infrastructure<br>• Fragmentation of native habitat due to oil/gas development & associated infrastructure |
| | **3.2 Mining & Quarrying** Exploring for, developing, and producing minerals and rocks (e.g., coal mines, alluvial gold panning, gold mines, rock quarries) | • Mining operations<br>• Rock mining in nesting & winter habitat<br>• Uranium mining |
| | **3.3 Renewable Energy** Exploring, developing, and producing renewable energy (e.g., geothermal power production, solar farms, wind farms, birds flying into windmills) | • Collision with wind turbines<br>• Behavioral avoidance of renewable energy development & associated infrastructure<br>• Fragmentation of native habitat due to renewable energy development & associated infrastructure |
| **4 Transportation & Service Corridors** Threats from long narrow transport corridors and the vehicles that use them, including associated wildlife mortality | **4.1 Roads & Railroads** Surface transport on roadways and dedicated tracks (e.g., highways, secondary roads, logging roads, bridges and causeways, road kill, fencing associated with roads) | • Collision (e.g., auto)<br>• Fragmentation |

| Level 1 | Level 2 | Level 3 – illustrative examples |
|---|---|---|
| | **4.2 Utility & Service Lines**<br>Transport of energy & resources (e.g., electrical and phone wires, oil and gas pipelines, electrocution of wildlife) | • Collision (e.g., powerlines) |
| | **4.3 Shipping Lanes** (*not applicable to Colorado*) | |
| | **4.4 Flight Paths**<br>(e.g., impacting birds) | • Low-flying military jets & helicopters |
| **5 Biological Resource Use**<br>Threats from consumptive use of "wild" biological resources including both deliberate and unintentional harvesting effects; also persecution or control of specific species | **5.1 Hunting & Collecting Terrestrial Animals**<br>Killing or trapping wild animals for commercial, recreation, subsistence, research or cultural purposes, or for control/persecution reasons | • Extermination / evictions in urban settings<br>• Loss of habitat due to prairie dog control<br>• Mortality and prey reduction through rodent control<br>• Poisoning (indirect effect of prairie dog control) |
| | **5.2 Gathering Terrestrial Plants**<br>Harvesting plants, fungi, and other non-timber/non-animal products for commercial, recreation, subsistence, research or cultural purposes, or for control reasons | |
| | **5.3 Logging & Wood Harvesting**<br>Harvesting trees and other woody vegetation for timber, fiber, or fuel (e.g., clear cutting of hardwoods, pulp operations, fuel wood collection) | • Clearcutting<br>• Even-age timber management<br>• Removal of cavity trees<br>• Fragmentation<br>• Replacement of mature/old growth with younger, more even-aged stands |
| | **5.4 Fishing & Harvesting Aquatic Resources**<br>Harvesting aquatic wild animals or plants for commercial, recreation, subsistence, research, or cultural purposes, or for control/persecution | |
| **6 Human Intrusions & Disturbance**<br>Threats from human activities that alter, destroy and disturb habitats and species associated with non-consumptive uses of biological resources | **6.1 Recreational Activities**<br>People spending time in nature or traveling in vehicles outside of established transport corridors, usually for recreational reasons (e.g., off-road vehicles, snowmobiles, mountain bikes, hikers, skiers, birdwatchers, pets in rec areas, temporary campsites, caving, rock-climbing) | • Campsites and hiking<br>• ORV trail development and use<br>• Motorized and non-motorized recreation<br>• Recreational caving<br>• Rock climbing, hiking near cliffs & crevices<br>• Trails in drainages near nests<br>• Unregulated backcountry winter recreation |

| Level 1 | Level 2 | Level 3 – illustrative examples |
|---|---|---|
| | **6.2 War, Civil Unrest & Military Exercises**<br>Actions by military forces without a permanent footprint (e.g., tanks and other military vehicles, training exercises and ranges, defoliation, munitions testing) | |
| | **6.3 Work & Other Activities**<br>People spending time in or traveling in natural environments for reasons other than recreation, military activities, or research (e.g., law enforcement, drug smugglers, illegal immigrants, vandalism) | • Proximal non-recreation disturbance |
| **7 Natural System Modifications**<br>Threats from actions that convert or degrade habitat in service of "managing" natural or semi-natural systems, often to improve human welfare | **7.1 Fire & Fire Suppression**<br>Suppression or increase in fire frequency and/or intensity outside of its natural range of variation (e.g., fire suppression to protect homes, inappropriate fire management, escaped agricultural fires, arson, campfires) | • Altered fire regime<br>• Fire suppression leading to high intensity fires<br>• Altered fire regime and juniper encroachment<br>• Wildfires exacerbated by climate change |
| | **7.2 Dams & Water Management/Use**<br>Changing water flow patterns from their natural range of variation either deliberately or as a result of other activities (e.g., dam construction, dam operations, sediment control, change in salt regime, wetland filling, levees and dikes, surface water diversion, groundwater pumping, channelization, artificial lakes) | • Altered hydrological regime – dewatering<br>• Altered hydrological regime – siltation and sedimentation<br>• Altered hydrological regime – wetland drainage<br>• Altered hydrological regime – altered flow and fluctuating water temperatures<br>• Decreased water quality and/or quantity<br>• Natural system modification (hydrological) - dam, diversion, or drop structure construction or modification |

| Level 1 | Level 2 | Level 3 – illustrative examples |
|---|---|---|
| | **7.3 Other Ecosystem Modifications**<br>Other actions that convert or degrade habitat in service of "managing" natural systems to improve human welfare (e.g., land reclamation projects, abandonment of managed lands, rip-rap along shorelines, mowing grass, tree thinning in parks, beach construction, removal of snags from streams) | • Altered animal community (change in predator/prey balance)<br>• Altered animal community (loss of beaver)<br>• Altered native vegetation (cottonwood/willow degradation)<br>• Altered native vegetation (loss of older aspen stands)<br>• Altered native vegetation (loss of shoreline nesting, roosting, and perching habitat) |
| **8 Invasive & Other Problematic Species & Genes**<br>Threats from non-native and native plants, animals, pathogens /microbes, or genetic materials that have or are predicted to have harmful effects on biodiversity following their introduction, spread and/or increase in abundance | **8.1 Invasive Non-Native/Alien Species**<br>Harmful plants, animals, and microbes not originally found within the ecosystem(s) in question and directly or indirectly introduced and spread into it by human activities (e.g., feral cattle, household pets, zebra mussels) | • Invasive animals - bullfrogs<br>• Invasive animals - European starlings<br>• Invasive animals - white sucker<br>• Invasive animals – aquatic predators (e.g., smallmouth bass, northern pike, walleye, burbot)<br>• Invasive plants – tamarisk<br>• Invasive plants – cheatgrass |
| | **8.2 Problematic Native Species**<br>Harmful plants, animals, or microbes that are originally found within the ecosystem(s) in question, but have become "out-of-balance" or "released" directly or indirectly due to human activities (e.g., overabundant native deer) | • Habitat loss / degradation due to beetle kill<br>• Habitat loss due to insect damage and fire<br>• Predation and parasites |
| | **8.3 Introduced Genetic Material**<br>Human altered or transported organisms or genes (e.g., pesticide resistant crops, using nonlocal seed stock, genetically modified insects for biocontrol) | • Invasive animals - hybridization |

| Level 1 | Level 2 | Level 3 – illustrative examples |
|---|---|---|
| **9 Pollution**<br>Threats from introduction of exotic and/or excess materials or energy from point and nonpoint sources | **9.1 Household Sewage & Urban Waste Water**<br>Water-borne sewage and non-point runoff from housing and urban areas that include nutrients, toxic chemicals and/or sediments (e.g., discharge from municipal waste treatment plants, leaking septic systems, fertilizers and pesticides from lawns and golf-courses) | • Water pollution |
| | **9.2 Industrial & Military Effluents**<br>Water-borne pollutants from industrial and military sources including mining, energy production, and other resource extraction industries that include nutrients, toxic chemicals and/or sediments | • Waste or residual materials (excess sediment loads)<br>• Waste or residual materials (mine tailings, excess sediment loads, etc.) |
| | **9.3 Agricultural & Forestry Effluents**<br>Water-borne pollutants from agricultural, silvicultural, and aquaculture systems that include nutrients, toxic chemicals and/or sediments (e.g., nutrient loading from fertilizer runoff, herbicide runoff, manure from feedlots, soil erosion) | • Herbicide/pesticide spraying or runoff (grasshopper control)<br>• Herbicide/pesticide spraying or runoff and nonpoint source pollution<br>• Nutrient loads<br>• Pesticide spraying (prey reduction)<br>• Poisoning (fire ant insecticides)<br>• Reduced water quality due to herbicide/pesticide runoff |
| | **9.4 Garbage & Solid Waste**<br>Rubbish and other solid materials including those that entangle wildlife | |
| | **9.5 Air-Borne Pollutants**<br>Atmospheric pollutants from point and nonpoint sources (e.g., acid rain, smog from vehicle emissions, excess nitrogen deposition) | • Air pollution (precipitating/concentrating on high elevation snow fields) |
| | **9.6 Excess Energy**<br>Inputs of heat, sound, or light that disturb wildlife or ecosystems (e.g., noise from highways or airplanes, heated water from power plants, lamps attracting insects) | |

| Level 1 | Level 2 | Level 3 – illustrative examples |
|---|---|---|
| **10 Geological Events**<br>Threats from catastrophic geological events | **10.1 Volcanoes** (*not applicable to Colorado*) | |
| | **10.2 Earthquakes/Tsunamis** (*not likely to be applicable to Colorado*) | |
| | **10.3 Avalanches/Landslides**<br>Avalanches or landslides | |
| **11 Climate Change & Severe Weather**<br>Threats from long-term climatic changes which may be linked to global warming and other severe climatic/weather events that are outside of the natural range of variation | **11.1 Habitat Shifting & Alteration**<br>Major changes in habitat composition and location (e.g., desertification, tundra thawing) | • Climate variability (intensification or alteration of normal weather patterns, e.g., droughts, tornados)<br>• Habitat shifting and alteration due to climate change |
| | **11.2 Droughts**<br>Periods in which rainfall falls below the normal range of variation (e.g., severe lack of rain, loss of surface water sources) | • Lack of water due to drought and exacerbated by climate change |
| | **11.3 Temperature Extremes**<br>Periods in which temperatures exceed or go below the normal range of variation (e.g., heat waves, cold spells, disappearance of glaciers) | |
| | **11.4 Storms & Flooding**<br>Extreme precipitation and/or wind events (e.g., thunderstorms, tornados, hailstorms, ice storms or blizzards, dust storms) | • Climate variability (e.g., prolonged rain or hail events) |

# Appendix B – Climate Change Vulnerability Index (CCVI) Scoring for Species

This appendix contains CCVIs at two scales (western U.S. and state of Colorado) for pinyon jay, gray vireo, burrowing owl, and golden eagle. See Appendix C for background on the CCVI tool and definitions for each scoring category. Citations for references in the following accounts are listed in Section 15 of this report.

# PINYON JAY CLIMATE CHANGE VULNERABILITY INDEX
# WESTERN U.S. DISTRIBUTION

## Climate Vulnerability Rank: Highly Vulnerable

This rangewide rank is based on the following factors: 1) warming temperatures, which are predicted throughout the core of the species range, are correlated with declines in pine seed crops (the primary food source for pinyon jays), 2) the range of the pinyon jay is projected to decrease by the end of the century, and 3) pinyon jays have a mutualistic relationship with pinyon pine, which are likely to be adversely affected by climate change.

**Distribution***:* The pinyon jay is a resident in the western interior United States.

**Habitat:** Pinyon jays are closely tied to pinyon-juniper woodlands in the interior western United States (Wiggins 2005). These woodlands serve as the primary habitat for pinyon jays, but the birds also breed in other foothill and lower montane habitats in some parts of their range, including sagebrush, scrub oak, chaparral, ponderosa pine, and Jeffrey pine (Balda 2002).

**Ecological System:** Pinyon-Juniper Woodlands.

## CCVI Scoring

**A) Temperature:** Calculated using ClimateWizard: ensemble average, medium emission scenario (A1B), mid-century timeframe, average annual change. By mid-century this species is expected to be exposed to mean annual temperature increases of:

5.6$^{o}$F to 6.0$^{o}$F across 45% of its range,
5.5$^{o}$F across 46% of its range,
4.5$^{o}$F to 5.0$^{o}$F across 7% of its range,
3.9$^{o}$F to 4.4$^{o}$F across 2% of its range.

**A) Moisture Metric:** Calculated in GIS using NatureServe Hamon AET:PET moisture metric data (this index integrates projected temperature and precipitation changes to indicate how much drying will take place). Rangewide this species is predicted to be exposed to net drying of greater than:

>11.9 percent drying on 1% of its range,
9.7 to 11.9 percent drying on 20% of its range,
7.4 to 9.6 percent drying on 49% of its range,
5.1 to 7.3 percent drying on 29% of its range,
2.8 to 5.0 percent drying on 9% of its range.

**B1) Exposure to sea level rise:** Neutral.
**B2a) Distribution relative to natural barriers:** Neutral.
**B2b) Distribution relative to anthropogenic barriers:** Neutral.

**B3) Impact of land use changes resulting from human responses to climate change:** Somewhat Increase. According to maps of energy development, there are existing and planned solar and wind energy facilities found within the breeding range of pinyon jay (NRDC 2016). Wind turbines can cause direct impacts to birds via collisions that result in injury or mortality (Kunz et al. 2007; Kuvlesky et al. 2007), as well as indirect impacts via habitat loss and barriers to movement (Drewitt and Langston 2006; Kuvlesky et al. 2007; Pruett et al. 2009; Kiesecker et al. 2011). Solar energy facilities could also cause habitat loss or degradation.

**C1) Dispersal and movements:** Neutral/Somewhat Increase. The pinyon jay is capable of long distance movement, but it is a year-round resident in the western U.S. (Wiggins 2005). Pinyon jays are generally tied to pinyon-juniper woodland habitats, but will leave woodland nesting sites in search of food in other habitats (Balda 2002, Wiggins 2005).

**C2ai) Historical thermal niche:** Neutral. This species has experienced average or greater than average (>57°F/43°C) temperature variation in the past 50 years.

**C2aii) Physiological thermal niche:** Increase. This species is not limited to cool or cold habitats.

**C2bi) Historical hydrological niche:** Neutral. Considering the range of mean annual precipitation across occupied cells, the species has experienced average or greater than average >40 inches/1,016 mm) precipitation variation in the past 50 years.

**C2bii) Physiological hydrological niche:** Somewhat Increase.

**C2c) Dependence on a specific disturbance regime likely to be impacted by climate change:** Somewhat Increase/Increase. Drought can cause pinyon die-off and lack of regeneration of stands, which may result in the loss of habitat and food source for pinyon jays (Gillihan 2006, Redmond et al. 2012). Warmer, drier conditions across the pinyon jay's range are expected to result in increased frequency, intensity, and/or duration of droughts, with potential for adverse impacts to pinyon pine.

**C2d) Dependence on ice, ice-edge, or snow-cover habitats:** Neutral.

**C3) Restriction to uncommon landscape/geological features or derivatives:** Neutral.

**C4a) Dependence on other species to generate required habitat:** Somewhat Increase. Pinyon jays depend primarily on pines (*Pinus* spp.) and junipers (*Juniperus* spp.) for nesting and foraging habitat (Balda 2002, Wiggins 2005).

**C4b) Dietary versatility (animals only):** Somewhat Increase. Although they are omnivorous, it appears that pine seeds are their primary food source (Wiggins 2005).

**C4c) Pollinator versatility (Plants only):** Not applicable.

**C4d) Dependence on other species for propagule dispersal:** Neutral.

**C4e) Sensitivity to pathogens or natural enemies:** Neutral.

**C4f) Sensitivity to competition from native or non-native species:** Neutral.

**C4g) Forms part of an interspecific interaction not covered by 4a-d**: Neutral.

**C5a) Measured genetic variation:** Neutral. Although genetic variation is relatively poorly understood across the range of pinyon jay, studies in Arizona have revealed moderate to high genetic diversity in pinyon jays (Busch et al. 2009).

**C5b) Occurrence of bottlenecks in recent evolutionary history:** Unknown.

**C5c) Reproductive system (plants only):** Not applicable.

**C6) Phenological response to changing seasonal temperature and precipitation dynamics:** Unknown.

**D1) Documented response to recent climate change:** Unknown.
**D2) Modeled future change in population or range size:** Increase. The entire range of the pinyon jay is projected to decrease by 25–31 percent between 2010 and 2099 (van Riper et al. 2014).
**D3) Overlap of modeled future range with current range:** Increase. The National Audubon Society (2013) predicts only a 7% overlap in summer range and a 34% overlap in winter range by 2080 compared to current range.
**D4) Occurrence of protected areas in modeled future (2050) distribution:** Unknown.

# Pinyon Jay Climate Change Vulnerability Index
# Colorado Distribution

## Climate Vulnerability Rank: Highly Vulnerable

This rangewide rank is based on the following factors: 1) warming temperatures are correlated with declines in pine cone seed crops which serve as an important food source for pinyon jays, and climate models predict warming temperatures in Colorado, 2) the range of the pinyon jay is projected to decrease in both summer and winter, and 3) pinyon jays have a mutualistic relationship with pinyon pine species, which are likely to be adversely affected by climate change.

**Distribution*:*** The pinyon jay is a breeding resident in the western interior United States. In Colorado, the pinyon jay is a permanent resident in the southern, western, central, and southern portions of the state (Kingery 1998, Wiggins 2005).

**Habitat:** Pinyon jays are closely tied to pinyon-juniper woodlands in Colorado (Wiggins 2005). These woodlands serve as the primary habitat for pinyon jays, but the birds breed in other foothill and lower montane habitats as well, including sagebrush, Gambel oak, mountain mahogany, and ponderosa pine (Johnsgard 1986, Kingery 1998, Balda 2002, Wiggins 2005).

**Ecological System:** Pinyon-Juniper Woodlands

## CCVI Scoring

**A) Temperature:** Calculated using ClimateWizard: ensemble average, medium emission scenario (A1B), mid-century timeframe, average annual change. By mid-century this species is expected to be exposed to mean annual temperature increases of:

- 5.6°F to 6.0°F across 80% of its range,
- 5.5°F across 20% of its range.

**A) Moisture Metric:** Calculated in GIS using NatureServe Hamon AET:PET moisture metric data (this index integrates projected temperature and precipitation changes to indicate how much drying will take place). Rangewide this species is predicted to be exposed to net drying of greater than:

- >11.9 percent drying on 11% of its range,
- 9.7 to 11.9 percent drying on 55% of its range,
- 7.4 to 9.6 percent drying on 29% of its range.

**B1) Exposure to sea level rise.** Neutral.
**B2a) Distribution relative to natural barriers.** Neutral.
**B2b) Distribution relative to anthropogenic barriers.** Neutral.

**B3) Impact of land use changes resulting from human responses to climate change**. Neutral. According to energy development maps, there are very few existing and planned solar and wind energy facilities found within the breeding range of pinyon jay in Colorado (NRDC 2016).
**C1) Dispersal and movements.** Neutral/Somewhat Increase. The pinyon jay is capable of long distance movement, but it is a year-round resident in Colorado (Johnsgard 1986, Kingery 1998, Wiggins 2005). Pinyon jays are generally tied to pinyon-juniper woodland habitats, but will leave woodland nesting sites in search of food in other habitats (Balda 2002, Wiggins 2005).
**C2ai) Predicted sensitivity to temperature: historical thermal niche.** Neutral. This species has experienced average or greater than average (>57°F/43°C) temperature variation in the past 50 years.
**C2aii) Predicted sensitivity to temperature: physiological thermal niche.** Increase. This species is associated with pinyon-juniper and juniper woodlands in Colorado, and is not limited to cool or cold habitats (Balda 2002), but increasing temperatures are correlated with declining pinyon pine seed cone crops (Redmond et al. 2012). Temperatures in Colorado have increased by approximately 2°F between 1977 and 2006 (Ray et al. 2008, Lukas et al. 2014). Climate models indicate future warming in Colorado (Lukas et al. 2014). Increased temperatures in Colorado could mean a decline in food sources and habitat for pinyon jay (Seager et al. 2007).
**C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche**. Neutral. Considering the range of mean annual precipitation across occupied cells, the species has experienced average or greater than average >40 inches/1,016 mm) precipitation variation in the past 50 years.
**C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche.** Somewhat Increase. Fire frequency is projected to increase in pinyon juniper woodlands (Lenihan et al. 2008). Pinyon and juniper do not resprout after fires, they reproduce only from seed. So future increases in fire frequency could result in suitable habitat for pinyon jays.
**C2c) Dependence on a specific disturbance regime likely to be impacted by climate change.** Increase. Drought can cause pinyon die-off and lack of regeneration of stands, which may result in the loss of habitat and food source for pinyon jays (Gillihan 2006, Redmond et al. 2012).
**C2d) Dependence on ice, ice-edge, or snow-cover habitats.** Neutral.
**C3) Restriction to uncommon landscape/geological features or derivatives.** Neutral.
**C4a) Dependence on other species to generate required habitat.** Somewhat Increase. Pinyon jays depend primarily on pines (*Pinus* spp.) and junipers (*Juniperus* spp.) for nesting and foraging habitat (Balda 2002, Wiggins 2005).
**C4b) Dietary versatility (animals only).** Somewhat Increase. Although they are omnivorous, it appears that pine seeds are their primary food source (Wiggins 2005).
**C4c) Pollinator versatility (Plants only).** Not applicable.
**C4d) Dependence on other species for propagule dispersal.** Neutral.
**C4e) Sensitivity to pathogens or natural enemies.** Neutral.
**C4f) Sensitivity to competition from native or non-native species.** Neutral.
**C4g) Forms part of an interspecific interaction not covered by 4a-d**. Neutral.

**C5a) Measured genetic variation.** Neutral. Although genetic variation is relatively poorly understood in Colorado pinyon jay populations, studies in Arizona have revealed moderate to high genetic diversity in pinyon jays (Busch et al. 2009).

**C5b) Occurrence of bottlenecks in recent evolutionary history.** Unknown.

**C5c) Reproductive system (plants only).** Not applicable.

**C6) Phenological response to changing seasonal temperature and precipitation dynamics.** Unknown.

**D1) Documented response to recent climate change.** Unknown.

**D2) Modeled future change in population or range size.** Increase. The entire breeding range of the pinyon jay is projected to decrease by 25–31 percent between 2010 and 2099, based on models of current and future breeding ranges (van Riper et al. 2014). The National Audubon Society (2013) predicts a 24% decrease in summer range and a 37% decrease in winter range by 2080. Percentages specific to Colorado are not known, but maps from these sources show decreasing habitat suitability within the state.

**D3) Overlap of modeled future range with current range.** Increase.

**D4) Occurrence of protected areas in modeled future (2050) distribution.** Unknown.

# GRAY VIREO CLIMATE CHANGE VULNERABILITY INDEX
# WESTERN U.S. DISTRIBUTION

## Climate Vulnerability Rank: Less Vulnerable

The gray vireo received a CCVI rank of Less Vulnerable in the southwestern U.S. because it is has not been shown to be tied to cool or cold habitats that could be lost to climate change, it has experienced a greater than average precipitation in the past 50 years, and it is not heavily dependent on uncommon geologic features or other species.

**Distribution*:*** It is found in the southwestern United States and parts of three states in Mexico: Baja California, Baja California Sur and Sonora (Barlow et al. 1999). The gray vireo breeds in Arizona, California, Colorado, Utah, Nevada, New Mexico, Texas, and Baja California (Barlow et al. 1999).

**Habitat:** The gray vireo inhabits pinyon-juniper and oak scrub associations and chaparral in hot, arid mountains and high plains scrubland in the southwestern U.S. (Barlow et al. 1999).

**Ecological System(*s*):** Pinyon-juniper woodlands, juniper woodlands, oak shrublands, chaparral, sagebrush shrublands

## CCVI Scoring

**A) Temperature:** Calculated using ClimateWizard: ensemble average, medium emission scenario (A1B), mid-century timeframe, average annual change. By mid-century this species is expected to be exposed to mean annual temperature increases of:

5.6ºF to 6.0ºF across 42% of its range,
5.5ºF across 50% of its range,
4.5ºF to 5.0ºF across 8% of its range.

**A) Moisture Metric:** Calculated in GIS using NatureServe Hamon AET:PET moisture metric data (this index integrates projected temperature and precipitation changes to indicate how much drying will take place). Rangewide this species is predicted to be exposed to net drying of greater than:

>11.9 percent drying on 1% of its range,
9.7 to 11.9 percent drying on 7% of its range,
7.4 to 9.6 percent drying on 49% of its range,
5.1 to 7.3 percent drying on 29% of its range,
2.8 to 5.0 percent drying on 17% of its range,
<2.8 percent drying on 2% of its range.

**B1) Exposure to sea level rise.** Neutral.

**B2a) Distribution relative to natural barriers.** Neutral. Significant natural barriers do not exist for this species as it is found in low elevation areas of the southwestern U.S.

**B2b) Distribution relative to anthropogenic barriers.** Neutral. No significant anthropogenic barriers exist for the gray vireo since they can fly over potential obstructions.

**B3) Impact of land use changes resulting from human responses to climate change**. Somewhat Increase. Desert habitat where species winters may be susceptible to large-scale solar farm development (Butler et al. 2013).

**C1) Dispersal and movements.** Neutral. The gray vireo is capable of long distance migration.

**C2ai) Predicted sensitivity to temperature: historical thermal niche.** Neutral. Considering the mean seasonal temperature variation for occupied cells, the species has experienced average (57.1 - 77° F/31.8 - 43.0° C) temperature variation in the past 50 years.

**C2aii) Predicted sensitivity to temperature: physiological thermal niche.** Neutral. This species is associated with pinyon-juniper and juniper woodlands, oak shrublands, and desert shrublands in the southwestern US and is not limited to cool or cold habitats (Kingery 1998).

**C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche**. Neutral. Considering the range of mean annual precipitation across occupied cells, the species has experienced greater than average (> 40 inches/1,016 mm) precipitation variation in the past 50 years.

**C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche.** Neutral. There is no evidence that gray vireo are dependent on a strongly seasonal hydrologic regime.

**C2c) Dependence on a specific disturbance regime likely to be impacted by climate change.** Neutral.

**C2d) Dependence on snow-covered habitats.** Neutral. This species is found in some of the hottest, driest areas of the southwestern US and is not dependent on snow-covered habitats.

**C3) Restriction to uncommon geological features or derivatives.** Neutral.

**C4a) Dependence on other species to generate habitat.** Somewhat Increase. The gray vireo relies on the Elephant Tree (*Bursera microphylla*) for habitat and food during the winter months.

**C4b) Dietary versatility.** Somewhat Increase. Although the gray vireo eats a variety of insects, including large caterpillars and grasshoppers (Barlow et al. 1999), it relies heavily on the fruit of the Elephant Tree (*Bursera microphylla*) during the winter and is a primary disperser of its seeds via regurgitation (Bates 1992).

**C4c) Pollinator versatility (Plants only, not applicable).** N/A. This is for scoring plants.

**C4d) Dependence on other species for propagule dispersal.** Neutral.

**C4e) Sensitivity to pathogens or natural enemies.** Unknown.

**C4f) Sensitivity to competition from native or non-native species.** Unknown.

**C4g) Forms part of an interspecific interaction not covered by 4a-f**. Neutral.

**C5a) Measured genetic variation.** Unknown.

**C5b) Occurrence of bottlenecks in recent evolutionary history.** Unknown.

**C6) Phenological response to changing seasonal temperature and precipitation dynamics.** Unknown.

**D1) Documented response to recent climate change.** Unknown.

**D2) Modeled future (2050) change in population size or range size.** Neutral. The gray vireo's breeding range in the southwestern US is projected to increase from 58 –71 percent between

2010 and 2099 (van Riper et al. 2014), and is also projected to increase by National Audubon Society (2013).

**D3) Overlap of modeled future (2050) range with current range.** Somewhat Increase. According to National Audubon Society (2013), the future breeding range modeled out to 2080 has only a 3% overlap with existing range. We do not have the percent overlap by 2050. A 3% overlap would warrant a Greatly Increase score, but we have down-graded the score based on lower confidence in the model (too few presence points) and disagreement between the National Audubon Society model and the van Riper et al. (2014) model.

**D4) Occurrence of protected areas in modeled future (2050) distribution.** Unknown.

# GRAY VIREO CLIMATE CHANGE VULNERABILITY INDEX
# COLORADO DISTRIBUTION

## Climate Vulnerability Rank: Less Vulnerable

The gray vireo received a CCVI rank of Less Vulnerable in Colorado. The gray vireo is predicted to experience exposure to hotter temperatures and drier conditions throughout its most of its range in Colorado, with temperatures predicted to be 5.6 to 6.0 ˚F warmer. However, based on current knowledge about the species' life history, factors that would increase its vulnerability (e.g., preference for cool/moist conditions, specialist requirements for diet, inability to travel long distances) do not seem to apply. Although the gray vireo is closely tied to juniper species, the distribution of these trees is predicted to increase, with presumed/potential benefit to gray vireos.

**Distribution*:*** In Colorado, gray vireo are found in the westernmost counties of the state, as well as in southeastern corner of the state near the town of Lamar (Kingery 1998). Most areas in Colorado where gray vireo occur are relatively remote. On DoD installations in Colorado, gray vireo are found in juniper and pinyon juniper woodlands at Fort Carson and PCMS.

**Habitat:** In Colorado, the gray vireo occurs at elevations ranging from 4,400 to 6,400 feet, primarily in juniper or pinyon juniper woodlands with relatively open canopies that are interspersed with patches of sagebrush, grasses, and shrubs (Kingery 1998).

**Ecological System(s):** Pinyon-juniper woodlands, juniper woodlands, oak shrublands, sagebrush shrublands

## CCVI Scoring

**A) Temperature:** Calculated using ClimateWizard: ensemble average, medium emission scenario (A1B), mid-century timeframe, average annual change. By mid-century this species is expected to be exposed to mean annual temperature increases of:

5.6°F to 6.0°F across 94% of its range,
5.5°F across 6% of its range.

**A) Moisture Metric:** Calculated in GIS using NatureServe Hamon AET:PET moisture metric data (this index integrates projected temperature and precipitation changes to indicate how much drying will take place). Rangewide this species is predicted to be exposed to net drying of greater than:

>11.9 percent drying on 2% of its range,
9.7 to 11.9 percent drying on 33% of its range,
7.4 to 9.6 percent drying on 50% of its range,
5.1 to 7.3 percent drying on 14% of its range,
2.8 to 5.0 percent drying on 1% of its range.

**B1) Exposure to sea level rise.** Neutral.

**B2a) Distribution relative to natural barriers.** Neutral. Significant natural barriers do not exist for this species in Colorado.

**B2b) Distribution relative to anthropogenic barriers.** Neutral. No significant anthropogenic barriers exist for the gray vireo since they can fly over potential obstructions.

**B3) Impact of land use changes resulting from human responses to climate change**. Neutral. Our current assumption is that the likeliest future land use change as direct mitigation for climate change would be accelerated development of wind energy. The greatest potential for wind energy in Colorado is mostly outside the range of gray vireo. Development of solar energy is conceivable, but many utilities have frozen their solar programs for the time being (http://www.seia.org/state-solar-policy/colorado).

**C1) Dispersal and movements.** Neutral. The gray vireo is capable of long distance migration.

**C2ai) Predicted sensitivity to temperature: historical thermal niche.** Neutral. Considering the mean seasonal temperature variation for occupied cells, the species has experienced average (57.1 - 77° F/31.8 - 43.0° C) temperature variation in the past 50 years.

**C2aii) Predicted sensitivity to temperature: physiological thermal niche.** Neutral. This species is associated with pinyon-juniper and juniper woodlands, oak shrublands, and sagebrush shrublands in Colorado and is not limited to cool or cold habitats (Kingery 1998).

**C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche**. Neutral. Considering the range of mean annual precipitation across occupied cells, the species has experienced greater than average (> 40 inches/1,016 mm) precipitation variation in the past 50 years.

**C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche.** Neutral. There is no evidence that gray vireo are dependent on a strongly seasonal hydrologic regime.

**C2c) Dependence on a specific disturbance regime likely to be impacted by climate change.** Neutral.

**C2d) Dependence on snow-covered habitats.** Neutral. This species is found in some of the hottest, driest areas of Colorado.

**C3) Restriction to uncommon geological features or derivatives.** Neutral.

**C4a) Dependence on other species to generate habitat.** Somewhat Increase. The gray vireo relies on the elephant tree (*Bursera microphylla*) for habitat and food during the winter months.

**C4b) Dietary versatility.** Neutral. Although the gray vireo relies heavily on the fruit of the elephant tree (*Bursera microphylla*) in its winter range (Bates 1992), in Colorado it eats a variety of insects (Barlow et al. 1999).

**C4c) Pollinator versatility (Plants only, not applicable).** N/A. This is for scoring plants.

**C4d) Dependence on other species for propagule dispersal.** Neutral.

**C4e) Sensitivity to pathogens or natural enemies.** Unknown.

**C4f) Sensitivity to competition from native or non-native species.** Unknown. The gray vireo is subjected to nest parasitism by brown-headed cowbirds across its range, but the impact(s) to populations are not well understood.

**C4g) Forms part of an interspecific interaction not covered by 4a-f**. Neutral.

**C5a) Measured genetic variation.** Unknown.

**C5b) Occurrence of bottlenecks in recent evolutionary history.** Unknown.

**C6) Phenological response to changing seasonal temperature and precipitation dynamics.** Unknown.

**D1) Documented response to recent climate change.** Unknown.

**D2) Modeled future (2050) change in population size or range size.** Neutral. The gray vireo's breeding range in Colorado is projected to increase, especially in the southeastern corner of the state between 2010 and 2099 (van Riper et al. 2014).

**D3) Overlap of modeled future (2050) range with current range.** Unknown. National Audubon Society (2013) predicts only a 3% overlap between gray vireo's current breeding range and its modeled 2080 range, but overlap specific to Colorado is unknown.

**D4) Occurrence of protected areas in modeled future (2050) distribution.** Unknown.

# BURROWING OWL
# CLIMATE CHANGE VULNERABILITY INDEX
# WESTERN U.S. DISTRIBUTION

## Climate Vulnerability Rank: Highly Vulnerable

This CCVI rank for western burrowing owl in the western U.S. is based on the following factors: 1) dependence on prairie dogs and other mammals to create suitable nesting habitat; 2) low levels of genetic diversity; 3) significant population declines in core breeding areas due to increased air temperatures and decreased precipitation, and 4) predicted loss of breeding and winter ranges due to climate change (Audubon Society 2015).

**Distribution*:*** The burrowing owl has a large global distribution. Its range includes Central America, Mexico, the central and western U.S., and Canada (Haug et al. 1993). In the western U.S., it is a permanent resident in Arizona, California, New Mexico, and Texas. During breeding season its distribution includes the Great Plains and interior west.

**Habitat:** This species is found in dry, flat, treeless areas with short vegetation and the presence of burrowing mammals.

**Ecological System:** Primarily found in grasslands and deserts in the western U.S.

## CCVI Scoring

**A) Temperature:** Calculated using ClimateWizard: ensemble average, medium emission scenario (A1B), mid-century timeframe, average annual change. By mid-century this species is expected to be exposed to mean annual temperature increases of:

5.6°F to 6.0°F across 15% of its range,
5.5°F across 58% of its range,
4.5°F to 5.0°F across 19% of its range,
3.9°F to 4.4°F across 6% of its range,
<3.9°F across 2% of its range.

**A) Moisture Metric:** Calculated in GIS using NatureServe Hamon AET:PET moisture metric data (this index integrates projected temperature and precipitation changes to indicate how much drying will take place). Rangewide this species is predicted to be exposed to net drying of greater than:

>11.9 percent drying on 1% of its range,
9.7 to 11.9 percent drying on 18% of its range,
7.4 to 9.6 percent drying on 33% of its range,
5.1 to 7.3 percent drying on 27% of its range,

2.8 to 5.0 percent drying on 15% of its range,
<2.8 percent drying on 6% of its range.

**B1) Exposure to sea level rise.** Neutral.

**B2a) Distribution relative to natural barriers.** Neutral.

**B2b) Distribution relative to anthropogenic barriers.** Neutral.

**B3) Impact of land use changes resulting from human responses to climate change**. Somewhat Increase. According to Department of Energy wind resource maps, the eastern portion of burrowing owl range contain excellent wind resources and potential for wind energy development (DOE 2004). The highest concentration of existing wind turbines in the U.S. occurs in Great Plains states (U.S. Energy Information Administration 2011). Wind turbines can cause direct impacts to birds via collisions that result in injury or mortality (Kunz et al. 2007; Kuvlesky et al. 2007), as well as indirect impacts via habitat loss and barriers to movement (Drewitt and Langston 2006; Kuvlesky et al. 2007; Pruett et al. 2009; Kiesecker et al. 2011).

**C1) Dispersal and movements.** Neutral. The burrowing owl is capable of long distance migration – e.g., burrowing owls banded in Alberta, Canada have been recovered in Mexico (USFWS 2003).

**C2ai) Historical thermal niche.** Neutral. Considering the mean seasonal temperature variation for occupied cells, the species has experienced average (57.1 - 77° F/31.8 - 43.0° C) temperature variation in the past 50 years.

**C2aii) Physiological thermal niche.** Neutral. This species is not limited to cool or cold habitats.

**C2bi) Historical hydrological niche**. Neutral. Considering the range of mean annual precipitation across occupied cells, the species has experienced greater than average (> 40 inches/1,016 mm) precipitation variation in the past 50 years.

**C2bii) Physiological hydrological niche.** Neutral. Burrowing owls are not closely tied to a specific hydrological niche.

**C2c) Dependence on a specific disturbance regime likely to be impacted by climate change.** Neutral.

**C2d) Dependence on snow-covered habitats.** Neutral.

**C3) Restriction to uncommon geological features or derivatives.** Neutral.

**C4a) Dependence on other species to generate habitat.** Somewhat Increase. Burrowing owls nest in burrows that are created by prairie dogs and other mammals.

**C4b) Dietary versatility.** Neutral.

**C4c) Pollinator versatility (Plants only).** Not applicable.

**C4d) Dependence on other species for propagule dispersal.** Neutral.

**C4e) Sensitivity to pathogens or natural enemies.** Neutral.

**C4f) Sensitivity to competition from native or non-native species.** Neutral.

**C4g) Forms part of an interspecific interaction not covered by 4a-f**. Neutral.

**C5a) Measured genetic variation.** Increase. Low levels of genetic variation have been documented in burrowing owls, based on microsatellite data from populations distributed throughout North America (Macias-Duarte et al. 2010). Populations are reported to be essentially panmictic (i.e., all individuals are potential partners with no mating restrictions) (Korfanta et al. 2005).

**C5b) Occurrence of bottlenecks in recent evolutionary history.** Unknown.

**C6) Phenological response to changing seasonal temperature and precipitation dynamics.** Neutral.

**D1) Documented response to recent climate change.** Somewhat Increase. Documented responses to climate change have shown a significant decline of 98% in a breeding population in New Mexico over a 16 year period that was strongly associated with decreased precipitation and increased air temperature. These climate variables affected arrival on breeding grounds, pair formation, nest initiation, hatch dates, and body mass (Cruz-McDonnell and Wolf 2016).
**D2) Modeled future (2050) change in population size or range size.** Increase. Audubon Society's climate models predict that by 2080, burrowing owls could lose 77% of their current breeding range (Audubon Society 2015).
**D3) Overlap of modeled future (2050) range with current range.** Increase. The National Audubon Society (2015) predicts a 23% decrease in summer range and a 33% decrease in winter range by 2080.
**D4) Occurrence of protected areas in modeled future (2050) distribution.** Unknown.

# BURROWING OWL
# CLIMATE CHANGE VULNERABILITY INDEX
# COLORADO DISTRIBUTION

## Climate Vulnerability Rank: Moderately Vulnerable

This rank is based on the following factors: 1) dependence on prairie dogs and other mammals to create suitable nesting habitat; 2) low levels of genetic diversity; 3) lack of protection on private lands; 4) significant population declines in core breeding areas due to increased air temperatures and decreased precipitation, 5) predicted loss of 77% of current breeding range due to climate change (Audubon Society 2015).

**Distribution*:*** Breeding records cover much of the state, although it is more common on the plains of eastern Colorado (Andrews and Righter 1992, Kingery 1998).

**Habitat:** This species is found in dry open treeless areas and is associated with burrowing mammals. Burrows are usually surrounded by bare ground and provide protection from weather extremes (Haug et al. 1993). Although capable of digging their own burrows where burrowing mammals are absent, burrowing owls usually use existing burrows, particularly those of prairie dogs.

**Ecological System:** Shortgrass Prairie

## CCVI Scoring

**A) Temperature:** Calculated using ClimateWizard: ensemble average, medium emission scenario (A1B), mid-century timeframe, average annual change. By mid-century this species is expected to be exposed to mean annual temperature increases of:

5.6°F to 6.0°F across 26% of its range,
5.5°F across 74% of its range.

**A) Moisture Metric:** Calculated in GIS using NatureServe Hamon AET:PET moisture metric data (this index integrates projected temperature and precipitation changes to indicate how much drying will take place). Rangewide this species is predicted to be exposed to net drying of greater than:

>11.9 percent drying on 2% of its range,
9.7 to 11.9 percent drying on 62% of its range,
7.4 to 9.6 percent drying on 32% of its range,
5.1 to 7.3 percent drying on 4% of its range.

**B1) Exposure to sea level rise.** Neutral.
**B2a) Distribution relative to natural barriers.** Neutral.

**B2b) Distribution relative to anthropogenic barriers.** Neutral.
**B3) Impact of land use changes resulting from human responses to climate change**. Somewhat Increase. According to Department of Energy wind resource maps, the eastern quarter of Colorado near the New Mexico and Nebraska borders has excellent wind resources (DOE 2004). Wind turbines can cause direct impacts to birds via collisions that result in injury or mortality (Kunz et al. 2007; Kuvlesky et al. 2007), as well as indirect impacts via habitat loss and barriers to movement (Drewitt and Langston 2006; Kuvlesky et al. 2007; Pruett et al. 2009; Kiesecker et al. 2011).
**C1) Dispersal and movements.** Neutral. The burrowing owl is capable of long distance migration.
**C2ai) Historical thermal niche.** Neutral. Considering the mean seasonal temperature variation for occupied cells, the species has experienced average (57.1 - 77° F/31.8 - 43.0° C) temperature variation in the past 50 years.
**C2aii) Physiological thermal niche.** Neutral. This species is not limited to cool or cold habitats.
**C2bi) Historical hydrological niche**. Neutral. Considering the range of mean annual precipitation across occupied cells, the species has experienced greater than average (> 40 inches/1,016 mm) precipitation variation in the past 50 years.
**C2bii) Physiological hydrological niche.** Neutral.
**C2c) Dependence on a specific disturbance regime likely to be impacted by climate change.** Neutral.
**C2d) Dependence on snow-covered habitats.** Neutral.
**C3) Restriction to uncommon geological features or derivatives.** Neutral.
**C4a) Dependence on other species to generate habitat.** Somewhat Increase. Burrowing owls nest in burrows that are created by prairie dogs and other mammals.
**C4b) Dietary versatility.** Neutral.
**C4c) Pollinator versatility (Plants only).** Not applicable.
**C4d) Dependence on other species for propagule dispersal.** Neutral.
**C4e) Sensitivity to pathogens or natural enemies.** Neutral.
**C4f) Sensitivity to competition from native or non-native species.** Neutral.
**C4e) Forms part of an interspecific interaction not covered by 4a-f**. Neutral.
**C5a) Measured genetic variation.** Increase. Low levels of genetic variation have been documented in burrowing owls, based on microsatellite data from populations distributed throughout North America (Macias-Duarte et al. 2010). Populations are reported to be essentially panmictic (i.e., all individuals are potential partners with no mating restrictions) (Korfanta et al. 2005).
**C5b) Occurrence of bottlenecks in recent evolutionary history.** Unknown.
**C6) Phenological response to changing seasonal temperature and precipitation dynamics.** Unknown. Responses to climate change have been documented in New Mexico, but not in Colorado.
**D1) Documented response to recent climate change.** Unknown.
**D2) Modeled future (2050) change in population size or range size.** Increase. The National Audubon Society (2015) climate models predict that by 2080, Burrowing Owls could lose 77% of their current breeding range. The percentage of loss within Colorado is unknown, but maps clearly show reduced summer range in the state.
**D3) Overlap of modeled future (2050) range with current range.** Unknown.
**D4) Occurrence of protected areas in modeled future (2050) distribution.** Unknown.

# GOLDEN EAGLE CLIMATE CHANGE VULNERABILITY INDEX
# WESTERN U.S. DISTRIBUTION

## Climate Vulnerability Rank: Moderately Vulnerable

This rank is based on: the projected increases in temperature for the assessed area, increased wind energy development and the greater risk to mortality from wind turbines than other raptors, and a predicted decrease in breeding range. Climate projections suggest that summer temperatures across the range of the golden eagle in the assessed area will increase 6°F by the end of the century under a lower emissions scenario, with increases of more than 10°F by the end of the century under a higher emissions scenario (Karl et al. 2009).

**Distribution:** Golden eagles are a wide-ranging species occurring throughout western North America, but are rare in the east. They occupy a wide range of habitats and in the west are common near open spaces that support abundant populations of their prey, particularly where cliffs occur that supply nesting sites for breeding pairs (Kochert et al. 2002). Golden eagles breed also in northern latitudes worldwide including in Europe, Asia north of the Himalaya foothills, northern Africa, and the northern and central parts of the Arabian Peninsula (NatureServe 2015).

**Habitat:** Golden eagles use a very wide range of habitats. For nesting they most frequently use cliffs but will also nest in trees. Because of their large size and predatory nature, they require large areas of foraging habitat. For foraging they use high- and mid-elevation pine forest, pinyon-juniper woodlands, sagebrush and other shrub habitats, grassland, and agricultural habitats are all used by Golden eagles.

## CCVI Scoring

**A) Temperature:** Calculated using ClimateWizard: ensemble average, medium emission scenario (A1B), mid-century timeframe, average annual change. By mid-century this species is expected to be exposed to mean annual temperature increases of:

5.6°F to 6.0°F across 24% of its range,
5.5°F across 52% of its range,
4.5°F to 5.0°F across 18% of its range,
3.9°F to 4.4°F across 5% of its range,
<3.9°F across 1% of its range.

**A) Moisture Metric:** Calculated in GIS using NatureServe Hamon AET:PET moisture metric data (this index integrates projected temperature and precipitation changes to indicate how much drying will take place). Rangewide this species is predicted to be exposed to net drying of greater than:

>11.9 percent drying on 2% of its range,
9.7 to 11.9 percent drying on 17% of its range,

7.4 to 9.6 percent drying on 34% of its range,
5.1 to 7.3 percent drying on 26% of its range,
2.8 to 5.0 percent drying on 14% of its range
<2.8 percent drying on 7% of its range.

**B1) Exposure to sea level rise**. Neutral. This is an inland terrestrial species.

**B2a) Distribution relative to natural barriers.** Neutral. Significant natural barriers do not exist for this species. This raptor is a volant species that can traverse mountain ranges and large bodies of water.

**B2b) Distribution relative to anthropogenic barriers.** Neutral. Significant anthropogenic barriers do not exist for this species. This raptor is a volant species that can fly over or around potential anthropogenic barriers.

**B3) Impact of land use changes resulting from human responses to climate change**. Somewhat increase. Golden eagles are at greater risk to mortality from wind turbines than other raptors (USFWS 2011). Wind energy development is expected to increase within the range of the golden eagle (NRDC 2016).

**C1) Dispersal and movements.** Neutral. Golden eagles readily disperse more than 10 kilometers from hatching site to breeding areas (Kochert et al. 2002)

**C2ai) Historical thermal niche.** Neutral. In the assessed area, the golden eagle has experienced 69.7° F, or average (51.7 - 77° F/31.8 - 43.0° C) temperature variation over the last 50 years.

**C2aii) Physiological thermal niche.** Somewhat increase. In North America, golden eagle's breeding success appears to be compromised by the number of extremely hot days during the brood rearing period (Steenhof et al. 1997). Climate projections suggest that summer temperatures across the assessed area will increase 6°F by the end of the century under a lower emissions scenario, with increases of more than 10°F by the end of the century under a higher emissions scenario (Karl et al. 2009).

**C2bi) Historical hydrological niche**. Neutral. The golden eagle has experienced greater than average (> 40 inches/1,016 mm) precipitation variation in the past 50 years.

**C2bii) Physiological hydrological niche.** Neutral. Golden eagle reproductive success appears to be independent of any particular precipitation regime (Steenhof et al. 1997, Crandall 2005).

**C2c) Dependence on a specific disturbance regime likely to be impacted by climate change.** Neutral. The golden eagle is not dependent on any disturbance regime such as fire or flooding; they are most dependent upon suitable prey populations in foraging areas (Steenhof et al. 1997 and Crandall 2005).

**C2d) Dependence on snow-covered habitats.** Neutral. The golden eagle is not dependent on habitats with ice, snow, or on snowpack.

**C3) Restriction to uncommon geological features or derivatives.** Neutral. The golden eagle is not dependent upon any uncommon geological elements. They often nest on cliffs, but also will nest in trees and on the ground, river banks and human structures (Kochert et al. 2002). Climate change should not impact the availability of suitable cliff sites for nesting.

**C4a) Dependence on other species to generate habitat.** Neutral. The golden eagle is not dependent on any other species to create suitable habitat for its existence.

**C4b) Dietary versatility.** Neutral. The golden eagle depends upon a variety of small mammal as prey including hares (*Lepus* spp.) and rabbits (*Sylvilagus* spp.); also ground squirrels (*Spermophilus* spp.), prairie dogs (*Cynomys* spp.) and marmots (*Marmota* spp.) (Kochert et al. 2002).
**C4d) Dependence on other species for propagule dispersal**. Neutral. The golden eagle is a self-disperser.
**C4e) Sensitivity to other pathogens.** Somewhat Increase. There is some evidence, particularly in northern portions of its range, that the golden eagle could in the future experience an increase in the distribution and abundance of pathogens due to climate change (Mete et al. 2014, Van Hemert et al. 2014).
**C4f) Sensitivity to competition from native or non-native species.** Neutral. There is no indication that a native or non-native potential competitor of golden eagles will be favored by climate change.
**C4g) Forms part of an interspecific interaction not covered by 4a-d**. Neutral. No other interspecific interactions, other than those discussed above, are important to the persistence of the golden eagle.
**C5a) Measured genetic variation.** Neutral. Measures of heterozygosity and overall nucleotide variability of the golden eagle as average compared to other avian taxa (Bourke and Dawson 2006 and Doyle et al. 2014).
**C5b) Occurrence of bottlenecks in recent evolutionary history**. Unknown.
**C6) Phenological response to changing seasonal temperature and precipitation dynamics.** Unknown.
**D1) Response to recent climate change.** Unknown.
**D2) Modeled future change in population or range size.** Somewhat Increase. The predicted breeding range of the golden eagle in the assessed area is predicted to decline by 41 percent (National Audubon Society 2013).
**D3) Overlap of modeled future range with current range.** Neutral. Modeling of the future range of the golden eagle indicates a large overlap between the current distribution and the expected distribution in 2050 (National Audubon Society 2013).
**D4) Protected areas.** Unknown.

# GOLDEN EAGLE CLIMATE CHANGE VULNERABILITY INDEX
# COLORADO DISTRIBUTION

## Climate Vulnerability Rank: Less Vulnerable

**Distribution:** In Colorado, golden eagles breed primarily in montane habitats in the west and canyon habitats in the southeast. There is some limited breeding in northeast Colorado. In winter, golden eagles range more widely and occur commonly throughout Colorado.

**Habitat:** Golden eagles use a very wide range of habitats. For nesting they most frequently use cliffs but will also nest in trees. Because of their large size and predatory nature, they require large areas of foraging habitat. For foraging they use high- and mid-elevation pine forest, pinyon-juniper woodlands, sagebrush and other shrub habitats, grassland, and agricultural habitats are all used by Golden eagles.

## CCVI Scoring

**A) Temperature:** Calculated using ClimateWizard: ensemble average, medium emission scenario (A1B), mid-century timeframe, average annual change. By mid-century this species is expected to be exposed to mean annual temperature increases of:

5.6°F to 6.0°F across 54% of its range,
5.5°F across 46% of its range.

**A) Moisture Metric:** Calculated in GIS using NatureServe Hamon AET:PET moisture metric data (this index integrates projected temperature and precipitation changes to indicate how much drying will take place). Rangewide this species is predicted to be exposed to net drying of greater than:

>11.9 percent drying on 7% of its range,
9.7 to 11.9 percent drying on 55% of its range,
7.4 to 9.6 percent drying on 32% of its range,
5.1 to 7.3 percent drying on 5% of its range,
2.8 to 5.0 percent drying on 1% of its range.

**B1) Exposure to sea level rise**. Neutral. This is an inland terrestrial species.

**B2a) Distribution relative to natural barriers.** Neutral. Significant natural barriers do not exist for this species. This raptor is a volant species that can traverse mountain ranges and large bodies of water.

**B2b) Distribution relative to anthropogenic barriers.** Neutral. Significant anthropogenic barriers do not exist for this species. This raptor is a volant species that can fly over or around potential anthropogenic barriers.

**B3) Impact of land use changes resulting from human responses to climate change**. Somewhat increase. Golden eagles are at greater risk to mortality from wind turbines than other raptors (USFWS 2011). Wind energy development is expected to increase within the range of the golden eagle in Colorado (NRDC 2016).

**C1) Dispersal and movements.** Neutral. Golden eagles readily disperse more than 10 kilometers from hatching site to breeding areas (Kochert et al. 2002)

**C2ai) Historical thermal niche.** Neutral. In Colorado, the golden eagle has experienced 72.5° F, or average (51.7 - 77° F/31.8 - 43.0° C) temperature variation over the last 50 years.

**C2aii) Physiological thermal niche.** Somewhat increase. In North America, golden eagle's breeding success appears to be compromised by the number of extremely hot days during the brood rearing period (Steenhof et al. 1997).

**C2bi) Historical hydrological niche**. Neutral. Within Colorado, the golden eagle has experienced 55 inches, or greater than average (> 40 inches/1,016 mm) precipitation variation in the past 50 years.

**C2bii) Physiological hydrological niche.** Neutral. Golden eagle reproductive success appears to be independent of any particular precipitation regime (Steenhof et al. 1997, Crandall 2005).

**C2c) Dependence on a specific disturbance regime likely to be impacted by climate change.** Neutral. The golden eagle is not dependent on any disturbance regime such as fire or flooding and are most dependent upon suitable prey populations in foraging areas ((Steenhof et al. 1997 and Crandall 2005).

**C2d) Dependence on snow-covered habitats.** Neutral. The golden eagle is not dependent on habitats with ice, snow, or on snowpack.

**C3) Restriction to uncommon geological features or derivatives.** Neutral. The golden eagle is not dependent upon any uncommon geological elements. They often nest on cliffs, but also will nest in trees and on the ground, river banks and human structures (Kochert et al. 2002). Climate change should not impact the availability of suitable cliff sites for nesting.

**C4a) Dependence on other species to generate habitat.** Neutral. The golden eagle is not dependent on any other species to create suitable habitat for its existence.

**C4b) Dietary versatility.** Neutral. The golden eagle depends upon a variety of small mammal as prey including hares (*Lepus* spp.) and rabbits (*Sylvilagus* spp.); also ground squirrels (*Spermophilus* spp.), prairie dogs (*Cynomys* spp.) and marmots (*Marmota* spp.) (Kochert et al. 2002).

**C4d) Dependence on other species for propagule dispersal**. Neutral. The golden eagle is a self-disperser.

**C4e) Sensitivity to other pathogens.** Neutral. There is no evidence that within Colorado, the golden eagle is currently or in the future will be affected by pathogens or natural enemies as a result of climate change.

**C4f) Sensitivity to competition from native or non-native species.** Neutral. There is no indication that a native or non-native potential competitor of golden eagles will be favored by climate change.

**C4g) Forms part of an interspecific interaction not covered by 4a-f**. Neutral. No other interspecific interactions, other than those discussed above, are important to the persistence of the golden eagle.

**C5a) Measured genetic variation.** Neutral. Measures of heterozygosity and overall nucleotide variability of the golden eagle as average compared to other avian taxa (Bourke and Dawson 2006 and Doyle et al 2014).

**C5b) Occurrence of bottlenecks in recent evolutionary history**. Unknown.
**C6) Phenological response to changing seasonal temperature and precipitation dynamics.** Unknown.
**D1) Response to recent climate change.** Unknown.
**D2) Modeled future change in population or range size.** Somewhat Increase. The predicted breeding range of the golden eagle in the assessed area is predicted to decline by 41 percent (National Audubon Society 2013).
**D3) Overlap of modeled future range with current range.** Neutral. Modeling of the future range of the golden eagle within Colorado indicates a large overlap between the current distribution and the expected distribution in 2050 (National Audubon Society 2013).
**D4) Protected areas.** Unknown.

# PREBLE'S MEADOW JUMPING MOUSE
# CLIMATE CHANGE VULNERABILITY INDEX
# COLORADO DISTRIBUTION

## Climate Vulnerability Rank: Extremely Vulnerable

This rangewide rank is based on the following factors: 1) majority of distribution in urbanized setting limits range shift options, 2) reliance on habitat closely tied to the hydrological regime, where higher temperatures are likely to lead to drier conditions and reduced habitat suitability, 3) potential for higher temperatures and greater climate variability to disrupt hibernation.

**Distribution***:* The distribution of Preble's meadow jumping mouse is restricted to a narrow band of riparian habitat along the eastern edge of the Rocky Mountains, from southeastern Wyoming southward along the Front Range of Colorado to Colorado Springs.

**Habitat:** The PMJM is a riparian obligate that lives in dense, lush vegetation consisting of shrubs and grass and forb ground cover, sometimes with a tree overstory, along creeks, rivers, and other associated waterbodies.

**Ecological System:** East Slope Riparian

## CCVI Scoring

**A) Temperature:** Estimated using ClimateWizard: ensemble average, medium emission scenario (A1B), mid-century timeframe, average annual change. By mid-century this species is expected to be exposed to mean annual temperature increases of 5.5$^{o}$F across 100% of its range.
**A) Moisture Metric:** Estimated using NatureServe Hamon AET:PET moisture metric data (this index integrates projected temperature and precipitation changes to indicate how much drying will take place). Rangewide this species is predicted to be exposed to net drying of greater than:

- >11.9 percent drying on 10% of its range,
- 9.7 to 11.9 percent drying on 70% of its range,
- 7.4 to 9.6 percent drying on 20% of its range.

**B1) Exposure to sea level rise.** Neutral.
**B2a) Distribution relative to natural barriers.** Somewhat Increase.
Currently habitat to the north is less hospitable than within current distribution. However, if climate-mediated habitat shifts occur and create more habitat to the north, then PMJM will have an option to disperse northward. Habitat is restricted to a peninsula-like orientation with limits to dispersal to the west and east and south.
**B2b) Distribution relative to anthropogenic barriers.** Greatly Increase.
Greater than 80% of PMJM range is within an urban landscape context.

**B3) Impact of land use changes resulting from human responses to climate change**. Increase. Because there have been proposals to dam the Cache la Poudre River, and the South Platte River could be a candidate for future damming for hydropower, we've given PMJM an "increase vulnerability" category.

**C1) Dispersal and movements.** Neutral. PMJM are known to move >1km along riparian corridors.

**C2ai) Predicted sensitivity to temperature: historical thermal niche.** Neutral. This species has experienced average or greater than average (>57°F/43°C) temperature variation in the past 50 years.

**C2aii) Predicted sensitivity to temperature: physiological thermal niche.** Increase. For PMJM critical period regarding climate change is hibernation. PMJM tend to select hibernacula on north-facing slopes along creeks and rivers (based on telemetry data from U.S. Air Force Academy). Temperatures there are more stable because of less solar exposure. PMJM are known to emerge from hibernation as soil temperatures increase, so keeping stable, cold soil temperatures is vital.

**C2bi) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: historical hydrological niche**. Increase. Considering the range of mean annual precipitation across occupied cells, the species has experienced small (4 - 10 inches/100 - 254 mm) precipitation variation in the past 50 years.

**C2bii) Predicted sensitivity to changes in precipitation, hydrology, or moisture regime: physiological hydrological niche.** Greatly Increase. Because PMJM are strongly tied to some of the most humid environments in Colorado, expected changes to this moisture regime will likely change suitable habitat.

**C2c) Dependence on a specific disturbance regime likely to be impacted by climate change.** Increase. Because PMJM habitat is maintained by periodic flooding, alterations to flooding regimes will decrease habitat quality.

**C2d) Dependence on ice, ice-edge, or snow-cover habitats.** Somewhat Increase. The blanket of snow in winter can be advantageous for hibernating PMJM because of the insulation from solar radiation and decreased likelihood of awakening during hibernation (saving fat reserves and increasing overwinter survival). Note: male overwinter survival can be compromised by late snow if it obscures food resources (males emerge a month in advance of females).

**C3) Restriction to uncommon landscape/geological features or derivatives.** Neutral.

**C4a) Dependence on other species to generate required habitat.** Neutral. It is helpful to have beaver/muskrat, but not critical.

**C4b) Dietary versatility (animals only).** Neutral.

**C4c) Pollinator versatility (Plants only).** Not applicable.

**C4d) Dependence on other species for propagule dispersal.** Neutral.

**C4e) Sensitivity to pathogens or natural enemies.** Unknown.

**C4f) Sensitivity to competition from native or non-native species.** Unknown.

**C4g) Forms part of an interspecific interaction not covered by 4a-d**. Unknown.

**C5a) Measured genetic variation.** Neutral. But note we are unsure about comparative variability of PMJM with other species.

**C5b) Occurrence of bottlenecks in recent evolutionary history.** Neutral.

**C5c) Reproductive system (plants only).** Not applicable.

**C6) Phenological response to changing seasonal temperature and precipitation dynamics.** Unknown.

**D1) Documented response to recent climate change.** Unknown.

**D2) Modeled future change in population or range size.** Unknown.

**D3) Overlap of modeled future range with current range.** Unknown.

**D4) Occurrence of protected areas in modeled future (2050) distribution.** Unknown.

# Appendix C: NatureServe's Climate Change Vulnerability Index – Overview and Methods

## Overview

This overview has been synthesized and reprinted, with permission, from Young et al. (2011). The Climate Change Vulnerability Index (CCVI), developed by NatureServe, is a Microsoft Excel-based tool that facilitates rapid assessment of the vulnerability of plant and animal species to climate change within a defined geographic area. In accordance with well-established practices (Schneider et al. 2007, Williams et al. 2008), the CCVI divides vulnerability into two components:

> **Exposure** to climate change within the assessment area (e.g., a highly sensitive species will not suffer if the climate where it occurs remains stable).
> **Sensitivity/adaptive capacity** of the species to climate change (e.g., an adaptable species will not decline even in the face of significant changes in temperature and/or precipitation).

Exposure to climate change is measured by examining the magnitude of predicted temperature and moisture change across the species' distribution within the study area. CCVI guidelines suggest using the downscaled data from Climate Wizard (http://climatewizard.org) for predicted change in temperature. Projections for changes in precipitation are available in Climate Wizard, but precipitation estimates alone are often an unreliable indicator of moisture availability because increasing temperatures promote higher rates of evaporation and evapotranspiration. Moisture availability, rather than precipitation per se, is a critical resource for plants and animals and therefore forms the other part of the exposure measure within the CCVI, together with temperature. To predict changes in moisture availability, NatureServe and partners developed the Hamon AET:PET moisture metric as part of the CCVI. The metric represents the ratio of actual evapotranspiration (i.e., the amount of water lost from a surface through evaporation and transpiration by plants) to potential evapotranspiration (i.e., the total amount of water that could be evaporated under current environmental conditions, if unlimited water was available). Negative values represent drying conditions.

Sensitivity is assessed using 21 factors divided into two categories: 1) indirect exposure to climate change; and 2) species specific factors (including dispersal ability, temperature and precipitation sensitivity, physical habitat specificity, interspecific interactions, and genetic factors). For each factor, species are scored on a sliding scale from greatly increasing, to having no effect on, to decreasing vulnerability. The CCVI accommodates more than one answer per factor in order to address poor data or a high level of uncertainty for that factor. The scoring system integrates all exposure and sensitivity measures into an overall vulnerability score that indicates relative vulnerability compared to other species and the relative importance of the factors contributing to vulnerability.

The Index treats exposure to climate change as a modifier of sensitivity. If the climate in a given assessment area will not change much, none of the sensitivity factors will weigh heavily, and a species is likely to score at the Less Vulnerable end of the range. A large change in temperature or moisture availability will amplify the effect of any related sensitivity, and will contribute to a score reflecting higher vulnerability to climate change. In most cases, changes in temperature and moisture availability will combine to modify sensitivity factors. However, for factors such as sensitivity to temperature change (factor 2a) or precipitation/moisture regime (2b), only the specified climate driver will have a modifying effect.

The five possible scores are:

**Extremely Vulnerable**: Abundance and/or range extent within geographical area assessed extremely likely to substantially decrease or disappear by 2050.
**Highly Vulnerable**: Abundance and/or range extent within geographical area assessed likely to decrease significantly by 2050.
**Moderately Vulnerable**: Abundance and/or range extent within geographical area assessed likely to decrease by 2050.
**Less Vulnerable**: Available evidence does not suggest that abundance and/or range extent within the geographical area assessed will change (increase/decrease) substantially by 2050. Actual range boundaries may change.
**Insufficient Evidence**: Available information about a species' vulnerability is inadequate to calculate an Index score.

## Scoring Factors in the CCVI

The factors used to generate the CCVI score and definitions for scoring categories are listed below.

***A. Exposure to Local Climate Change***

1. **Temperature** – percent of species known range/distribution that is expected to experience temperature increase, in categories defined by the CCVI, as follows:

| |
|---|
| >6.0°F warmer |
| 5.6-6.0°F warmer |
| 5.5.0°F warmer |
| 4.5-5.0°F warmer |
| 3.9-4.4.0°F warmer |
| <3.9°F warmer |

2. **Moisture (AET:PET Moisture Metric) –** This index integrates projected temperature and precipitation changes to indicate how much drying will take place. This metric was created by NatureServe as part of the CCVI. Categories are:

| |
|---|
| < -0.119 |
| -0.097 - -0.119 |
| -0.074 - -0.096 |
| -0.051 - -0.073 |
| -0.028 - -0.050 |
| >-0.028 |

***B. Indirect Exposure to Climate Change***

1. **Exposure to sea level rise:** not applicable to Colorado.
2. **Distribution relative to barriers**: degree to which species' vulnerability is influenced by its ability to shift range/distribution in response to climate change.
3. **Predicted impact of land use changes resulting from human responses to climate change**. This factor is intended to identify species that might be further threatened by strategies designed to mitigate or adapt to climate change (e.g., renewable energy projects such as wind-farms, solar arrays, biofuels production, hydro-power; tree-planting for carbon offsets).

Scoring categories for **barriers** are:

| | |
|---|---|
| *Greatly Increase Vulnerability:* | Barriers completely OR almost completely surround the current distribution such that the species' range in the assessment area is unlikely to be able to shift significantly with climate change, or the direction of climate change-caused shift in the species' favorable climate envelope is fairly well understood and barriers prevent a range shift in that direction. See *Neutral* for species in habitats not vulnerable to climate change. |
| | *Examples for natural barriers:* lowland terrestrial species completely surrounded by high mountains (or bordered closely and completely on the north side by high mountains); cool-water stream fishes for which barriers would completely prevent access to other cool-water areas if the present occupied habitat became too warm as a result of climate change; most nonvolant species that exist only on the south side of a very large lake in an area where habitats are expected to shift northward with foreseeable climate change. |
| | *Examples for anthropogenic barriers:* species limited to small habitats within intensively developed urban or agricultural landscapes through which the species cannot pass, A specific example of this category is provided by the quino checkerspot butterfly (*Euphydryas editha quino*), a resident of northern Baja California and southern California; warming climates are forcing this butterfly northward, but urbanization in San Diego blocks its movement (Parmesan 1996, Nature 382:765). |
| *Increase Vulnerability:* | Barriers border the current distribution such that climate change-caused distributional shifts in the assessment area are likely to be greatly but not completely or almost completely impaired. |
| | *Examples for natural barriers:* certain lowland plant or small mammal species whose ranges are mostly (50-90%) bordered by high mountains or a large lake. |

| | |
|---|---|
| | *Examples for anthropogenic barriers:* most streams inhabited by a fish species have dams that would prevent access to suitable habitat if the present occupied habitat became too warm as a result of climate change; intensive urbanization surrounds 75% of the range of a salamander species. |
| *Somewhat Increase Vulnerability:* | Barriers border the current distribution such that climate change-caused distributional shifts in the assessment area are likely to be significantly but not greatly or completely impaired. |
| | *Examples for natural barriers:* certain lowland plant or small mammal species whose ranges are partially but not mostly bordered by high mountains or a large lake. |
| | *Examples for anthropogenic barriers:* 10-50% of the margin of a plant species' range is bordered by intensive urban development; 25% of the streams occupied by a fish species include dams that are likely to impede range shifts driven by climate change. |
| *Neutral:* | Significant barriers do not exist for this species, OR small barriers exist in the assessment area but likely would not significantly impair distributional shifts with climate change, OR substantial barriers exist but are not likely to contribute significantly to a reduction or loss of the species' habitat or area of occupancy with projected climate change in the assessment area. |
| | *Examples of species in this category:* most birds (for which barriers do not exist); terrestrial snakes in extensive plains or deserts that may have small barriers that would not impede distributional shifts with climate change; small alpine-subalpine mammal (e.g., ermine, snowshoe hare) in extensive mountainous wilderness area lacking major rivers or lakes; fishes in large deep lakes or large main-stem rivers that are basically invulnerable to projected climate change and lack dams, waterfalls, and significant pollution; a plant whose climate envelope is shifting northward and range is bordered on the west by a barrier but for which no barriers exist to the north. |

Definitions of scoring categories for **predicted impact of land use changes** are:

| | |
|---|---|
| *Increase Vulnerability:* | The natural history/requirements of the species are known to be incompatible with mitigation-related land use changes that are likely to very likely to occur within its current and/or potential future range. This includes (but is not limited to) the following: |
| | Species requiring open habitats within landscapes likely to be reforested or afforested. If the species requires openings within forests that are created/maintained by natural processes (e.g., fire), and if those processes have a reasonable likelihood of continuing to operate within its range, a lesser impact category may be appropriate. |
| | Bird and bat species whose migratory routes, foraging territory, or lekking sites include existing and/or suitable wind farm sites. If numerous wind farms already exist along the species' migratory route, negative impacts have been found in relevant studies; if such studies exist but negative impacts have not been found, a lesser impact category may be appropriate. |
| | Greater than 20% of the species' range within the assessment area occurs on marginal agricultural land, such as CRP land or other open areas with suitable soils for agriculture ("prime farmland", etc.) that are not currently in agricultural production OR > 50% of the species' range within the assessment area occurs on any non-urbanized land with suitable soils, where there is a reasonable expectation that such land may be converted to biofuel production. |
| | The species occurs in one or more river/stream reaches not yet developed for hydropower, but with the potential to be so developed. |
| | Species of deserts or other permanently open, flat lands with potential for placement of solar arrays. |
| *Somewhat Increase Vulnerability:* | The natural history/requirements of the species are known to be incompatible with mitigation-related land use changes that *may possibly* occur within its current and/or potential future range, including any of the above (under Increase). |

| | |
|---|---|
| *Neutral:* | The species is unlikely to be significantly affected by mitigation-related land use changes that may occur within its current and/or potential future range, including any of the above; OR it is unlikely that any mitigation-related land use changes will occur within the species' current and/or potential future range. |

## Section C – Sensitivity

### 1. Dispersal and movement

Definitions of scoring categories are:

| | |
|---|---|
| *Greatly Increase Vulnerability:* | Species is characterized by severely restricted dispersal or movement capability. Species is represented by sessile organisms that almost never disperse more than 10 meters per dispersal event. |
| *Increase Vulnerability:* | Species is characterized by highly restricted dispersal or movement capability. Species rarely disperses through unsuitable habitat more than about 10-100 meters per dispersal event; OR dispersal beyond a very limited distance (or outside a small isolated patch of suitable habitat) periodically or irregularly occurs but is dependent on highly fortuitous or rare events; OR species has substantial movement capability but exhibits a very high degree of site fidelity. |
| *Somewhat Increase Vulnerability:* | Species is characterized by limited or moderate but not highly or severely restricted dispersal or movement capability. A significant percentage (at least approximately 5%) of propagules or individuals disperse approximately 100-1,000 meters per dispersal event (rarely farther); OR species has substantial movement capability but exhibits a moderate to high degree of site fidelity and has very limited existing or potential habitat within the assessment area; OR dispersal likely is consistent with one of the following examples: species that exist in small isolated patches of suitable habitat but regularly disperse or move among patches that are up to 1,000 meters (rarely farther) apart; plants whose propagules are dispersed primarily by small animals (e.g., some rodents) that typically move propagules approximately 100-1,000 meters from the source (propagules may be cached or transported incidentally on fur or feathers. |
| *Neutral:* | Species is characterized by good to excellent dispersal or movement capability. Species has propagules or dispersing individuals that commonly move more than 1 kilometer from natal or source areas; OR species tends to occupy all or most areas of suitable habitat, or readily or predictably moves more than 1 kilometer to colonize newly available habitat (e.g., recently restored areas, areas that become suitable as a result of fire, insect infestations, or other environmental changes, etc.); OR dispersal capability likely is consistent with one of the following examples. Note that species in the Neutral category are not necessarily "early successional" or "r-selected" species but also may include certain "late successional" or equilibrium ("K-selected") species that have excellent innate or vector-aided dispersal capability. |
| *Somewhat Decrease Vulnerability:* | Species is characterized by good dispersal or movement capability. Species has propagules or dispersing individuals that readily move 1-10 kilometers from natal or source areas (rarely farther), or dispersal capability likely is consistent with one of the following examples. Examples include: plant species regularly dispersed up to 10 km (rarely farther) by large or mobile animals (e.g., plant has seeds that are cached, regurgitated, or defecated 1-10 kilometers from the source by birds [e.g., corvids, songbirds that eat small fleshy fruits] or mammals or that are transported on fur of large mobile animals such as most Carnivora or ungulates). |
| *Decrease Vulnerability:* | Species is characterized by excellent dispersal or movement capability. Species has propagules or dispersing individuals that readily move more than 10 kilometers from natal or source areas, or dispersal capability likely is consistent with one of the following examples. |

| | |
|---|---|
| | Examples include: plant or animal species whose individuals often or regularly are dispersed more than 10 kilometers by migratory or otherwise highly mobile animals, air or ocean currents, or humans, including species that readily become established outside their native ranges as a result of intentional or unintentional translocations by humans. |

2. **Sensitivity to temperature and moisture changes**: This factor pertains to the breadth of temperature and precipitation conditions, at both broad and local scales, within which a species is known to be capable of reproducing, growing, or otherwise existing. Species with narrow environmental tolerances/requirements may be more vulnerable to habitat loss from climate change than are species that thrive under diverse conditions.

   (a.i.) **historical thermal niche**: This factor measures large-scale temperature variation that a species has experienced in recent historical times (i.e., the past 50 years), as approximated by mean seasonal temperature variation (difference between highest mean monthly maximum temperature and lowest mean monthly minimum temperature). It is a proxy for species' temperature tolerance at a broad scale.

Definitions of scoring categories are:

| | |
|---|---|
| *Greatly Increase Vulnerability:* | Considering the mean seasonal temperature variation for occupied cells, the species has experienced **very small (< 37° F/20.8° C)** temperature variation in the past 50 years. Includes cave obligates and species occurring in thermally stable groundwater habitats. |
| *Increase Vulnerability:* | Considering the mean seasonal temperature variation for occupied cells, the species has experienced **small (37 - 47° F/20.8 - 26.3° C)** temperature variation in the past 50 years. |
| *Somewhat Increase Vulnerability:* | Considering the mean seasonal temperature variation for occupied cells, the species has experienced **slightly lower than average (47.1 - 57° F/26.3 - 31.8° C)** temperature variation in the past 50 years. |
| *Neutral:* | Considering the mean seasonal temperature variation for occupied cells, the species has experienced **average (57.1 - 77° F/31.8 - 44.0° C)** temperature variation in the past 50 years. |

   (a.ii.) **physiological thermal niche**: This factor assesses the degree to which a species is restricted to relatively cool or cold environments that are thought to be vulnerable to loss or significant reduction as a result of climate change.

Definitions of scoring categories are:

| | |
|---|---|
| *Greatly Increase Vulnerability:* | Species is completely or almost completely (> 90% of occurrences or range) restricted to relatively cool or cold environments that may be lost or reduced in the assessment area as a result of climate change. |
| *Increase Vulnerability:* | Species is moderately (50-90% of occurrences or range) restricted to relatively cool or cold environments that may be lost or reduced in the assessment area as a result of climate change. |
| *Somewhat Increase Vulnerability:* | Species is somewhat (10-50% of occurrences or range) restricted to relatively cool or cold environments that may be lost or reduced in the assessment area as a result of climate change. |
| *Neutral:* | Species distribution is not significantly affected by thermal characteristics of the environment in the assessment area, or species occupies habitats that are thought to be not vulnerable to projected climate change. |

(b.i.) **historical hydrological niche**: This factor measures large-scale precipitation variation that a species has experienced in recent historical times (i.e., the past 50 years), as approximated by mean annual precipitation variation across occupied cells within the assessment area.

Definitions of scoring categories are:

| | |
|---|---|
| *Greatly Increase Vulnerability:* | Considering the range of mean annual precipitation across occupied cells, the species has experienced **very small (< 4 inches/100 mm)** precipitation variation in the past 50 years. |
| *Increase Vulnerability:* | Considering the range of mean annual precipitation across occupied cells, the species has experienced **small (4 - 10 inches/100 - 254 mm)** precipitation variation in the past 50 years. |
| *Somewhat Increase Vulnerability:* | Considering the range of mean annual precipitation across occupied cells, the species has experienced **slightly lower than average (11 - 20 inches/255 - 508 mm)** precipitation variation in the past 50 years. |
| *Neutral:* | Considering the range of mean annual precipitation across occupied cells, the species has experienced **average (21 - 40 inches/509 - 1,016 mm)** precipitation variation in the past 50 years. |

(b.ii.) **physiological hydrological niche**: This factor pertains to a species' dependence on a narrowly defined precipitation/hydrologic regime, including strongly seasonal precipitation patterns and/or specific aquatic/wetland habitats (e.g., certain springs, vernal pools, seeps, seasonal standing or flowing water) or localized moisture conditions that may be highly vulnerable to loss or reduction with climate change.

Definitions of scoring categories are:

| | |
|---|---|
| *Greatly Increase Vulnerability:* | Completely or almost completely (>90% of occurrences or range) dependent on a specific aquatic/wetland habitat or localized moisture regime that is likely to be highly vulnerable to loss or reduction with climate change. |
| *Increase Vulnerability:* | Moderately (50-90% of occurrences or range) dependent on a strongly seasonal hydrologic regime and/or a specific aquatic/wetland habitat or localized moisture regime that is likely to be highly vulnerable to loss or reduction with climate change. |
| *Somewhat Increase Vulnerability:* | Somewhat (10-50%) dependent on a strongly seasonal hydrologic regime and/or a specific aquatic/wetland habitat or localized moisture regime that is highly vulnerable to loss or reduction with climate change. |
| *Neutral:* | Species has little or no dependence on a strongly seasonal hydrologic regime and/or a specific aquatic/wetland habitat or localized moisture regime that is highly vulnerable to loss or reduction with climate change OR hydrological requirements are not likely to be significantly disrupted in major portion of the range OR species tolerates a very wide range of moisture conditions. |

(c ) **dependence on specific disturbance regime**: This factor pertains to a species' response to specific disturbance regimes such as fires, floods, severe winds, pathogen outbreaks, or similar events.

Definitions of scoring categories are:

| | |
|---|---|
| *Increase Vulnerability:* | Strongly affected by specific disturbance regime, and climate change is likely to change the frequency, severity, or extent of that disturbance regime in a way that reduces the species' distribution, abundance, or habitat quality. For example, many sagebrush-associated species in regions predicted to experience increased fire frequency/intensity would be scored here due to the anticipated deleterious effects of increased fire on their habitat. |
| *Somewhat Increase Vulnerability:* | Moderately affected by specific disturbance regime, and climate change is likely to change the frequency, severity, or extent of that disturbance regime in a way that reduces the species' distribution, abundance, or habitat quality, OR strongly affected by specific disturbance regime, and climate change is likely to change that regime in a way that causes minor disruption to the species' distribution, abundance, or habitat quality. For example, plants in a riverscour community that are strongly tied to natural erosion and deposition flood cycles, which may shift position within the channel rather than disappear as a result of climate change. |
| *Neutral:* | Little or no response to a specific disturbance regime, or climate change is unlikely to change the frequency, severity, or extent of that disturbance regime in a way that affects the range or abundance of the species. |

(d) **dependence on ice, ice-edge, or snow covered habitats**:

Definitions of scoring factors are:

| | |
|---|---|
| Greatly Increase Vulnerability: | Highly dependent (>80% of subpopulations or range) on ice- or snow-associated habitats; or found almost exclusively on or near ice or snow during at least one stage of the life cycle. |
| Increase Vulnerability: | Moderately dependent (50-80% of subpopulations or range) on ice- or snow-associated habitats; or often found most abundantly on or near ice or snow but also regularly occurs away from such areas. |
| Somewhat Increase Vulnerability: | Somewhat (10-49% of subpopulations or range) dependent on ice- or snow-associated habitats, or may respond positively to snow or ice but is not dependent on it. |
| Neutral: | Little dependence on ice- or snow-associated habitats (may be highly dependent in up to 10% of the range). |

3. **Restriction to uncommon geological features or derivatives:** This factor pertains to a species' need for a particular soil/substrate, geology, water chemistry, or specific physical feature (e.g., caves, cliffs, active sand dunes) for reproduction, feeding, growth, or otherwise existing for one or more portions of the life cycle (e.g., normal growth, shelter, reproduction, seedling establishment). It focuses on the commonness of suitable conditions for the species on the landscape, as indicated by the commonness of the features themselves combined with the degree of the species' restriction to them. Climate envelopes may shift away from the locations of fixed (within at least a 50 year timeframe) geological features or their derivatives, making species tied to these uncommon features potentially more vulnerable to habitat loss from climate change than are species that thrive under diverse conditions.

Definitions of scoring categories are:

| | |
|---|---|
| *Increase Vulnerability:* | **Highly dependent** upon, i.e., more or less endemic to (> 85% of occurrences found on) a particular highly uncommon geological feature or derivative (e.g., soil, water chemistry). Such features often have their own endemics. Examples include organisms more or less restricted to inland sand dunes or shale barrens, obligate cave-dwelling organisms, fish species that require a highly uncommon substrate particle size for their stream bottoms, such as the Colorado pikeminnow (*Ptychocheilus lucius*) that spawns only on rare cobble bars cleared of debris by strong upstream currents. |
| *Somewhat Increase Vulnerability:* | **Moderately dependent** upon a particular geological feature or derivative, i.e., (1) an indicator of but not an endemic to (65-85% of occurrences found on) the types of features described under Increase, OR (2) more or less restricted to a geological feature or derivative that is not highly uncommon within the species' range, but is not one of the dominant types. |
| *Neutral:* | Having a **clear preference** for (> 85% of occurrences found on) a certain geological feature or derivative, where the feature is among the dominant types within the species' range OR s**omewhat flexible** in dependence upon geological features or derivatives (i.e., found on a subset of the dominant substrate/water chemistry types within its range); OR **highly generalized** relative to dependence upon geological features or derivatives; species is described as a generalist and/or occurrences have been documented on widely varied substrates or water chemistries. |

4. **Reliance on specific interactions -** The primary impact of climate change on many species may occur via effects on synchrony with other species on which they depend, rather than through direct physiological stress.

   a) **Dependence on other species to generate habitat**:

Definitions of scoring categories are:

| | |
|---|---|
| Greatly Increase Vulnerability: | Required habitat generated primarily by one species. |
| Increase Vulnerability: | Required habitat generated primarily by one species, and that species is at most moderately vulnerable to climate change within the assessment area. See examples of species requiring other species to generate habitat under Greatly Increase Vulnerability. If the climate change vulnerability of the habitat-generating species is unknown, check both Greatly Increase and Increase Vulnerability. |
| Somewhat Increase Vulnerability: | Required habitat generated by only a few species. For example, burrowing owls (Athene cunicularia) depend on excavations made by relatively few species of burrowing mammals; certain plant species depend on large grazing animals to generate disturbance required for establishment and early growth. |
| Neutral: | Required habitat generated by more than a few species, or species does not require any uncommon/restricted habitats, or habitat requirements do not involve species-specific processes. |

   (b) **Dietary versatility**: applicable only to animals.

Definitions of scoring categories are:

| | |
|---|---|
| Increase Vulnerability: | Completely or almost completely (>90%) dependent on one species during any part of the year; equivalent alternatives to this single-species food resource are not readily available. . For example, Clark's nutcracker (Nucifraga columbiana) depends heavily on the seeds of whitebark pine (*Pinus albicaulis*). |

| | |
|---|---|
| Somewhat Increase Vulnerability: | Completely or almost completely (>90%) dependent during any part of the year on (1) a few species from a restricted taxonomic group or (2) a narrow guild the members of which are thought to respond similarly to climate change. For example, the larvae of various fritillary butterflies rely heavily on a few species of violets; the great purple hairstreak is dependent on a few mistletoe species. |
| Neutral: | Diet flexible; during any season species readily switches among multiple food resources according to availability; not strongly dependent on one or a few species; omnivorous, with diet including numerous species of both plants and animals. |

(c) **Pollinator versatility**: applicable only to plants.

(d) **Dependence on other species for propagule dispersal**:

Definitions for scoring categories are:

| | |
|---|---|
| Increase Vulnerability: | Completely or almost completely (roughly > 90%) dependent on a single species for propagule dispersal. For example, whitebark pine would fit here because Clark's nutcracker is the primary dispersal agent. |
| Somewhat Increase Vulnerability: | Completely or almost completely (roughly > 90%) dependent on a small number of species for propagule dispersal. |
| Neutral: | Disperses on its own (most animals) OR propagules can be dispersed by more than a few species. |

(e) **Sensitivity to pathogens or natural enemies**: pathogens and natural enemies (e.g., predators, parasitoids, or herbivores) that can increase or become more pathogenic due to climate change, or vectors of disease when they expand their distributions due to changes in climate and therefore become more harmful or influence a greater portion of the distribution of the species being evaluated.

Definitions for scoring categories are:

| | |
|---|---|
| Increase Vulnerability: | Species is negatively affected to a high degree by a pathogen or natural enemy that is likely to increase in distribution, abundance, or impact as a result of climate change. |
| Somewhat Increase Vulnerability: | Species is negatively affected to a moderate degree by a pathogen or natural enemy that is likely to increase in distribution, abundance, or impact as a result of climate change. |
| Neutral: | There is no indication that the species is currently or in the foreseeable future likely to be significantly affected by a pathogen or natural enemy that is likely to increase in distribution, abundance, or impact as a result of climate change; OR the negative impact of pathogens or natural enemies is likely to decrease with climate change. Example: A warmer/drier climate may reduce the negative impact of certain fungal pathogens that depend/thrive on relatively cold/moist conditions. |

(f) **Sensitivity to competition from native or non-native species**: To score this factor, some indication is needed that a potential competitor is favored by projected future climates.

Definitions for scoring categories are:

| | |
|---|---|
| Increase Vulnerability: | Strongly affected by a native or non-native competing species that is likely to be favored by climate change. |

| | |
|---|---|
| Somewhat Increase Vulnerability: | Moderately affected to a moderate degree by a native or nonnative competing species that is likely to be favored by climate change. |
| Neutral: | Little or no response to a native or non-native species that is likely to shift its distribution or abundance due to climate change OR climate change is likely to decrease or have no effect on the spread or abundance of a native or non-native species that negatively impacts the species. |

(g) **Forms part of an interspecific interaction not covered by C4a-f.** Here an interspecific interaction can include mutualism, parasitism, or commensalism. Refers to interactions unrelated to habitat, seedling establishment, diet, pollination, or propagule dispersal.

Definitions for scoring categories are:

| | |
|---|---|
| Increase Vulnerability: | Requires an interaction with a single other species for persistence. |
| Somewhat Increase Vulnerability: | Requires an interaction with one member of a small group of taxonomically related species for persistence. Could also include cases where specificity is not known for certain, but is suspected. Many orchids will be scored in this category because of their requirement for a specific fungal partner for germination. |
| Neutral: | Does not require an interspecific interaction, or if it does, many potential candidates for partners are available. |

5. **Genetic factors**

**(a) Measured genetic variation**: Species with less standing genetic variation will be less able to adapt because the appearance of beneficial mutations is not expected to keep pace with the rate of 21st Century climate change.

Definitions for scoring categories are:

| | |
|---|---|
| Increase Vulnerability: | Genetic variation reported as "very low" compared to findings using similar techniques on related taxa (i.e., lack of genetic variation has been identified as a conservation issue for the species). |
| Somewhat Increase Vulnerability: | Genetic variation reported as "low" compared to findings using similar techniques on related taxa. |
| Neutral: | Genetic variation reported as "average" compared to findings using similar techniques on related taxa. |

**(b) Occurrences of bottlenecks in recent evolutionary history** (use only if C5a is "unknown"): In the absence of rangewide genetic variation information, this factor can be used to infer whether reductions in species-level genetic variation that would potentially impede its adaptation to climate change may have occurred. Only species that suffered population reductions and then subsequently rebounded qualify for the Somewhat Increase or Increase Vulnerability categories.

Definitions for scoring categories are:

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|---|---|
| Increase Vulnerability: | Evidence that total population was reduced to < 250 mature individuals, to one occurrence, and/or that occupied area was reduced by >70% at some point in the past 500 years. |
| Somewhat Increase Vulnerability: | Evidence that total population was reduced to 251-1000 mature individuals, to less than 10 occurrences, and/or that occupied area was reduced by 30-70% at some point in the past 500 years. |
| Neutral: | No evidence that total population was reduced to < 1000 mature individuals and/or that occupied area was reduced by >30% at some point in the past 500 years. |

6. **Phenological response to changing seasonal temperature or precipitation dynamics**: Recent research suggests that some phylogenetic groups are declining due to lack of response to changing annual temperature dynamics (e.g., earlier onset of growing season, longer growing season).

Definitions for scoring categories are:

| | |
|---|---|
| Increase Vulnerability: | Seasonal temperature or precipitation dynamics within the species' range show detectable change, but phenological variables measured for the species show no detectable change |
| Somewhat Increase Vulnerability: | Seasonal temperature or precipitation dynamics within the species' range show detectable change, and phenological variables measured for the species show some detectable change, but the change is significantly less than that of other species in similar habitats or taxonomic groups. |
| Neutral: | Seasonal temperature or precipitation dynamics within the species' range show detectable change, and phenological variables measured for the species show detectable change which is average compared to other species in similar habitats or taxonomic groups, OR seasonal dynamics within the species' range show no detectable change. |

**<u>Section D – Documented or modeled response to climate change</u>** <u>(optional)</u>

1. **Documented response to recent climate change** (e.g., range contraction or phenology mismatch with critical resources): This factor pertains to the degree to which a species is known to have responded to recent climate change based on published accounts in the peer-reviewed literature. Time frame for the reduction or increase is 10 years or 3 generations, whichever is longer. Examples include population declines due to phenology mismatches between species and critical food or pollinator resources. Note that not all responses to climate change necessarily indicate vulnerability. Species that respond to climate change by shifting (but not contracting) their range, for example, show adaptability to climate change and should be scored as Neutral for this factor. Similarly, species that respond by changing their phenology (without a related decline in population) should also be scored as Neutral.

Definitions of scoring factors are:

| | |
|---|---|
| Greatly Increase Vulnerability: | Distribution or abundance undergoing major reduction (>70% over 10 years or three generations) believed to be associated with climate change. |
| Increase Vulnerability: | Distribution or abundance undergoing moderate reduction (30-70% over 10 years or three generations) believed to be associated with climate change. |

| | |
|---|---|
| Somewhat Increase Vulnerability: | Distribution or abundance undergoing small but measureable (10-30% over 10 years or three generations) believed to be associated with climate change. |
| Neutral: | Distribution and abundance not known to be increasing or decreasing with climate change. Includes species undergoing range shifts without significant change in distributional area or species undergoing changes in phenology but no change in net range size or population size. |

2. **Modeled future (2050) change in range or population size:** This factor can include both distribution models and population models. Models should be developed based on reasonably accurate locality data (error < 5km) using algorithms that are supported by peer-reviewed literature. Areas of obvious over-prediction should be removed from current and predicted future distributions. Projections should be based on "middle of the road" climate scenarios for the year 2050. Range size should be based on "extent of occurrence" sensu IUCN Red List. Population models should be based on known processes as described in peer-reviewed literature. If necessary, check multiple boxes to reflect variation in model output.

Definitions of scoring factors are:

| | |
|---|---|
| Greatly Increase Vulnerability: | Predicted future range disappears entirely from the assessment area OR predicted future abundance declines to zero as a result of climate change processes. |
| Increase Vulnerability: | Predicted future range represents 50-99% decrease relative to current range within the assessment area OR predicted future abundance represents 50-99% decrease associated with climate change processes. |
| Somewhat Increase Vulnerability: | Predicted future range represents a 20-50% decrease relative to current range within the assessment area OR predicted future abundance represents 20-50% decrease associated with climate change processes. |
| Neutral: | Predicted future range represents no greater than a 20% change relative to current range within the assessment area OR predicted future abundance represents increases or decreases < 20% associated with climate change processes. |

3. **Overlap of modeled future (2050) range with current range**: Distribution models of current and projected future ranges should meet standards described in the notes for D2. Overlap is calculated as the percent of the current range represented by an intersection of the predicted future and current ranges. *If the range disappears or declines > 70% within the assessment area, such that factor D2 is coded as "Greatly Increase Vulnerability," this factor should be skipped to avoid double-counting model results.*

Definitions of scoring factors are:

| | |
|---|---|
| Greatly Increase Vulnerability: | There is no overlap between the current and predicted future range within the assessment area. |
| Increase Vulnerability: | Predicted future range overlaps the current range by 30% or less within the assessment area. |

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|---|---|
| Somewhat Increase Vulnerability: | Predicted future range overlaps the current range by 30-60% within the assessment area. |
| Neutral: | Predicted future range overlaps the current range by > 60% within the assessment area. |

4. **Occurrence of protected areas in modeled future (2050) distribution**: "Protected area" refers to existing parks, refuges, wilderness areas, and other designated conservation areas that are relatively invulnerable to outright habitat destruction from human activities and that are likely to provide suitable conditions for the existence of viable populations of the species. Models of current and projected future ranges should meet standards described in the notes for D2. Modeled future distribution may refer to a single season (e.g., breeding season distribution or winter distribution) for migratory species. This factor considers ranges and protected areas within the assessment area only.

Definitions of scoring factors are:

| | |
|---|---|
| Increase Vulnerability: | < 5% of the modeled future distribution within the assessment area is encompassed by one or more protected areas. |
| Somewhat Increase Vulnerability: | 5-30% of the modeled future distribution within the assessment area is encompassed by one or more protected areas. |
| Neutral: | >30% of the modeled future distribution within the assessment area is encompassed by one or more protected areas. |

*Factors not considered* —The Index development team did not include factors that are already considered in conservation status assessments. These factors include population size, range size, and demographic factors. The goal is for the NatureServe Climate Change Vulnerability Index to complement NatureServe Conservation Status Ranks and not to partially duplicate factors. Ideally, Index values and status ranks should be used in concert to determine conservation priorities.

## Application of Climate Data

Scoring factors related to historic and predicted future climate (temperature, precipitation, and moisture availability, Factors A1, A2, C2ai, and C2bi in the CCVI) were calculated in GIS using the methods described below. Refer to the species profiles in the following section of this report for details on scoring rationale and references for all other factors.

Exposure to predicted temperature increase was calculated using species distribution data and an ensemble average of 16 CMIP3 climate prediction models averaged over the summer season (June – August) using the high (A2) CO2 emissions scenario. The high emissions scenario was used because it is most similar to current emissions. Data were obtained from Climate Wizard, and the analysis period was to the year 2050 (which is actually an average of projections for years 2040 – 2069).

The summer season was used because it was considered the most critical time period for most species.

Exposure to projected drying (integration of projected temperature and precipitation change, i.e., the Hamon AET: PET moisture metric) was calculated using the dataset created by NatureServe as part of the CCVI. Note that NatureServe based their moisture metric calculations on the same Climate Wizard dataset as above, *except* that they used the A1B carbon dioxide emissions scenario. Because the modeling methods used by NatureServe were not available, we were unable to recalculate using the A2 scenario. Thus, we used the data as provided, which we considered a reasonable alternative since the A1B and A2 scenarios predict similar changes through the mid-21st Century, the period used in this analysis. We calculated the percent of each species' range/ distribution that falls within each rating category. All calculations used the "summer" (June – August) data subset.

The *historical thermal niche* factor measures large-scale temperature variation that a species has experienced in recent historical times (i.e., the past 50 years), as approximated by mean seasonal temperature variation (difference between highest mean monthly maximum temperature and lowest mean monthly minimum temperature). It is a proxy for species' temperature tolerance at a broad scale. This factor was calculated in GIS by assessing the relationship between species' distributions and historical temperature variation data downloaded from NatureServe. Historical temperature variation was measured as the mean July high minus the mean January low, using PRISM data from 1951-2006, expressed as a single averaged value for the entire species range.

The *historical hydrological niche* factor measures large-scale precipitation variation that a species has experienced in recent historical times (i.e., the past 50 years), as approximated by mean annual precipitation variation across occupied cells within the assessment area. Ratings for this factor were calculated in GIS by overlaying the species' distributions on mean annual precipitation data (PRISM 4km annual average precipitation, in inches, 1951-2006) downloaded from Climate Wizard, and subtracting the lowest pixel value from the highest value.

## References

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# Appendix D: Acronyms

| Acronym | Definition |
|---|---|
| 1SBCT | First Stryker Brigade Combat Team |
| 2IBCT | Second Infantry Brigade Combat Team |
| 3ACR | Third Armored Cavalry |
| 3ABCT | Third Armored Brigade Combat Team |
| ACUB | Army Compatible Use Buffer |
| AGFD | Arizona Game and Fish Department |
| BBA | Breeding Bird Atlas |
| BBS | Breeding Bird Survey |
| BCR | Bird Conservancy of the Rockies |
| BCRs | Bird Conservation Regions |
| BLM | Bureau of Land Management |
| BTPD | Black-tailed Prairie Dog |
| CBC | Christmas Bird Count |
| CCVI | Climate Change Vulnerability Index |
| CITES | Convention on International Trade in Endangered Species |
| CMIP | Coupled Model Intercomparison Project |
| CNHP | Colorado Natural Heritage Program |
| CPW | Colorado Parks and Wildlife |
| CRP | Conservation Reserve Program |
| CSP | Central Shortgrass Prairie |
| DECAM | Directorate of Environmental Compliance and Management |
| DoD | Department of Defense |
| DPTM | Directorate of Plans, Training, and Mobilization |
| DPW | Directorate of Public Works |
| EA | Environmental Assessment |
| EIS | Environmental Impact Statement |
| EPA | Environmental Protection Agency |
| ES | Erosion Status |
| FC | Fort Carson |
| FD | Fire Department |
| FNA | Flora of North America |
| FONSI | Finding of No Significant Impact |
| FRCC | Fire Regime Condition Class |
| GBBO | Great Basin Bird Observatory |
| GCM | Global Circulation Model |
| GIS | Geographic Information System |
| GWOT | Global War on Terrorism |
| INRMP | Integrated Natural Resource Management Plan |
| IPCC | International Panel on Climate Change |

| Acronym | Definition |
| --- | --- |
| ITAM | Integrated Training Area Management |
| IUCN | International Union for Conservation of Nature |
| LCTA | Land Condition Trend Analysis |
| LMA | Land Management Area |
| LRAM | Land Rehabilitation and Maintenance |
| MDCP | Maneuver Damage Control Program |
| NCCS | NASA Center for Climate Simulation |
| NEPA | National Environmental Policy Act |
| NEX | NASA Earth Exchange |
| NFWPCAP | National Fish, Wildlife, and Plants Climate Adaptation Partnership |
| NMA | No Management Area |
| NMDGF | New Mexico Department of Game and Fish |
| NRCS | Natural Resources Conservation Service |
| PCMS | Piñon Canyon Maneuver Site |
| PIF | Partners in Flight |
| PMJM | Preble's Meadow Jumping Mouse |
| PSDI | Palmer Drought Severity Index |
| RCP | Representative Concentration Pathway |
| RTLA | Range and Training Land Assessment |
| SAR | Species at Risk |
| SGCN | Species of Greatest Conservation Need |
| SMA | Special Management Area |
| SRA | Sustainable Range Awareness |
| SSP | Southern Shortgrass Prairie |
| STM | State Transition Model |
| SWAP | State Wildlife Action Plan |
| TA | Training Area |
| TRI | Training Requirements Integration |
| USAFA | U.S. Air Force Academy |
| USCB | U.S. Census Bureau |
| USDA-FSA | U.S. Department of Agriculture, Farm Service Agency |
| USFS | U.F. Forest Service |
| USFWS | U.S. Fish and Wildlife Service |
| USGS | U.S. Geological Survey |
| USHUD | U.S. Department of Housing and Urban Development |
| WASH | Wildlife Aircraft Strike Hazard |
| WRCC | Western Regional Climate Center |
| WUI | Wildland Urban Interface |