National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Capulin Volcano National Monument

Natural Resource Condition Assessment

Natural Resource Report NPS/SOPN/NRR—2012/492

ON THE COVER

Cinder cone at Capulin Volcano National Monument. Robert Struthers photo.

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Executive Summary

The Natural Resource Condition Assessment (NRCA) Program, administered by National Park Service's (NPS) Water Resources Division, aims to provide documentation about current conditions of important park natural resources through a spatially explicit, multi-disciplinary synthesis of existing scientific data and knowledge. The NRCA for Capulin Volcano National Monument (NM) began in 2010 and 12 focal study natural resources were chosen for the monument's NRCA. These resources were arranged into three categories that ranged from broad to narrower contexts, including landscape, supporting (i.e., physical) environment, and biological integrity.

Capulin Volcano was proclaimed a national monument in 1916 for its near perfect volcanic cinder cone, and over the nearly 100 years since its inception, the surrounding area has maintained its rural character, which has helped the monument preserve the quality of its landscape-scale resources. The chosen resources for its landscape context included viewshed, soundscape, and night sky. Overall, these resources are in good condition. In fact out of 80 national parks monitored, Capulin Volcano NM was found to have one of the darkest night skies, primarily due to the lack of widespread development surrounding this area of northeastern New Mexico. Also, the sweeping views afforded from the top of the volcano embody the essence of New Mexico's official nickname "The Land of Enchantment" coined for the state's scenic beauty, which is very evident from within Capulin Volcano National Monument. In addition, the monument's relatively quiet soundscape affords visitors opportunities to hear sounds of nature, making a visit to the monument an overall high quality sensory experience.

Capulin Volcano's supporting physical environment condition, comprised of its air quality, geology, and groundwater resources, is more variable than its landscape-scale condition. The main geologic feature of the monument is the volcanic cinder cone-the monument's namesake. A historic road built in 1925 spirals around the cone to its top providing easy access for visitors to take in the aforementioned sweeping vistas surrounding the monument. The road's impervious surface concentrates runoff, creating erosion, sometimes severe, down the sides of the mountain resulting in a condition of significant concern for this geologic resource. The air quality at the monument is of a moderate concern, but the impact occurs from activities outside the monument's boundary, sometimes >100+ miles away. Chemicals that are emitted from factories, autos, and agricultural operations react with moisture in the environment, depositing elevated levels of nitrogen, sulfur, and ammonium on monument land. High levels of ozone also affect air quality related resources, such as vegetation, and visibility can be impacted by poor air quality as well. Moderate levels of these chemicals have been found at the monument, but stricter Environmental Protection Agency emission laws have decreased deposition levels across the United States over the past twenty years, therefore, future improvements to the monument's air quality condition seem likely. The monument's groundwater originates from the Capulin Basin, and even though groundwater depletion is a common national environmental concern, the monument's groundwater resource is currently in good condition.

Finally, the biological integrity for vegetation resources assessed included native grasslands, piñon-juniper habitats, and the rare Capulin goldenrod (*Solidago capulinensis*). Exotic plants were also addressed due to their potential threat to the native habitats but are not considered a resource. The biological integrity for wildlife included landbirds and the rare Capulin Alberta arctic butterfly (*Oeneis alberta capulinensis*). The vegetative communities are most threatened by invasive exotic plants. Some of the exotics found throughout the monument, specifically the non-native bromes, are well known to dramatically change the character of an ecosystem, including major shifts in community composition and structure. The monument's vegetation communities support its wildlife species, which depend on these habitats. These habitats become especially important when the species are already rare, such as the Capulin goldenrod and the Capulin Alberta arctic butterfly. So far, Capulin goldenrod has been found growing wild only on the volcanic slopes throughout the monument, and the rare Capulin Alberta arctic has been documented at only a few locations, including the monument's high elevation Arizona fescue (*Festuca arizonica*)-mountain muhly (*Muhlenbergia montana*) grassland. Future monitoring of these rare species will help provide additional information to determine their statuses, trends, and unique characteristics that help make Capulin Volcano National Monument a national treasure that truly is unique.

Acknowledgements

We wish to thank Jeff Albright, program lead of the Natural Resource Condition Assessment Program, Water Resources Program Center, National Park Service, who provided programmatic insight and guidance on project development and review. The authors are grateful to the staff at the National Park Service Natural Resource Stewardship and Science Directorate for their technical expertise, guidance, and reviews of their respective subjects. We are extremely grateful to all subject matter experts who provided valuable information pertaining to their respective areas of research and expertise. Their input helped to create a relevant, scientifically based document that provided new insights into the communities and processes found and occurring throughout the monument. We thank Terry Thompson for allowing us to use his spectacular panoramic photos of the monument's viewshed. Finally, we would like to express our gratitude and thanks to Capulin Volcano National Monument staff, whose input and reviews were very appreciated. To all those remaining who reviewed and commented on this report, thank you. Your contributions have increased its professional value.


NPS

Chapter 1: NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks." NRCAs also report on trends in resource condition (when possible), identify critical data gaps, and characterize a general level of confidence for study findings. The resources and indicators emphasized in a given project depend on the park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise to assess current conditions for a variety of potential study resources and indicators.

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement—not replace—traditional issue- and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

- are multi-disciplinary in scope;[1]
- employ hierarchical indicator frameworks;[2]
- identify or develop reference conditions/values for comparison against current conditions;[3]
- emphasize spatial evaluation of conditions and GIS (map) products;[4]
- summarize key findings by park areas; and[5]
- follow national NRCA guidelines and standards for study design and reporting products.

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs

NRCAs Strive to Provide…

- Credible condition reporting for a subset of important park natural resources and indicators
- Useful condition summaries by broader resource categories or topics, and by park areas

1 The breadth of natural resources and number/type of indicators evaluated will vary by park.

2 Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures ⇨ conditions for indicators ⇨ condition summaries by broader topics and park areas

3 NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management "triggers").

4 As possible and appropriate, NRCAs describe condition gradients or differences across a park for important natural resources and study indicators through a set of GIS coverages and map products.

5 In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

Important NRCA Success Factors

- Obtaining good input from park staff and other NPS subject-matter experts at critical points in the project timeline
- Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures] indicators] broader resource topics and park areas)
- Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings

do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.

Due to their modest funding, relatively quick time frame for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

The credibility of NRCA results is derived from the data, methods, and reference values used in the project work, which are designed to be appropriate for the stated purpose of the project, as well as adequately documented. For each study indicator for which current condition or trend is reported, we will identify critical data gaps and describe the level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject-matter experts at critical points during the project timeline is also important. These staff will be asked to assist with the selection of study indicators; recommend data sets, methods, and reference conditions and values; and help provide a multi-disciplinary review of draft study findings and products.

NRCAs can yield new insights about current park resource conditions but, in many cases, their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities,

DAWNELLE MALONE

A NRCA is intended to provide useful science-based information products in support of all levels of park planning.

frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is both credible and has practical uses for a variety of park decision making, planning, and partnership activities.

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities. What a NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning6 and help parks to report on government accountability measures.7 In addition, although in-depth analysis of the effects of climate change on park natural resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) Program.8 For example, NRCAs can provide current condition estimates and help establish reference conditions, or baseline values, for some of a park's vital signs monitoring indicators. They can also draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

NRCA Reporting Products…

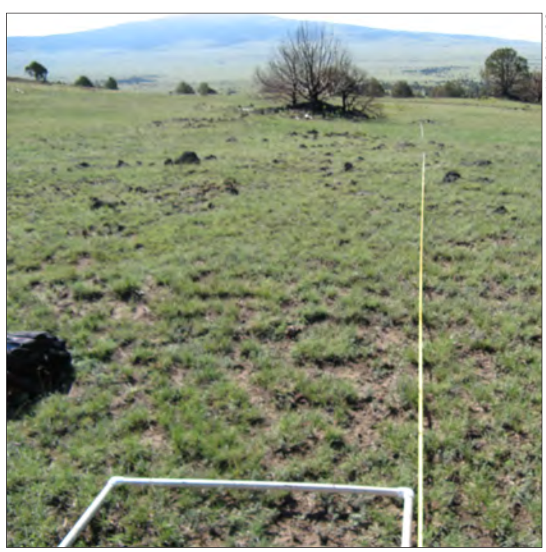
- Provide a credible, snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:
- Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations (near-term operational planning and management)
- Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values
  (longer-term strategic planning)
- Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public ("resource condition status" reporting)

Over the next several years, the NPS plans to fund a NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information on the NRCA program, visit http://www.nature.nps.gov/water/NRCondition_Assessment_Program/Index.cfm.

6 An NRCA can be useful during the development of a park's Resource Stewardship Strategy (RSS) and can also be tailored to act as a post-RSS project.

7 While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.

8 The I&M program consists of 32 networks nationwide that are implementing "vital signs" monitoring in order to assess the condition of park ecosystems and develop a stronger scientific basis for stewardship and management of natural resources across the National Park System. "Vital signs" are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.



SOPN STAFF

A NRCA uses a variety of data to assess the condition of a park's natural resources.

Capulin Volcano National Monument was established for providing "a striking example of recent extinct volcanoes… of great scientific and especially geologic interest" (Presidential Proclamation No. 1340 [39 Stat. 1792]).

Chapter 2: Introduction and Resource Setting

2.1 Introduction

2.1.1 Enabling Legislation/ Presidential Proclamation

Protection was first provided to what is now known as Capulin Volcano National Monument (NM) on January 16, 1891, when it was "…withdrawn from settlement, entry or other disposition under any of the public land laws, until such time as Congress may see fit to take action or until otherwise ordered by competent authority….". That authority came in the form of President Woodrow Wilson on August 9, 1916. He set Capulin Volcano NM aside by Presidential Proclamation No. 1340, to preserve "…a striking example of recent extinct volcanoes …" which "…is of great scientific and especially geologic interest" (Presidential Proclamation No. 1340 [39 Stat. 1792]). Public Law 87-635 passed by the 87th Congress on September 5, 1962, amended the proclamation to "…preserve the scenic and scientific integrity of Capulin Mountain National Monument…" because of the significance of Capulin Volcano. Finally, on December 31, 1987, Congress changed the Monument's name from, "Capulin Mountain National Monument" to "Capulin Volcano National Monument," by Public Law 100-225 (101 Stat. 1547) (NPS 2010).

2.1.2 Geographic Setting

Capulin Volcano NM is located in northeast New Mexico in Union County. The monument consists of one unit totaling 793 acres (321 ha) and contains three distinct management zones: park development, resource access, and natural conservation (NPS 2010). The

Figure 2.1.1-1. Capulin Volcano NM's resource access zone.

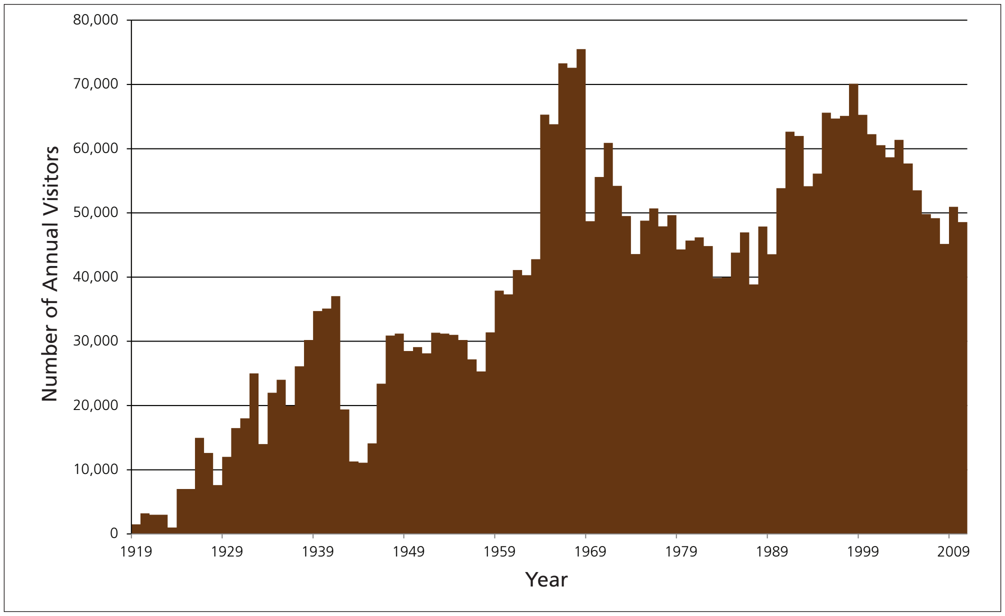


Figure 2.1.3-1. Annual number of recreational visitors to Capulin NM, 1919–2010 (NPS Public Use Statistics Office 2011).

park development zone manages the natural resources to accommodate visitor needs and access; the resource access zone allows for limited modification to natural resources for trails, interpretive media, and operational needs (Figure 2.1.1-1); and the natural conservation zone prioritizes managing the resources to maintain high integrity for wildlife and plant communities, and for restoring any damages found throughout this zone (NPS 2010).

The monument is located within the Raton-Clayton Volcanic Field, which encompasses approximately 7,500 square miles (19,425 sq. km) of northeastern New Mexico. It lies between three small villages: Capulin, Folsom, and Des Moines, New Mexico and is surrounded by privately owned cattle ranches and New Mexico State Land Office property, primarily leased to local ranchers for grazing privileges.

2.1.3 Visitation Statistics

The monument was created in 1916, and visitor data go back to 1919. The number of visitors was small in the first few years but reached at least 10,000 per year first in 1926 (Figure 2.1.3-1). The highest number of visitors recorded over the years was 75,500 in 1968. In 2009, there were 50,935 visitors recorded at the park. Visitation in 2010 was lower than in 2009, with 48,580 visitors (NPS Public Use Statistics Office 2011).

Data on visitation by month are available for 1979-2008. In every year during this 30-year period, the number of visitors peaked in June-August. In 2010, 59% of visitors came to Capulin Volcano NM during this time (Figure 2.1.3-2).

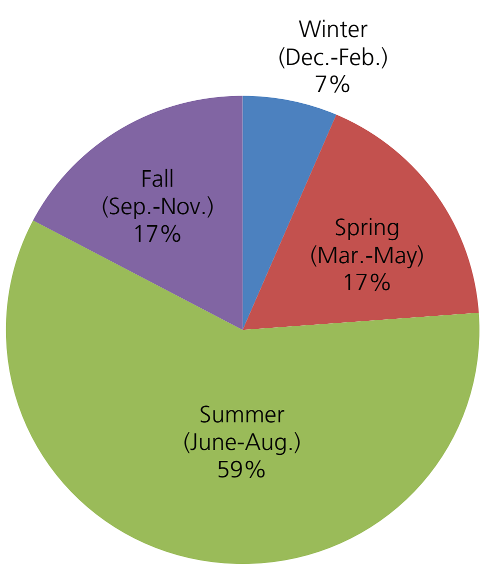


Figure 2.1.3-2. 2010 recreational visitors to Capulin Volcano NM by season (NPS Public Use Statistics Office 2011).

2.2 Natural Resources

A summary of the natural resources at Capulin Volcano NM is presented in section 2.2.1 representing information known prior to the completion of this condition assessment. A myriad of new data were gathered and compiled throughout this assessment process as a result of the meetings, consultations, and literature reviews pertaining to each natural resource topic. Therefore, some of the information presented in section 2.2.1 may have been included in subsequent chapters or omitted depending upon new findings.


ROBERT SCHANTZ


ROBERT SCHANTZ

Left: The Alberta arctic butterfly (*Oeneis alberta capulinensis*), is endemic to a few isolated windblown grassy mesas in the Raton Mesa complex in northeastern New Mexico. Right: The Spotted Towhee (*Pipilo maculatus*) is a common species observed within the monument.

2.2.1 Resource Descriptions

This section is extracted and adapted from Perkins et al. 2006.

<u>*Geology and Soils*</u>

A variety of volcanic features are located within Capulin Volcano NM boundaries. The cinder coneformed approximately 60,000 years ago, during the last active period in the Raton-Clayton volcanic field. The symmetry of the cinder cone was initially preserved because lava flowed only from vents located at the base of the volcano, but also the dry climate of northeastern New Mexico has contributed to its preservation. The surrounding lava flows cover the remainder of the monument.

Harfert (n.d.) states that the southeast and north slopes of the volcano are covered with a cinder/soil mix almost a foot deep, but it may be the presence of caliche that allows the unusual abundant growth of woody vegetation on the cinder cone. There are at least three zones of caliche layered concentrically around the cinder cone about two feet apart, extending throughout the cone except for the western breach area. Analysis of caliche samples displayed a composition of scoria, quartz or cristobalite, and a glassy black substance cemented together with calcium carbonate, containing a minor amount of clay minerals.

<u>*Hydrology*</u>

A basic water quality assessment was completed in 1999 by the NPS Water Resources Division; the only surface waters found at Capulin Volcano NM are the sewage lagoons. The groundwater is at potential risk from surrounding anthropogenic sources of contamination such as municipal wastewater discharges, ranching operations, and mining and quarrying activities, as well as acidification from atmospheric deposition.

<u>*Air quality*</u>

Capulin Volcano NM is designated as a Class II air quality area. Monitoring atmospheric wet deposition, as part of a national program, was started at Capulin Volcano NM in 1984 and continues to the present. A trend analysis of data from 1996–2005 found concentrations of ammonium, nitrate, and sulfate to be stable over that period (NPS, Air Resources Division 2010). Exposure to 80 parts per billion (ppb) ozone is infrequent, and exposure to 100 ppb is rare at the monument. Soil moisture serves to constrain the uptake of ozone at higher exposure levels, reducing the likelihood of foliar injury development (NPS 2005).

<u>*Land Use*</u>

Surrounding land use has a major impact on the aesthetic quality of visitor satisfaction. The view from the rim of the volcano is quite comprehensive and would be diminished by incompatible development near the monument. Most of the state-owned lands to the north, east, and west of the monument are leased for grazing. There are two private properties adjacent to the monument's boundary and active surface mining occurs approximately 6 miles northwest of the monument.

<u>*Wildlife*</u>

While no currently listed or category species of terrestrial mammals have been observed at Capulin Volcano NM, several species of interest have been documented. These include: Townsend's bigeared bat (*Plecotus townsendii*) (listed in New Mexico), and the Alberta arctic butterfly (*Oeneis alberta capulinensis*), endemic to a few isolated windblown grassy mesas in the Raton Mesa complex in northeastern New Mexico. The monument is one of the eastern-most locations with grassland, montane, and piñon-juniper habitat in close proximity.

Biological surveys completed in 2002 by Natural Heritage New Mexico detected 28 mammal species (39%) of the 57 animals expected at Capulin Volcano NM. During this survey, a black bear (*Ursus americanus*) spent several nights at the monument. Rangers have reported seeing pronghorn and elk just outside of park boundaries (Johnson et al. 2003). While no listed or category species were observed, Parmenter et al. (2000) note that the swift fox (New Mexico state listed species) may wander through monument land.

Two species of bats (*Myotis thysanodes* and *Myotis ciliolabrum*) found at Capulin Volcano NM had been listed as Category 2 species in 1994. When the US Fish and Wildlife Service dropped the category designation and created candidate species, the two bats were no longer classified (Parmenter et al. 2000). A third species, Townsend's big-eared bat (*Plecotus townsendii*), has been recently documented at Capulin Volcano NM (Johnson et al. 2003), and is listed by New Mexico.

Surveys conducted by Natural Heritage New Mexico in 2002, combined with observations by park staff, accounted for 56 (88.9%) of the 59 targeted bird species for Capulin Volcano NM. A total of 27 species (45.8%) were found in grassland habitats, 46 species (78%) in piñon-juniper habitats, and 15 species (25.4%) in human-impacted areas (Johnson et al. 2003). Five species currently on the Partners in Flight high priority list for the Mesa and Plains Physiographic Region were detected: canyon towhee (*Piplio fuscus*), Cassin's kingbird (*Tyrannus vociferans*), juniper titmouse (*Baeolophus griseus*), Cordilleran flycatcher (*Empidomax occidentalis*), and Virginia's warbler (*Vermivora virginiae*). A listed and category species inventory conducted in 2000 observed no qualifying birds, however loggerhead shrike (*Lanius ludovicianus*) has been previously recorded as a rare transient at the monument and adjacent prairie habitats may harbor Baird's sparrow (*Ammodramus bairdii*) during winter months (Parmenter et al. 2000). Natural Heritage New Mexico suggests that "the absence of livestock grazing on Capulin Volcano NM has apparently encouraged an increased diversity of grassland birds, especially ground- and shrub-nesting birds such as vesper sparrows (*Pooecetes gramineus*) and lark sparrows (*Chondestes grammacus*). At the same time, conifers appear to be invading several areas of grassland and potentially decreasing the area of habitat favored by grassland birds. Efforts to clear these areas, either mechanically or by prescribed fire, will help maintain grassland habitats should forest encroachment become severe" (Johnson et al. 2003). It should also be noted that playas located on adjacent land provide a major stopover for migratory birds.

Drought affected the 2002 survey period for reptiles. Only 10 species (29%) of the anticipated 34 species were found at Capulin Volcano NM. Due to the unique presence of grassland, montane, and piñon-juniper habitat in close proximity, other valuable resources of note are found in and adjacent to Capulin Volcano NM, including the eastern fence lizard and Texas horned lizard.

A list of beetle, grasshopper, and cricket species found at Capulin Volcano NM has been compiled. Although no listed or category invertebrates were found, Parmenter et al. (2000) noted a number of rarely recorded species, resulting in range extensions. They suggest that "the probability is high that undescribed new species of arthropods may be found at [Capulin Volcano NM], possibly representing endemic species [*Belotus abdominalis* (Soldier beetle), *Hyperaspis quadrivittata* (Ladybird beetle), *Sericoderus lateralis* (Minute fungus beetle),


COURTNEY MOORE

Much of Capulin Volcano NM is covered by piñon/juniper, interspersed with Ponderosa pine and/or shortgrass prairie grasslands.

Trox foveicollis (Skin beetle)]" (Parmenter et al. 2000).

<u>*Vegetation*</u>

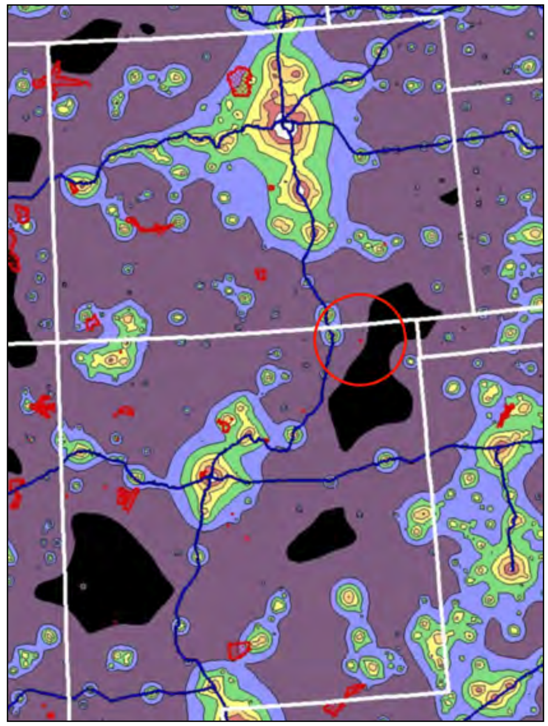
Capulin Volcano NM is located in the Arkansas Tablelands section of the Great Plains-Palouse Dry Steppe ecoregion. Three major habitat types are found within the monument's boundary: grasslands and montane woodlands of ponderosa pine and piñon-juniper forest on the cone itself. Six communities are identified and include crater grassland, disturbed grassland, piñon-juniper, lowland grassland, gamble oak, and ponderosa (Johnson et al. 2003). Three major ecological processes identified as affecting the monument are fire, grazing, and woody plant encroachment.

No threatened or endangered plants were located during the field survey conducted by Natural Heritage New Mexico in 2002. A total of 243 (92%) of the 255 potential species were documented (Johnson et al. 2003). Existing pockets of native short-grass prairie vegetation do remain within Capulin Volcano NM (Parmenter et al. 2000) even though the cinder cone has become dominated by piñon-juniper forest. Harfert (n.d.) proposes that, unlike other unforested cinder cones in the area, the dense vegetation on the volcano is due to the atypical caliche soils found interspersed on the slopes. This reduction of grasslands may negatively affect the small population of endemic Alberta arctic butterfly.

Due to the unique presence of grassland, montane, and piñon-juniper habitat in close proximity, other significant and valuable resources of note are found in and adjacent to Capulin Volcano NM, including ungrazed short-grass prairie, fringed sagewort (*Artemesia frigida*), piñon pine, gambel oak, and ponderosa pine.

<u>*Night Sky*</u>

The remote setting of Capulin Volcano NM has resulted in remarkably good night sky quality. Though numerous light domes from population centers are visible around the horizon, the majority of the night sky approaches pristine condition. Assessments were made under clear conditions across 4 nights from 2004 to 2009, and depict light pollution from Clayton, NM, Raton, NM, Trinidad, CO, and the combined glow from Pueblo-Colorado Springs-Denver, CO. Though trend data are not available, there is concern that continued urbanization along Interstate 25 would impact the delicate visual features of the night sky. A computer model of light pollution derived from satellite imagery shows Capulin Volcano NM at the edge of a dark area of NE New Mexico (Cinzano et al. 2001).



A computer model of light pollution derived from satellite imagery. Capulin Volcano NM is located within the red circle along the edge of a dark area of NE New Mexico.

2.3 Resource Issues Overview

Erosion accelerated by human disturbance and control of exotic vegetation are two critical issues facing Capulin Volcano NM. Runoff from the Volcano Road continues to cause significant erosion at and around drainage culverts. Unauthorized visitor trails inevitably cause erosion on slopes of the cinder cone from trampling of vegetation. An abandoned cinder pit located on the boundary of state land requires erosion control and revegetation. Capulin Volcano NM continues to try and acquire additional funding to address these erosion issues. An erosion mitigation plan needs to be developed for the Volcano Road at Capulin Volcano NM.

Control of exotic invasive plants is the second critical issue for Capulin Volcano NM. No federally listed noxious weeds have been found, although field bindweed (*Convolvulus arvensis*) is listed by the State of New Mexico as a Class C noxious weed (Johnson et al. 2003). These invasives cross park boundaries from adjacent lands and are introduced along roadsides

Invasive/exotic species (such as mullien [*Verbascum thapsus*] shown here) is a significant stressor to Capulin Volcano NM.

by vehicles and the use of hay for erosion control. While exotics can be found at various construction and disturbance sites throughout the monument, drastic control measures will be required along the fire road skirting the base of the cinder cone and at selected sites below the Volcano Road. Past control efforts have targeted climbing buckwheat (*Polygonum convolvulus*), common mullein (*Verbascum thapsus*), crested wheatgrass (*Agropyron cristatum*), field bindweed (*Convolvulus arvensis*), green bristlegrass (*Setaria viridis*), horehound (*Marrubium vulgare*), houndstongue (*Cynoglossum officinale*), mullein (*Verbascum thapsus*), prickly lettuce (*Lactuca serriola*), prickly Russian thistle (*Salsola tragus*), western salsify (*Tragopogon dubius*), western salsify (*Tragopogon pratensis*), white sweetclover (*Melilotus alba*), yellow bristlegrass (*Setaria pumila*), and yellow sweetclover (*Melilotus officinalis*) for removal.

An inventory of all vascular plants, including those introduced to the monument, was completed by Natural Heritage New Mexico in 2002. They noted that 22 introduced plant species had been previously detected at Capulin Volcano NM. Slim amaranth (*Amaranthus hybridus*) and prickly Russian thistle (*Salsola tragus*) were identified as the two most widespread introduced species within the monument's boundary. Eight species on the final plant list (*Bromus tectorum, Cichorium intybus, Chenopodium album, Cynoglossum officinale, Descurainia sophia, Kochia scoparia, Salsola tragus*, and *Verbascum thapsus*) are listed as noxious weeds by other states (Johnson et al. 2003). Inventory and mapping of noxious weeds has been completed by the Great Plains Cooperative Ecosystem Studies Unit. Japanese brome (*Bromus japonicus*) and downy brome (*Bromus tectorum*) were identified as the most serious threats due to their difficulty to control. It is determined that these annual bromes inhabit 45 acres (18.1 ha). A medium urgency designation has been given to common horehound (*Marrubium vulgare*) due to its invasive potential, although it currently has low occurrence and small populations at Capulin Volcano NM (Narumalani et al. 2004). Eradication measures will continue as funding requests are met. Local hay sources are being screened for the presence of noxious weeds in an effort to limit further introduction. Piñon pine and juniper are now invading the grassland in the areas on the volcano where the Alberta arctic butterfly was discovered. Recent surveys have failed to document the butterfly's presence, raising concern about the impact of this woody encroachment.

An assessment of the condition of the prairie and recommendations given for management were completed by Stubbendieck (1986). Parmenter et al. (2000) stated that the grass habitats at Capulin Volcano NM "appear to be well preserved and protected." Maintaining these grassland habitats will be vital for the Alberta arctic butterfly and other dependant plant and animal species. At present, an estimated 100 acres (40 ha) are in need of restoration for a number of reasons—utility disturbance, roads, nonnative invasives, woody encroachment, and exclusion of wild fire. The exclusion of grazing for several decades may also be impacting the health of these grasslands. A native plant propagation project was approved and completed in 2009. The project included a partnership with the Natural Resources Conservation Service Plant Materials Center in Las Lunas, New Mexico.

The frequency of fire within the Capulin area began to decrease as cattle ranching was introduced in the mid 1800s. The effects of the suppression are unknown and many have debated whether the piñon-juniper trees have encroached upon the grasslands and the cinder cone itself due to the lack of fire. Capulin

Volcano NM developed a Fire Management Plan (FMP) in 2004, which prescribed vegetation thinning treatments and fire throughout the entire monument with the goal of returning the areas currently occupied by shrubs and trees back to a savanna-like community. The FMP treatments were placed on hold in early 2009 to complete this condition assessment, although a contract had already been awarded for the last thinning treatment on the cone. Unmanaged diseases and pests both to plants and wildlife are an ongoing threat in any protected area. Current monitoring continues at Capulin Volcano NM for the gypsy moth (*Lymantria dispar*).

There are several issues pertaining to human use that need to be addressed at Capulin Volcano NM. Park visitors can have a negative impact on the natural resources of the monument. As discussed earlier, unauthorized trails expose the cinder cone to accelerated erosion. The Volcano Road, used by visitors to access the volcano crater, also causes erosion and allows for the introduction of invasive plants to the slopes of the cinder cone.

Changes associated with the land use surrounding the park can affect air, water, scenic quality and can affect biological communities through fragmentation and isolation. The views from Capulin Volcano NM are one of the most important features and resources. Development in a variety of forms will not only affect the viewshed but further diminish the night sky resource through the addition of all-night illumination. In 2003, the National Park Service's Night Sky Program scientists monitored this important resource.

2.4 Resource Stewardship

2.4.1 Management Directives and Planning Guidance

In addition to NPS staff recommendations and the monument's 2010 General Management Plan, which outlined the purpose of the monument and its significant resources and values, the Washington (WASO) level programs guided the selection of key natural resources for this condition assessment. This included the Southern Plains Inventory and Monitoring Network (SOPN) Program, Air Resources Division for air quality, and the Natural Sounds and Night Skies Program for the soundscape and night sky sections. In addition, NPScape data, developed by the I&M's Natural Resource Program Center, were used in the viewshed analysis.

SOPN Program

In an effort to improve overall park management through expanded use of scientific knowledge, the Inventory & Monitoring (I&M) Program was established to collect, organize, and provide natural resource data as well as information derived from data through analysis, synthesis, and modeling (NPS 2011). The primary goals of the I&M Program are to:

- inventory the natural resources under NPS stewardship to determine their nature and status;
- monitor park ecosystems to better understand their dynamic nature and condition and to provide reference points for comparisons with other altered environments;
- establish natural resource inventory and monitoring as a standard practice throughout the National Park System that transcends traditional program, activity, and funding boundaries;
- integrate natural resource inventory and monitoring information into NPS planning, management, and decision making; and
- share NPS accomplishments and information with other natural resource organizations and form partnerships for attaining common goals and objectives (NPS 2011).

To facilitate this effort, 270 parks with significant natural resources were organized into 32 regional networks. Capulin Volcano NM is part of the SOPN, which also includes ten additional parks. Through a rigorous multi-year, interdisciplinary scoping process, each network selected a number of important physical, chemical, and/or biological elements and processes for long-term monitoring. These ecosystem elements and processes are referred to as 'vital signs', and their respective monitoring programs are intended to provide high-quality, long-term information on the status and trends of those resources. For the SOPN, notable core vital signs were identified. Inventories on vascular plants, mammals, reptiles, birds, and geologic resources have been completed and monitoring on birds and grassland community is currently underway

Resource Stewardship Strategy

Each national park is directed to develop a Resource Stewardship Strategy (RSS) as part of the park management planning process. Indicators of resource condition, both natural and cultural, are selected by the park. After each indicator is chosen, a target value is determined and the current condition is compared to the desired condition. The completion of this NRCA is the first step in completing a RSS for the monument. Management plans will then be developed to outline actions to be taken over the next 15 to 20 years that will help achieve or maintain the desired condition(s) for each indicator. The RSS will be a multi-disciplinary effort, incorporating a variety of information from different sources.

2.4.2 Status of Supporting Science

Available data and reports varied significantly depending upon the resource topic. The existing data for each indicator that were used to assess condition or to develop reference condition are described in each indicator summary in chapter four. Part of the SOPN's mission is to collect, manage, analyze, and report long-term ecological data to support each park in determining the status, condition, and trend of important natural resources (USDI NPS 2008). In addition to data from the SOPN Program and research by other scientists and programs, subject matter experts provided significant information pertaining to soils, piñon-juniper ecology, and grassland ecology. Washington level programs including night sky, soundscape, and air quality also provided a wealth of information for this NRCA.

2.5 Literature Cited

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Piñon-juniper field meeting at Capulin Volcano NM.

Chapter 3: Study Scoping and Design

This NRCA is a collaborative project between the Capulin Volcano NM staff and the SOPN, both of the NPS. Stakeholders in this project include the monument's resource management staff and SOPN staff. The purpose of the condition assessment is to provide a "snapshot-in-time" evaluation of the condition of a select set of monument natural resources that were identified and agreed upon by the project team. Project findings will aid monument staff in the following objectives:

- Develop near-term management priorities.
- Engage in watershed or landscape scale partnership and education efforts.
- Conduct park planning (e.g., compliance, Resource Stewardship Strategy, resource management plans).

The approach we used to select natural resources was to assess the fundamental and important values of the monument as identified in its recent General Management Plan (GMP) (2010) as well as to consider broader natural resources as identified by the NPS' Natural Resource Program Center. The resources assessed are limited to natural-based topics, but cultural resources were also taken into consideration within the context of the chosen natural resources.

Due to the relatively small size of the monument (793 acres / 321 hectares), the entire monument was treated as one unit, however, the management zones, which are identified in the GMP were considered within the context of each resource topic as deemed necessary.

3.1 Preliminary scoping

The selection of resources to assess resulted from a series of meetings and subsequent discussions. These meetings and discussions focused on:

1. Confirming the purpose of the monument and its related significance statements and related values.
2. Identifying important natural and cultural resources and concerns for each topic.
3. Identifying data sources and gaps for each resource topic.

Certain constraints were placed on this NRCA, including the following:

- Condition assessments are conducted using existing data and information.
- Identification of data needs and gaps is driven by the project framework categories.
- A preliminary study framework was

developed as a result of the meetings and discussions, which listed the chosen resources and the degree of assessment (e.g., full or partial) based upon existing data and information.

- Specific project expectations and outcomes included the following:
- For key natural resource components, consolidate available park data, reports, and spatial information from appropriate sources including: Monument resource staff, scientific literature, NatureBib, NPSpecies, Inventory and Monitoring data, and available third-party sources. Enlist the help of subject matter experts for each resource topic when appropriate and feasible (refer to Appendix A for subject matter expert list).
- Define an appropriate description of reference condition for each of the key natural resource components and indicators so statements of current condition can be developed for the NRCA report.
- Where applicable, develop GIS products and graphic illustrations that provide spatial representation of resource data, ecological processes, resource stressors, trends, or other valuable information that can be better interpreted visually.
- Conduct analysis of specific existing data sets to develop descriptive statistics about key natural resource indicators.
- Discuss the issue of key natural resource indicators that are not contained within the monument or controlled directly by monument management activities (e.g., viewshed condition). There are important stressors that impact key natural resource components in the monument but are not under NPS jurisdiction.

Monument natural resource staff participated in project development, planning, and writing. Additional monument staff reviewed interim and final products and participated in assessment meetings. Monument staff, I&M staff, and additional writer/editors data mined information for their assigned focal study resources. For a complete list of team members, please refer to Appendix A.

3.2 Study Design

3.2.1 Indicator Framework, Focal Study Resources and Indicators

The Monument's NRCA utilizes an assessment framework adapted from "The State of the Nation's Ecosystems 2008: Measuring the Lands, Waters, and Living Resources of the United States", by the H. John Heinz III Center for Science, Economics and the Environment. This framework was endorsed by the National NRCA Program as an appropriate framework for listing resource components, indicators/measures, and resource conditions.

Each NRCA project represents a unique assessment of key natural resource components that are important to the specific park that is being assessed. As a result, the project framework is developed by the project participants to reflect the key resources of the park. For the purpose of this NRCA, 12 key monument resources were identified and are listed under the "Resource" column in Table 3.2.1-1. This list of focal study resources is not all inclusive of every natural resource at the monument, but it includes natural resources and processes that were of greatest concern at the time of this assessment.

Reference conditions were identified with the intent of providing a benchmark to which the current condition of each indicator/measure could be compared. Generally, this condition represents a historical reference in which human activity and disturbance were not major drivers of population and ecological processes. Attempts were made to utilize existing research and documentation to identify reference conditions; however, many of the indicators lack a quantifiable reference condition according to literature and data reviewed for this project. When a specific reference condition for the monument was unknown, an attempt was made to include state and federal standards or data from other relevant locations in order to provide some context for interpreting condition.

3.2.2 Reporting Areas

Since the monument is relatively small, the reporting area was one unit and encompassed the entire acreage within the monument's boundary. Due to the nature of some of the focal study resources, areas outside of the monument's boundary were assessed to determine overall condition within the monument (e.g., viewshed, air quality).

Table 3.2.1-1. Final Capulin Volcano National Monument Natural Resource Condition Assessment framework

Resource	Assessment Level	Indicators and Measures
		I. Landscape Condition Context
Viewshed	Full Assessment	Housing density Road density Proportion of the viewshed comprised of natural vs. man-made features Conspicuousness of man-made feature characteristics
Night Sky	Full Assessment	Bortle Dark-Sky Scale Limiting magnitude Sky brightness - Maximum Sky Brightness - Minimum Sky Brightness - Integrated Whole Sky - Integrated Sky Above 20 °
Soundscape	Limited Assessment	Noise Level Temporal Patterns of Noise
		II. Supporting Environment
Air Quality	Full Assessment	Visibility haze index Level of ozone Atmospheric wet deposition in total N and total S
Geology	Full Assessment	Presence/absence of accelerated erosion Severity of erosion
Groundwater	Full Assessment	Change in Groundwater Level
		III. Biological Integrity
		Vegetation
Piñon-Juniper	Full Assessment	Are the species present and their distribution consistent with supply and demand of light, water, nutrients, and growing space and, within their natural range of variability? Are stands densities within their range of natural variability for their growing conditions? Are the age class distributions of piñons and junipers consistent with the expected range of variability for this site/ecosystem type? Do the trees and understory plants appear vigorous and healthy for this site/ecosystem type? Are ecological processes (e.g., fire) operating within the natural range of variation? Are the current levels of insects and/or disease within the normal range for this ecosystem type?
Grasslands	Full Assessment	Rills Water flow patterns Pedestals and/or terracettes Bare ground Gullies Wind-scoured, blowout, and/or depositional areas Litter movement Soil surface resistance to erosion Soil surface loss or degradation Compaction layer (below soil surface) Plant mortality/decadence Invasive plants Species composition
Exotic Plants	Full Assessment	Significance of impact Feasibility of control Proportion of high priority blocks infested Proportion of interior plots infested Distribution of high priority species
Capulin Goldenrod (*Solidago capulinensis*)	Limited Assessment	Presence/absence of Capulin Goldenrod

Table 3.2.1-1. Final Capulin Volcano National Monument Natural Resource Condition Assessment framework (continued)

Resource	Assessment Level	Indicators and Measures
Wildlife		
Landbirds	Full Assessment	Species Occurrence - Temporal Context - Spatial Context - Conservation Context
Capulin Alberta Arctic Butterfly	Limited Assessment	Presence/absence of butterfly Presence/absence (and quality) of butterfly habitat Distance from Capulin Volcano NM to the closest known colonies of the subspecies

3.2.3 General Approach and Methods

This study involved reviewing existing literature and data for each of the resources listed, and, where appropriate, analyzing the data to provide summaries or to create new spatial representations. After gathering data regarding current condition of indicators and measures, a qualitative statement was developed comparing the current condition(s) at the monument to the reference condition(s) when possible.

Data Mining

Data and literature were found in multiple forms: NPS reports and monitoring plans (park, regional, and national level), other reports from various state and federal agencies, published and unpublished research documents, non-governmental organization reports, databases, and tabular data. Spatial data were provided by the monument, the SOPN, and by the Natural Resource Program Center. Data and literature acquired throughout the data mining process were inventoried and analyzed for thoroughness, relevancy, and quality pertaining to the indicators identified in the project framework. All reasonably accessible and relevant data were used to conduct this assessment.

Subject Matter Experts

Several researchers and subject matter experts were consulted while developing this assessment. Consultations ranged from on-site visits to personal communication, and reviews of resource sections. A full list of the team of experts can be found in Appendix A.

Data Analyses and Development

Data analysis and development/writing tasks were performed for specific resources based on the data mining process and recommendations provided by NPS staff. Data analyses and development were resource specific, and the methodology for individual analyses can be found within each section of chapter four.

Geographic Information System (GIS) technology was utilized to graphically depict the status and distribution of considered resources when possible.

Final Assessments

Final assessments were made by incorporating comments provided by subject matter experts, reviewers, and monument staff during the review of draft chapters. Additionally, continued contact with monument staff to address questions and comments pertaining to each resource topic was maintained throughout the data analysis and report writing phase to ensure accurate representation of staff knowledge. The final assessments represent the most relevant and timely data available for each resource topic based on the recommendations and insight provided by monument staff, researchers, subject matter experts, and assessment writers.

Indicator/Measures Assessment Format

Indicator assessments are presented in a standard format and their structure, by major heading, is as follows:

The condition/trend graphic provides a visual representation of the condition and trend of the indicator(s)/measure(s). This graphic is intended to give readers a quick interpretation of the authors' assessments of condition. The written statements of condition, located under the "*Condition and Trend*" heading, provides a more in-depth description of an indicator/measure(s)' condition. Figure 3.2.3-1 shows the condition/trend scorecard used to describe each indicator/measure.

Circle colors provide indication of condition or concern. Red circles signify that a resource is of significant concern to monument management;

yellow circles signify that a resource is of moderate concern to monument management; blue circles denote that an indicator is currently in good condition. Gray circles signify that there is insufficient information to make a statement about concern or condition of the indicator, therefore unknown.

Arrows inside of the circles signify the trend of the indicator/measure's condition. Upward pointing arrows signify that the indicator is improving; right pointing arrows signify that the indicator's condition is currently stable; downward pointing arrows indicate that the indicator's condition is worsening. Gray triple arrows specify that the trend of the indicator's condition is currently unknown. Figure 3.2.3-2 is an example of a final condition graphic used in the indicator assessments.

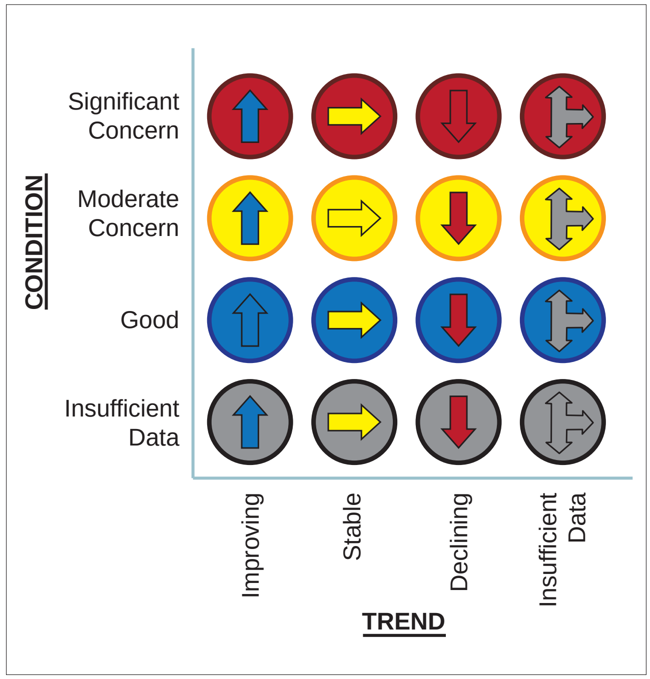

Figure 3.2.3-1. Condition and trend "scorecard" used in the Capulin Volcano NM NRCA.

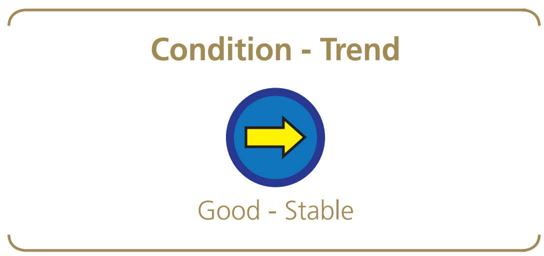

Figure 3.2.3-2. An example of a condition and trend graphic used in NRCAs.

Background and Importance

This section provides information regarding the relevance of the resource to the monument. This section also explains the characteristics of the resource that help the reader understand subsequent sections of the document.

Data and Methods

This section describes the existing datasets used for evaluating the indicators/measures. Methods used for processing or evaluating the data are also discussed where applicable. The indicators/measures are listed in this section as well, describing how we measured or qualitatively assessed the natural resource topic.

Reference Conditions

This section explains the reference conditions that were used to evaluate the current condition for each indicator. Additionally, explanations of available data and literature that describe the reference conditions are located in this section.

Condition and Trend

This section provides a summary of the condition and trend of the indicator/measure at the monument based on available literature, data, and expert opinions. This section highlights the key elements used in defining the condition and trend designation, represented by the condition/trend graphic, located at the beginning of each resource topic.

The level of confidence and key uncertainties are also included in the condition and trend section. This provides a summary of the unknown information and uncertainties due to lack of data, literature, and expert opinion, as well as our level of confidence about the presented information.

Sources of Expertise

Individuals who were consulted for the focal study resources are listed in this section. A short paragraph describing their background is also included.

Literature Cited

This section lists all of the referenced sources. A DVD is included in the final report with copies of all literature cited unless the citation was from a book. When possible, links to websites are also included.

3.3 Literature Cited

National Park Service. 2010. Capulin Volcano National Monument general management plan/environmental assessment. Denver, Colorado: Intermountain Regional Office. 105pp.

The H. John Heinz III Center for Science, Economics and the Environment. 2008. The State of the Nation's Ecosystems 2008: Measuring the Lands, Waters, and Living Resources of the United States. Washington, D.C.

Chapter 4: Natural Resource Conditions

In this chapter, we present the background and importance, methods, and condition assessment for each focal study resource that we considered for Capulin Volcano NM. In many cases, we did not have a quantitative measure for the indicators but tried to present meaningful categorical measures qualitatively that reflect the condition. We also explained why each indicator was chosen and what we considered as a good, moderate or significant concern reference condition for each indicator. We provide a summary of all focal study resource indicators and their page numbers for explanations of our methods and natural resource conditions in Table 4.1.

Table 4.1. Page numbers where the description, methods, and condition for each indicator are presented within this chapter.

Resource	Indicator	Description/ Methods	Condition
I. Landscape Condition Context			
Viewshed	Housing density	25	36
	Road density	25	37
	Proportion of the viewshed comprised of natural vs. man-made features	25	37
	Conspicuousness of man-made feature characteristics	25	37
Night Sky	Bortle Dark-Sky Scale	46	49
	Limiting magnitude	46	49
	Sky brightness (Maximum Sky Brightness, Minimum Sky Brightness, Integrated Whole Sky, Integrated Sky Above 20°)	47	50
Soundscape	Noise Level	56	57
	Temporal Patterns of Noise	56	60
Air Quality	Visibility haze index	67	69
	Level of ozone	67	69
	Atmospheric wet deposition in total N and total S	67	70
Geology	Presence/absence of accelerated erosion	82	83
	Severity of erosion	82	83
Groundwater	Change in Groundwater Level	92	92
III. Biological Integrity			
Vegetation			
Piñon-Juniper	Are the species present and their distribution consistent with supply and demand of light, water, nutrients, and growing space and, within their natural range of variability?	99	114
	Are stands densities within their range of natural variability for their growing conditions?	99	114
	Are the age class distributions of piñons and junipers consistent with the expected range of variability for this site/ecosystem type?	99	116
	Do the trees and understory plants appear vigorous and healthy for this site/ecosystem type?	99	116
	Are ecological processes (e.g., fire) operating within the natural range of variation?	99	116
	Are the current levels of insects and/or disease within the normal range for this ecosystem type?	99	118

Table 4.1. Page numbers where the description, methods, and condition for each indicator are presented within this chapter (cont.).

Resource	Indicator	Description/ Methods	Condition
Vegetation (cont).			
Grasslands	Rills	129	133
	Water flow patterns	129	133
	Pedestals and/or terracettes	129	133
	Bare ground	129	133
	Gullies	129	133
	Wind-scoured, blowout, and/or depositional areas	129	133
	Litter movement	129	133
	Soil surface resistance to erosion	129	133
	Soil surface loss or degradation	129	133
	Compaction layer (below soil surface)	129	133
	Plant mortality/decadence	129	134
	Invasive plants	129	134
	Species composition	129	134
Exotic Plants	Significance of impact	142	145
	Feasibility of control	142	146
	Proportion of high priority blocks infested	143	147
	Proportion of interior plots infested	143	147
	Distribution of high priority species	144	147
Capulin Goldenrod (*Solidago capulinensis*)	Presence/absence of Capulin Goldenrod	156	157
Wildlife			
Landbirds	Species Occurrence - Temporal Context	160	168
	Species Occurrence - Spatial Context	161	169
	Species Occurrence - Conservation Context	161	176
Capulin Alberta Arctic Butterfly	Presence/absence of butterfly	184	187
	Presence/absence (and quality) of butterfly habitat	186	188
	Distance from Capulin Volcano NM to the closest known colonies of the subspecies	186	189

4.1 Viewshed

Indicators/Measures

- Housing density
- Road density
- Proportion of the viewshed comprised of natural vs. man-made features
- Conspicuousness of man-made feature characteristics

Condition – Trend

Good – Stable

4.1.1 Background and Importance

The conservation of scenery is established in the NPS Organic Act, ("…to conserve the scenery and the wildlife therein…") and reaffirmed by the General Authorities Act, as amended, Management Policies (Section 1.4.6, and 4.0) (Johnson et al. 2008).

One of Capulin Volcano NM's primary purposes is to "preserve the scientific, educational, and *scenic* values and to provide for the understanding and enjoyment thereof by the public" (NPS 2010). Additionally, one of four significance statements identified in the monument's General Management Plan states, "The *dramatic view* from the top of the volcano provides people with an exceptional opportunity to connect with and understand the geological and cultural landscape." (NPS 2010). This emphasis on *scenic* and *view* establishes "an *unobstructed view* of the Raton-Clayton Volcanic Field" as a fundamental resource and value for the monument (NPS 2010).

During a 2003 visitor study at the monument, 253 visitor groups identified their primary activity as scenery/sightseeing (94%). In addition, those visitor groups rated scenic views as the most important resource within the monument (NPS 2003).

Visitors have a unique opportunity to view the surrounding landscape scenery, within and adjacent to the monument, by driving the road that leads to the top of the volcano, rising 304 meters above the surrounding High Plains (Figure 4.1.1-1). The monument's primary interpretive themes are showcased within the surrounding landscape, which include a geologically diverse volcanic field, a meeting place between the shortgrass prairie and the Rocky Mountains, and a dramatic, yet accessible volcano (NPS 2010). Viewing these themes within the context and vast scale in which they exist helps to foster the understanding and significance of the monument's purpose.

4.1.2 Data and Methods

The scenic view from the top of the volcano is explicitly expressed as a significant purpose, statement, resource, and value of the monument, even though the majority of its

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Figure 4.1.1-1. A sweeping view from the top of Capulin Volcano, with the Sangre de Cristo Mountain Range in the background.

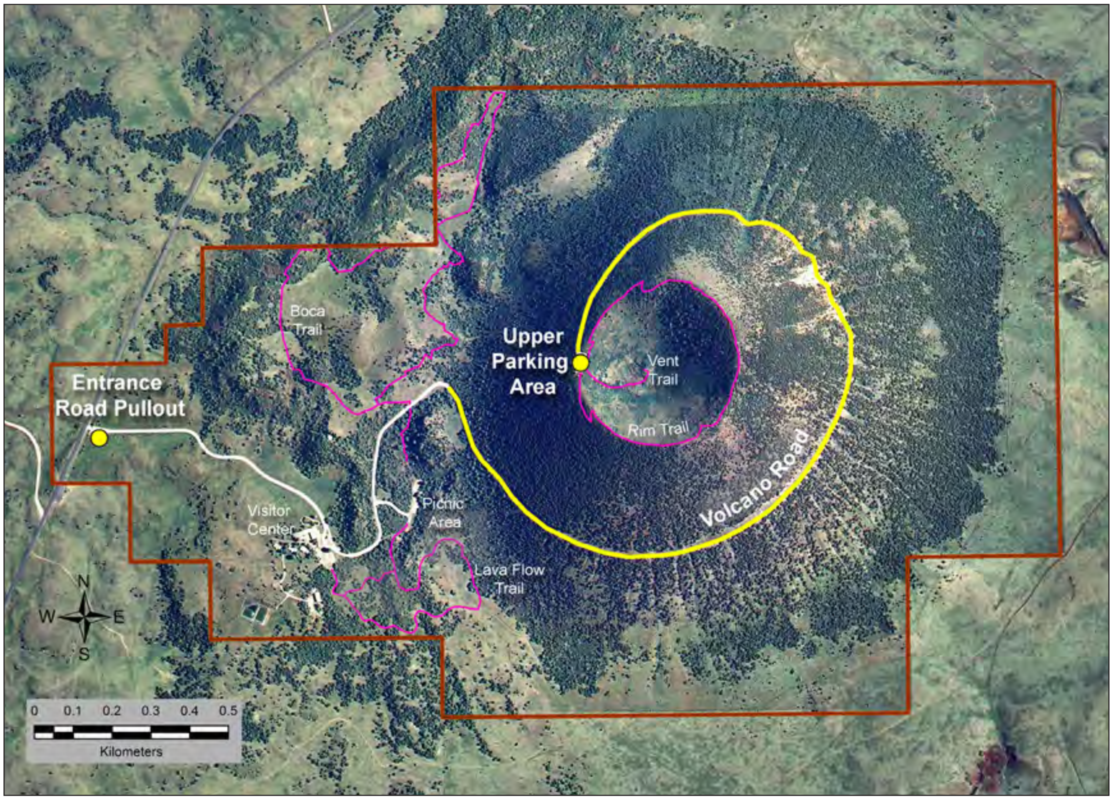

Figure 4.1.2-1. The viewshed vantage point locations, depicted with yellow circles and line, (entrance road pullout, upper parking area, and Volcano Road) used for our viewshed analyses.

scenery, as viewed from the pull-outs, parking lots, and Volcano Road, is located on lands that are not administered by the monument. Johnson et al. (2008) refer to such lands as a "borrowed landscape". These "borrowed landscapes" comprise the majority of the monument's viewshed, which is the visible area seen from a particular vantage point and will obviously vary depending on the location from which an area is observed. Consequently, the first step in our viewshed condition assessment was to determine the most appropriate vantage point(s) within the monument to use for our viewshed analyses.

Viewshed Vantage Points

The viewsheds that are probably the most frequently seen from within the monument are located where visitors are most likely to stop because of the sweeping vistas that these locations have to offer. There are a total of three sites/areas that we determined were appropriate viewshed vantage locations for this assessment. The first, and probably most important, is the parking area near the top of the cinder cone (Figure 4.1.2-1). Visitors drive Volcano Road specifically to see the volcanic features and sweeping views of the surrounding area. Nearly all visitors who take Volcano Road stop at the upper parking lot at the road's terminal point. From this location, visitors may hike the short trail into the vent of the cinder cone, or they may hike the Rim Trail that surrounds the vent, reaching the highest location within the monument of 2,494 meters. Regardless of whether visitors hike either of these two trails, almost all visitors take the time to view the surrounding landscape from the parking area unless there is inclement weather.

The second site we chose as a viewshed vantage point is where visitors stop at a pullout located at the entrance to the monument (Figure 4.1.2-1). This site is situated on an elevated bench with views of the surrounding landscape to the south and southwest, and also showcases the cinder cone if one looks east. Although the viewshed from this site is more limited than from the upper parking area, many visitors stop to take pictures of the entrance sign and take in their first views from within the monument.

There are other sites where visitors tend to stop (e.g., the visitor center and the picnic area along Volcano Road), but these areas do not offer the sweeping views seen from the upper parking lot and entrance road pullout.

The third viewshed area we considered is along Volcano Road (Figure 4.1.2-1). As visitors drive Volcano Road, they experience 360 degree views of the surrounding landscape. There is only one pullout along the road, with very limited capacity for vehicles to stop. Because there is only one small pullout on the road, the views most visitors experience from Volcano Road continuously change. Therefore, a series of several vantage points were grouped together to assess the viewshed from Volcano Road. The same spectacular views seen while driving along Volcano Road can also be enjoyed more leisurely from the Rim Trail, but far fewer visitors hike this trail than drive the road.

Indicators

Two categories of indicators were assessed: one that included relatively general Geographic Information Systems (GIS)-based indicators (housing and road densities), and one that focused more specifically on man-made features on the landscape (proportion of the viewshed comprised of man-made versus natural features and the conspicuousness of man-made feature characteristics).

GIS-based Indicators

Indicators/Measures

- Housing density
- Road density

For the GIS-based indicators, we used the viewshed analyses (Figures 4.1.2-2, -3, -4, -5). to depict the total visible area from each of the three vantage points previously described, taking into account changes in elevation and other obstructions such as tree, mountain, or building heights. These analyses were conducted by Cheryl McIntyre, an ecologist for the Sonoran Institute.

Vantage points were created by modifying existing GIS data to perform the viewshed analyses (refer to Appendix B for a more detailed account of the data manipulation process).

After the viewshed analyses were completed, housing and road density datasets were modified to depict the 2010 densities around the monument. These datasets were created by NPS Natural Resource Program Center by compiling and analyzing landscape-scale U.S. Census Bureau data that linked measurable attributes of landscape (i.e., road density, population and housing density, etc.) to resources within natural resource based parks, resulting in the NPScape dataset (Budde et al. 2009 and Gross et al. 2009).

The housing density dataset included the number and distribution of housing units within and adjacent to the monument. Similarly, the road density dataset included the type and extent of existing transportation networks, which provided the necessary information to assess the road density in the area surrounding the monument.

Feature-based Indicators

Indicators/Measures

- Proportion of the viewshed comprised of natural vs. man-made features

The other indicator category focused on man-made features on the landscape, both their proportion to natural features and their characteristics.

We recognize that how a given visitor perceives man-made features within a viewshed is highly subjective, and that there is no way for us to be completely objective in how we define or measure their perceptions. However, research has shown that there are certain landscape types and characteristics that people tend to prefer over others. In general, there is a wealth of research demonstrating that people tend to prefer natural over man-modified landscapes (Zube et al. 1982; Kaplan et al. 1989; Sheppard 2001; Kearney et al. 2008; Han 2010). This is probably especially true of our national park visitors. Thus, we identified the third viewshed condition indicator as the proportion of the viewshed that is comprised of natural versus man-made features.

We recognize that much of the landscape surrounding Capulin Volcano NM has been altered by various land uses, however, we focused primarily on what appears to be a natural or rural setting versus whether there is an obvious man-made component (e.g., roads, industries, powerlines). Man-made features such as these have been shown to have a negative affect on perceptions of visual quality (Arriaza et al. 2004).

We assessed the proportion of a given viewshed occupied by man-made features versus natural features by overlaying a grid, using a random start point, on photographs of the visible landscape (Figure 4.1.2-6). If a given grid

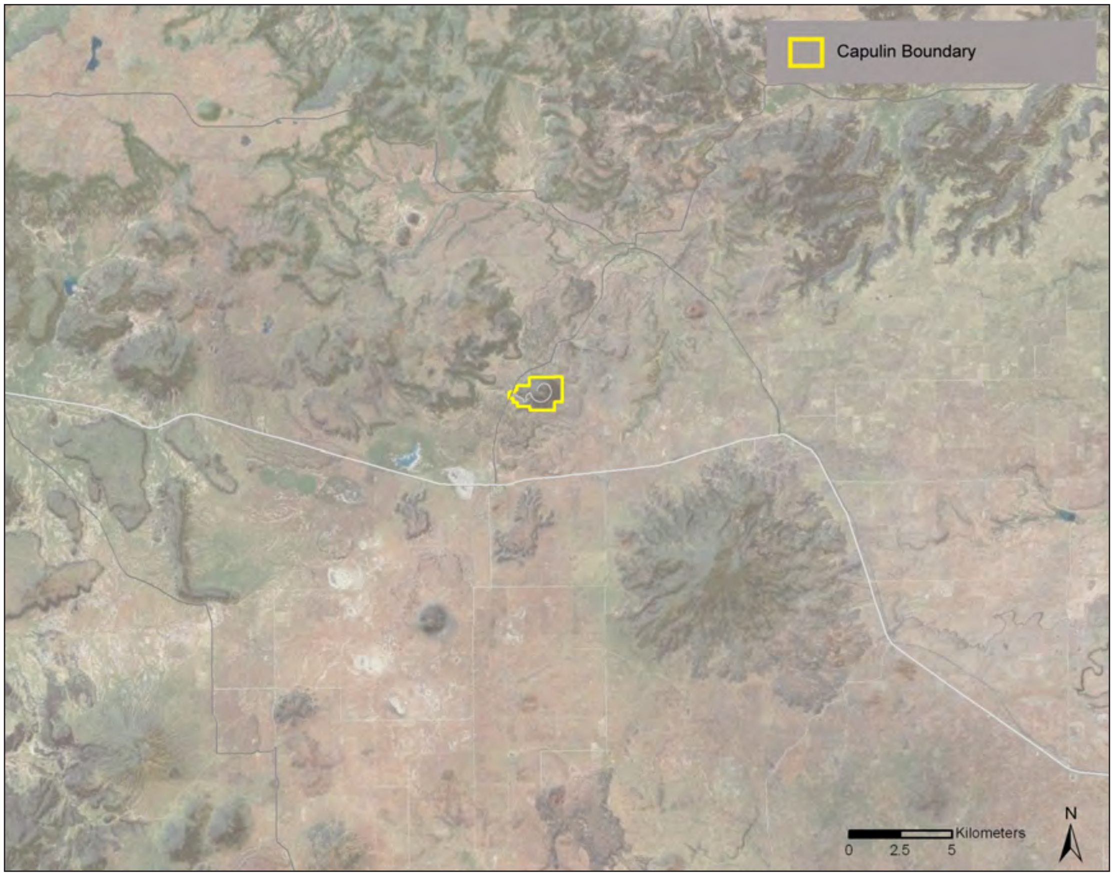

Figure 4.1.2-2. The region included in our GIS-based viewshed analysis of Capulin Volcano NM.

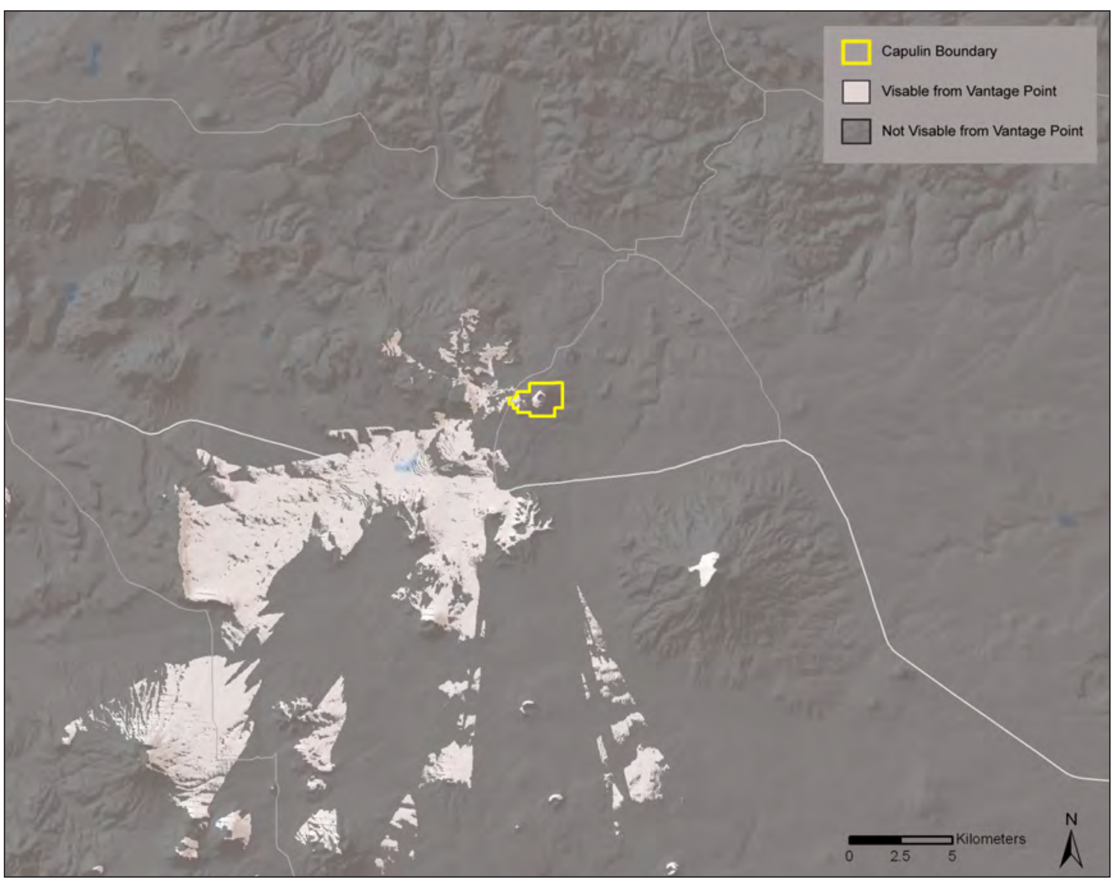

Figure 4.1.2-3. The viewshed from the entrance road pullout vantage point.

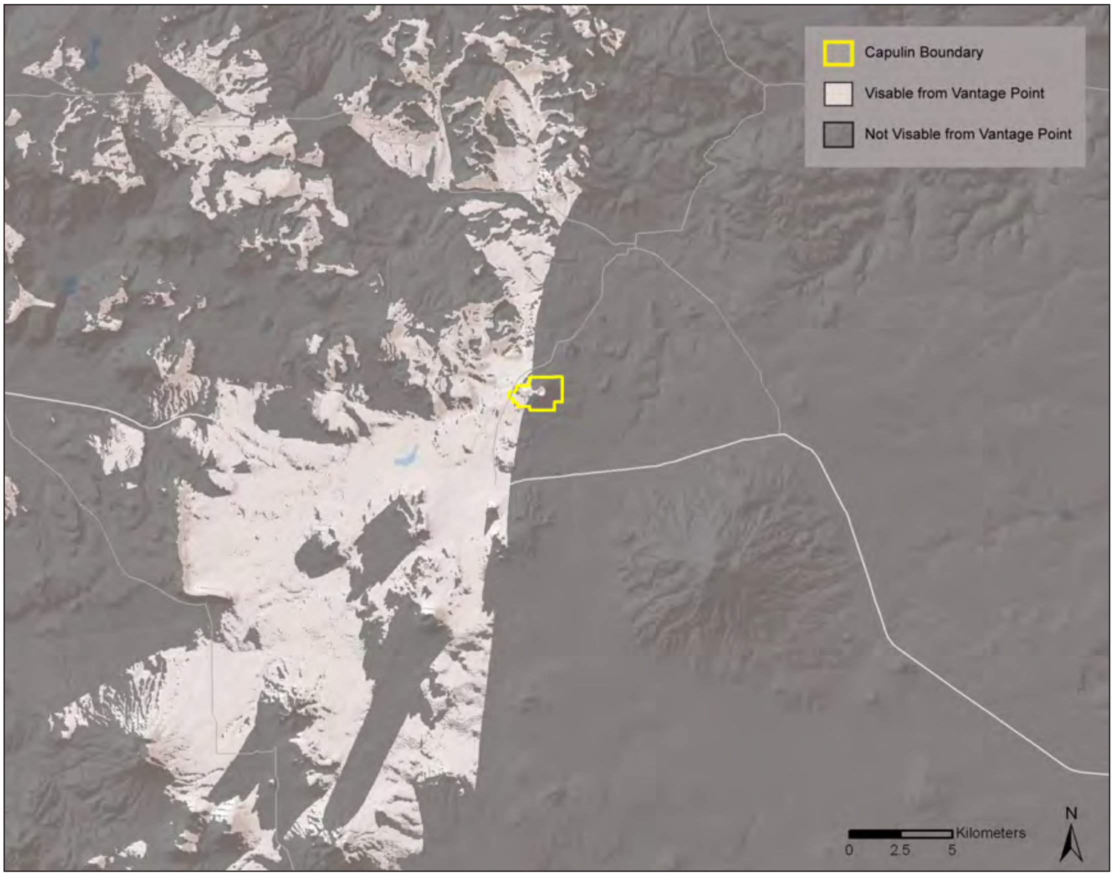

Figure 4.1.2-4.
The viewshed from the upper parking area vantage point.

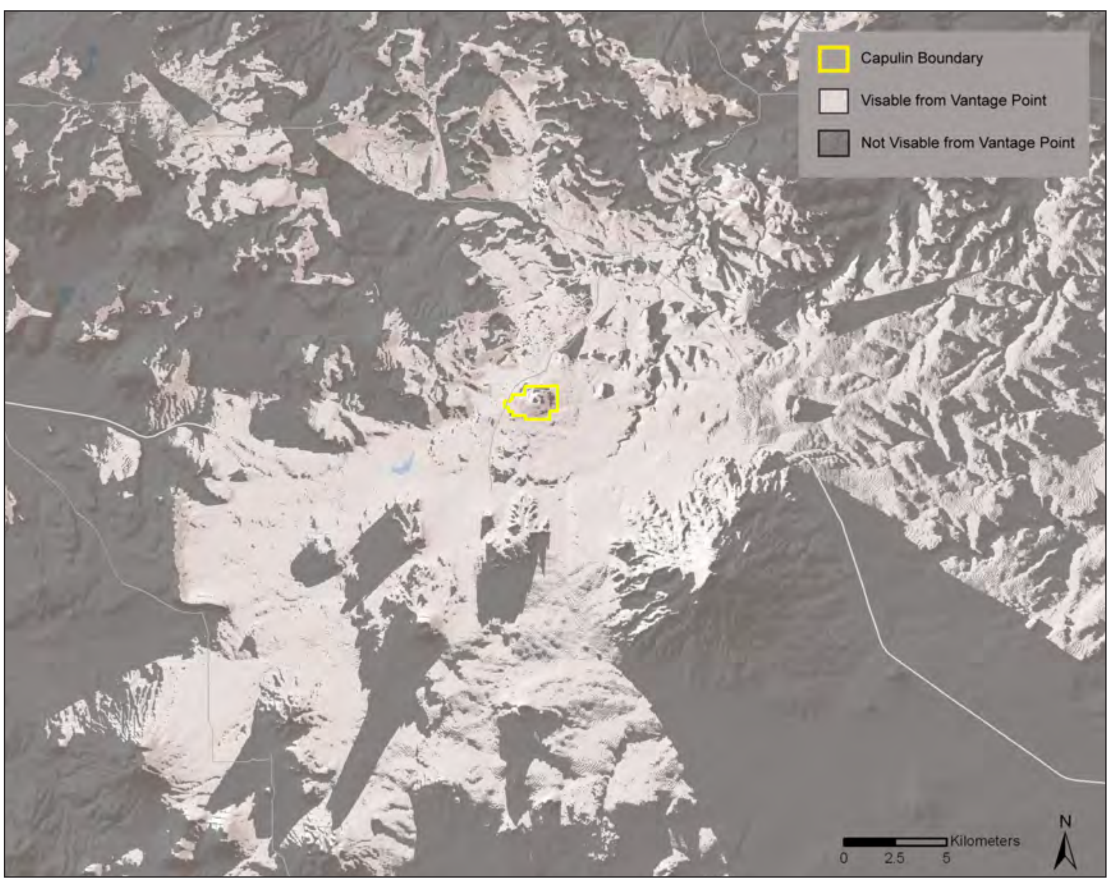

Figure 4.1.2-5.
The viewshed from Volcano Road vantage points..

ROBERT BENNETTS

Figure 4.1.2-6. We estimated the proportion of the monument's viewshed occupied by man-made features by overlaying a grid on photographs of the visible landscape and counting the number of points that fell on man-made vs. natural features.

point was located over a man-made feature or developed area, the point(s) was assigned to "man-made," otherwise it was assigned to "natural." The sky and foreground vegetation, where present, were excluded in the analysis to prevent skewing the results. The proportion of man-made versus natural points was used as an estimate for this indicator. The primary man-made features included in the assessment of this indicator were:

1. Roads
   - US Highway 64/87
   - NM325
   - NM-72
   - NM-456
   - Monument Entrance Road
   - Other rural roads (e.g., ranch roads)
   - Volcano Road
2. Villages/Rural Homes
   - Capulin
   - Des Moines
   - Folsom
   - Village homes
   - Private ranches
   - Other rural homes (not within a village)
3. Other Developments
   - Capulin Volcano NM visitor center, headquarters, maintenance complex, and housing complex
   - Cinder pits
   - Power lines
   - Fence lines
   - Radio and cell phone towers

Most of the man-made features are shown in Figures 4.1.2-7, -8, -9, -10, -11, and -12 as they appear from a viewshed perspective.

Indicators/Measures

- Conspicuousness of man-made feature characteristics

The next feature-based indicator assessed the type and/or degree of conspicuousness of man-made features based upon visitor perceptions. Studies have shown that not all man-made structures or features have the same impact on a visitor's preference. Further, visitor preferences can be influenced by a variety of factors, including such things as their cultural background, their familiarity with the landscape, and their environmental values, (Kaplan and Kaplan 1989; Virden and Walker 1999; Kaltenborn and Bjerke 2002; Kearney et al. 2008).

As stated previously, it is virtually impossible to be completely objective about how visitors value a particular landscape. Therefore, in developing appropriate viewshed indicators, we tried to incorporate those characteristics of the Capulin Volcano NM viewshed we believed were likely most important to visitors based on research from other areas. We have also tried to be transparent in how and why we rated certain feature characteristics so that anyone can assess how their own perspective might change the outcome of this assessment.

The visual impact from man-made feature characteristics was intended to account for how the characteristics of a given feature, or group of features might tend to influence how visitors perceive them. There has been a substantial volume of research demonstrating that man-made features on a landscape are perceived more positively when they are considered in harmony with the landscape (Kaplan and Kaplan 1989; Gobster 1999; Kearney 2008; others). For example, Kearney et al. (2008) showed that respondents tended to prefer development that blended with the natural setting through use of colors, smaller scale, and vegetative screening.

The specific characteristics we considered were those that have been identified in the literature that seem most applicable to the features at Capulin Volcano NM (Table 4.1.2-1). It should also be noted that the criteria in Table 4.1.2-1

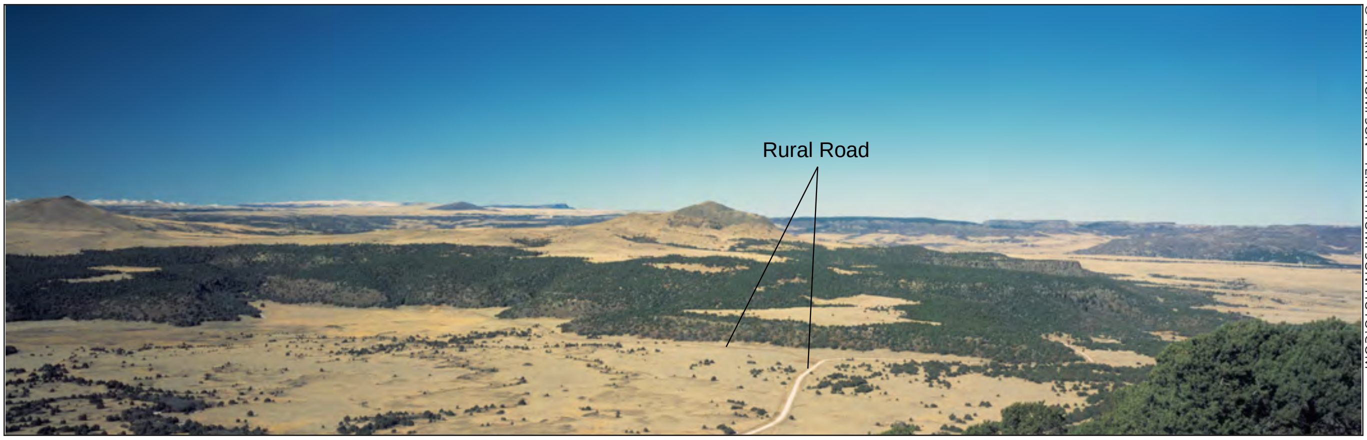

Figure 4.1.2-7. View to the north, northwest from Capulin Volcano NM showing primary man-made features considered in our assessment.

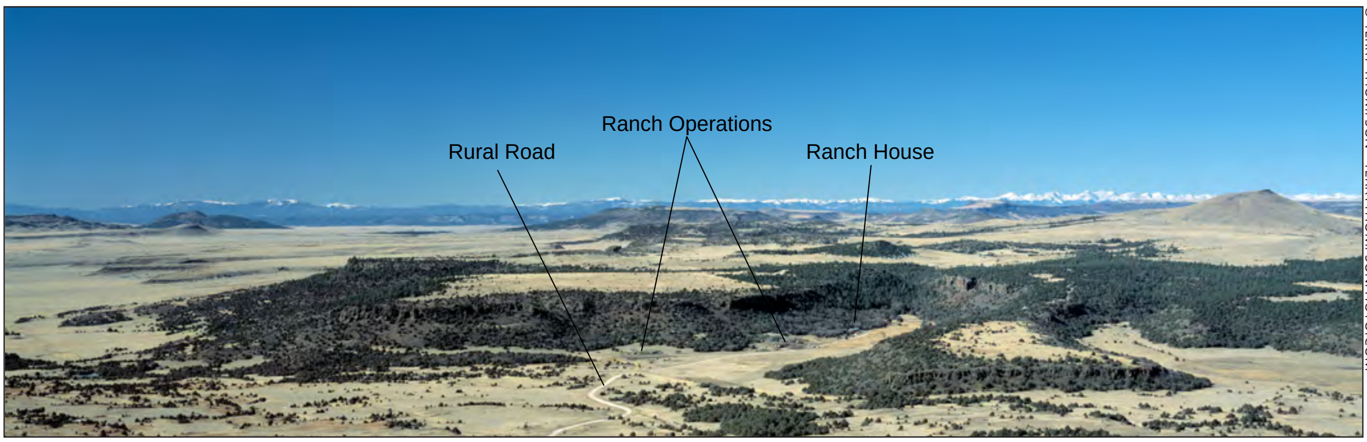

Figure 4.1.2-8. View to the west from Capulin Volcano NM showing primary man-made features considered in our assessment.

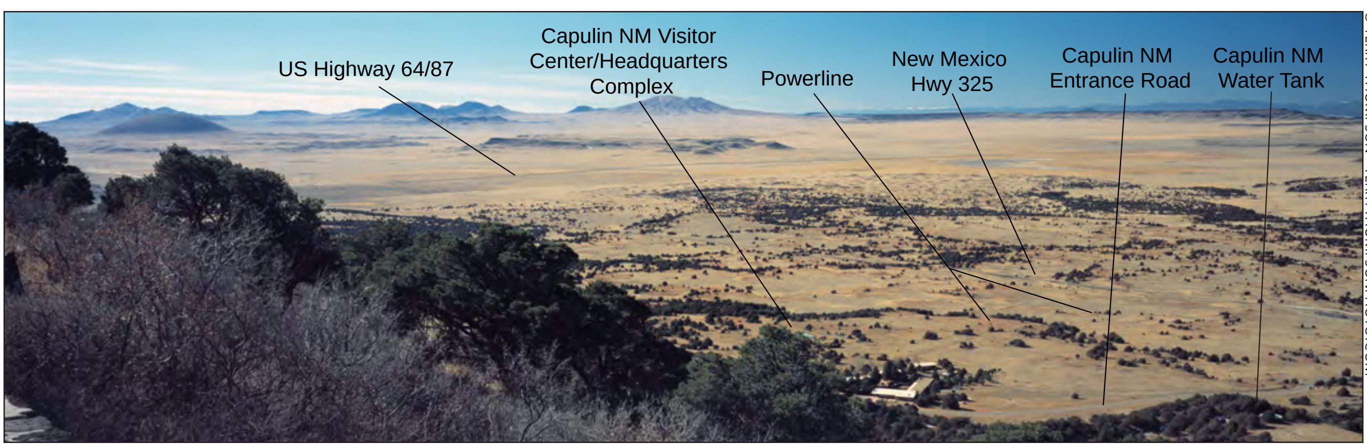

Figure 4.1.2-9 View to the southwest from Capulin Volcano NM showing primary man-made features considered in our assessment.

Figure 4.1.2-10. View to the southeast from Capulin Volcano NM showing primary man-made features considered in our assessment.

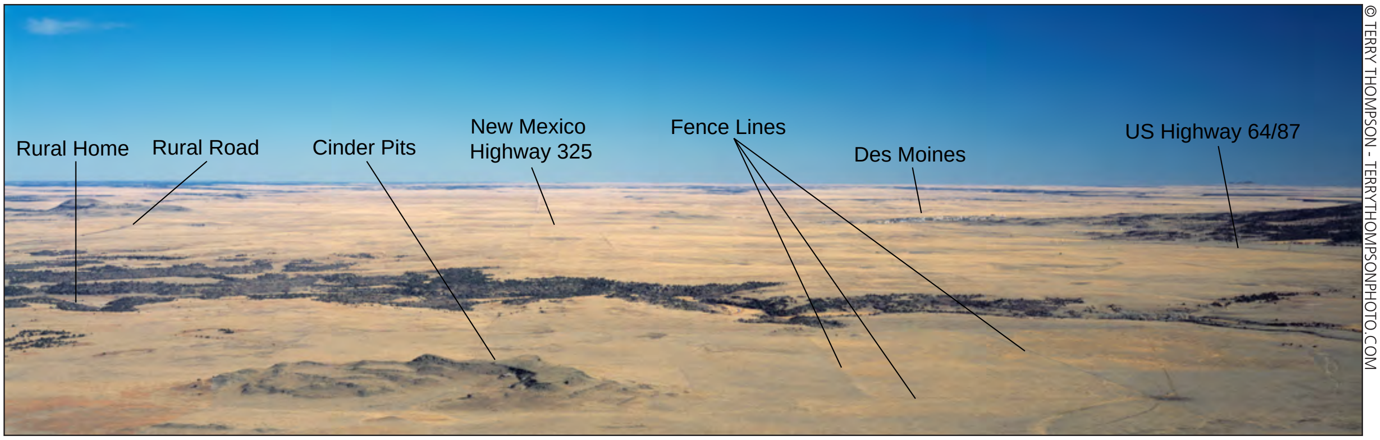

Figure 4.1.2-11. View to the east from Capulin Volcano NM showing primary man-made features considered in our assessment.

Figure 4.1.2-12. View to the north from Capulin Volcano NM showing primary man-made features considered in our assessment.

Table 4.1.2-1. Factors that may make a man-made feature more or less conspicuous within a viewshed

Characteristic	Less Conspicuous	More Conspicuous
Distance	Distant from the vantage point	Close to the vantage point
Size	Small relative to the landscape	Large relative to the landscape
Movement or noise	Lacks movement or noise	Exhibits conspicuous movement or noise
Color and shape	Colors and shapes blend into the landscape	Colors or shapes contrast with the landscape

were based on the man-made feature being prominent enough on the landscape for its characteristics to likely influence perceptions. For example, the color or shape of a house would not be important to Capulin Volcano NM's viewshed if the house is too far away to distinguish those characteristics while viewed from one of the vantage points. Subsequently, distance becomes the primary characteristic that affects the potential conspicuousness of the remaining characteristics (e.g., size, color, shape, movement, noise). Therefore, a hierarchy based on the distance characteristic having the most impact on the quality of the viewshed, followed by the size characteristic, then both the color/shape and noise/movement characteristics, was developed (Figure 4.1.2-13). A summary of the different man-made feature characteristics we considered for this indicator is provided in Table 4.1.2-1.

Man-made Feature Characteristics

Distance Characteristics: How far are the man-made features from a viewshed's vantage point(s)?

The influence that individual man-made features within a viewshed have on perception is substantially influenced by the distance from the observer to a specific feature(s). Two approaches, using distance zones, have been developed by land management agencies to address this aspect of visual quality. The U.S. Forest Service (USFS) uses three distance zones for general forest planning and a fourth zone for specific project planning (USFS 1995). The three zones are: foreground (<0.5 mi), middle ground (0.5 to 4 mi) and background (4 mi to the horizon). The fourth zone, used for project planning, is in the immediate foreground (0–300 ft).

The Bureau of Land Management (BLM) also uses three distance zones for its Visual Resource Management Program (BLM 1980). Distance zones used by the BLM are: foreground-middle ground (<3–5 miles), background (3–5 to 15 mi), and seldom seen areas, which include areas within the other distance zones that are not generally visible as well as anything >15 miles. Additionally, the USFS also uses a "seldom seen" designation, which is useful for both the USFS and BLM agencies because many of the visual quality assessments they conduct are along travel routes where the visible landscape is constantly changing. We did not consider such a zone because even though the views from Volcano Road change, they still offer views from a single cinder cone for which the viewshed is easily defined.

Distance Classes

We used three distance classes for this assessment that represent a merging of the USFS and BLM approaches: foreground (<1 mile), middle ground (1–5 miles), and background (>5 miles). These zones are summarized in (Table 4.1.2-2).

Foreground: Because of the steepness of the cinder cone, much of the immediate foreground (in the sense of USFS' project level zone of

Table 4.1.2-2. Distance classes for the proximity of a man-made feature from a vantage point

Distance Class		
Foreground	Middle ground	Background
<1 miles from vantage point	1 to 5 miles from vantage point	>5 miles from vantage point
It is possible to distinguish individual large birds or mammals to the outer limit.	It is still possible to distinguish individual trees or other large plants through texture or color.	It is no longer possible to distinguish differences in texture, and color has flattened.

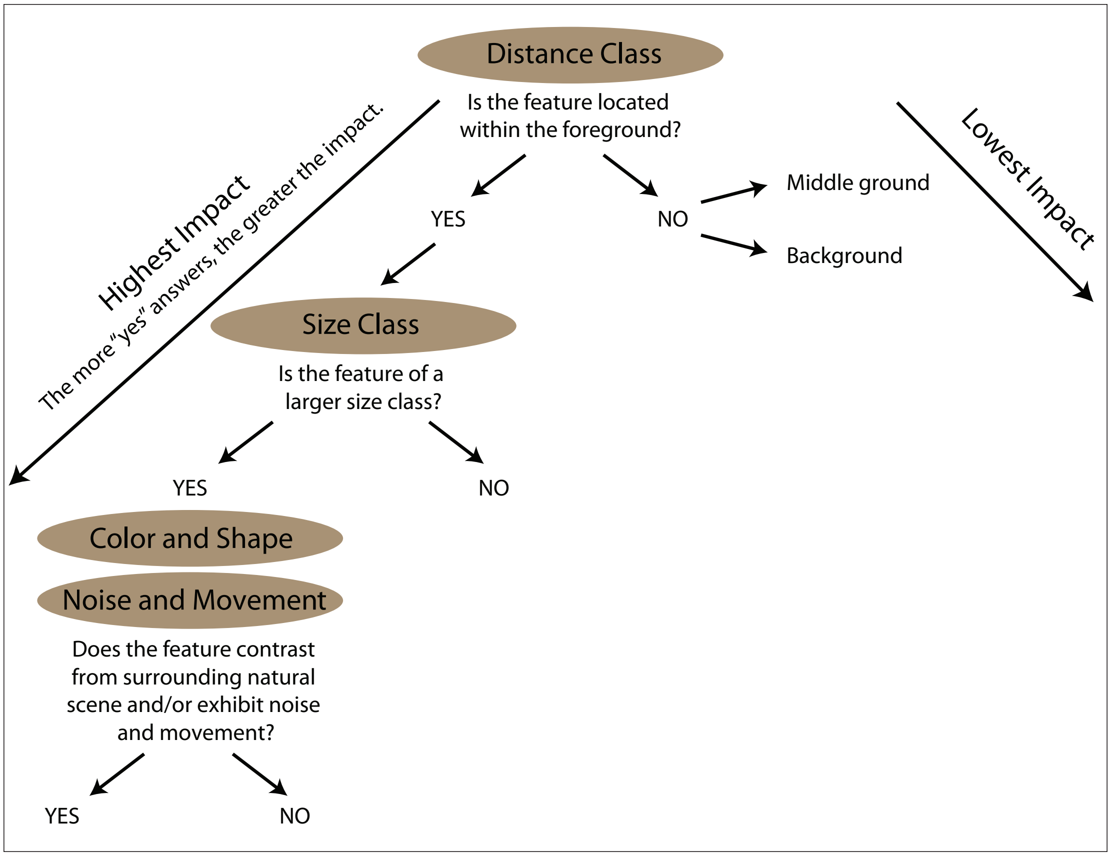

Figure 4.1.2-13. We used a hierarchical approach that included man-made feature characteristics which contribute to a feature's conspicuousness.

0-300 feet) has limited visibility, and it is the view of the surrounding landscape that attracts many visitors. Consequently, we were not as concerned with the immediate foreground for this part of the assessment, although the condition on the cinder cone itself is considered throughout this assessment in other chapters (e.g., vegetation, birds, geology). Because most of what is visible from our vantage points in the surrounding landscape starts beyond the base of the cinder cone, the 0.5 mile cutoff used by the USFS seemed too short for the foreground distance class at Capulin Volcano NM. Instead we considered the foreground's upper limit extending to 1 mile (Figure 4.1.2-14). Within this distance class, visitors should be able to distinguish variation in texture and color, such as the relatively subtle variation among vegetation patches, or some level of distinguishing clusters of tree boughs. In this distance, large birds and mammals would likely be visible as would small or medium-sized animals at the closer end of the zone (USFS 1995).

Middle ground: The middle ground distance class extends from 1 to 5 miles. We chose 5 miles as the upper limit rather than 4 miles used by the USFS or the range of 3–5 miles used by the BLM because their upper end represents the approximate point where the texture and form of individual plants are no longer apparent on the landscape (BLM 1980). Within this distance class, there is often still sufficient texture or color to distinguish some individual trees or other large plants (USFS 1995). It is also possible to still distinguish larger patches within major plant community types (e.g., grasslands), provided there is sufficient difference in color shades. Within the closer portion of this distance class, it still may be possible to see large birds when contrasted against the sky, but other wildlife would be difficult to see without the aid of binoculars or telescopes.

Background: The background distance class extends from 5 miles to the horizon, where texture disappears and color flattens. Depending on the actual distance, it is sometimes possible to distinguish among major vegetation types with highly contrasting colors (e.g., forested or grassland), but any subtle differences within these broad land cover classes would not be apparent without the use of binoculars or telescopes, and even then may be difficult.

Size Characteristics: What are the relative sizes of man-made features?

Figure 4.1.2-14. We used three distance classes for a feature's conspicuousness that represent a merging of the USFS and BLM approaches: foreground (<1 mile), middle ground (1–5 miles), and background (>5 miles).

Size is one characteristic that may influence how conspicuous a given feature dominates the landscape, and how it is perceived. For example, Kearney et al. (2008) found human preferences were lower for man-made developments that tended to dominate the view (e.g., large multi-story units) and were more favorable for smaller single family dwellings. In another study, Brush and Palmer (1979) found that farms tended to be viewed more favorably than views of towns or industrial sites, which ranked very low. This is consistent with other studies that have reported rural family dwellings such as farms or ranches as quaint, contributing to rural character (Schauman 1979; Sheppard 2001; Ryan 2006), or as symbolizing good stewardship (Sheppard 2001).

Table 4.1.2-3. General size classes for visible man-made features

Size Class	Examples
Low height and volume	Single family dwelling, such as homes and ranch houses.
Low height, but substantial volume	Small towns and complexes (e.g., Capulin National Monument visitor center/ headquarters complex).
Substantial height, but low volume	Radio and cell phone towers.
Substantial length, but low height and volume	Roads, powerlines, and fence lines.

The features on the landscape surrounding Capulin Volcano NM can be categorized into four size classes (Table 4.1.2-3), and reflect the preference groups reported by studies. Using some categories of perhaps mixed measures, we considered size classes within the context of height, volume, and length.

The first size class contains relatively small dwellings (i.e., single family homes or ranches) that are not particularly large in height or volume. The next class constitutes clusters of dwellings or other buildings, such as towns or the monument's visitor center, headquarters, and housing complex. The third class contains features that are very high (substantially more than a typical house or other buildings). This group would include features such as radio or cell phone towers. The fourth class is comprised of features that have substantial length, but not much height or volume. This group includes roads, powerlines, and fence lines. We have included powerlines in this group (i.e., without substantial relative height) because the powerlines in Capulin Volcano NM's viewshed are typically small wooden pole type lines that are not typically taller than a two-story house. Large metal powerlines (e.g., 500 kilovolt lines) would likely have constituted its own group if they were present.

Contrast Characteristics: Do the colors, contours, and shapes of the man-made features blend into the landscape?

Table 4.1.2-4. Categories used to describe how well a given man-made feature contrasts/blends with the surrounding landscape

Degree to Which Man-Made Feature Contrasts/Blends With Surrounding Landscape		
Less Contrasting with the Landscape	Somewhat Contrasting with the Landscape	Contrasting with the Landscape
The color, contour, and shape blend well with the surrounding landscape.	The color, contour, and shape contrast to a moderate degree with the surrounding landscape.	The color, contour, and shape are in marked contrast with the surrounding landscape.

There have been numerous studies that have shown that how people perceive a man-made feature in a rural scene depends greatly on how well it seems to fit or blend with that environment (Kearney et al. 2008; Ryan, 2006). For example, Kearney et al. (2008) found preferences for homes that exhibit lower contrast with their surroundings as a result of color, screening vegetation, etc. (see also Figure 4.1.2-15). The idea of color harmony (i.e., how well the color of a feature blends or contrasts with the surroundings) is well known in both urban and rural settings. Many cities even have ordinances or codes to ensure that new developments blend with their surroundings, including color (Stamps and Nasar 1997).

It has been shown that colors lighter in tone or higher in saturation relative to their surroundings, have a tendency to attract attention (i.e., contrast with their surroundings), whereas darker colors (relative to their surroundings) tend to fade into the background (Ratcliff 1972; O'Conner 2008). This is consistent with the findings of Kearney et al. (2008) who found that darker color was one of the factors contributing to a feature blending in with its environment and therefore preferred. Some research has indicated that color can be used to offset other factors such as size that may evoke a more negative perception (O'Conner 2009).

Similarly, shapes of features that contrast sharply with their surroundings may also have an influence on how they are perceived. This has been a dominant focus within visual resource programs of land management agencies (Ribe 2005). In forest management, negative perceptions relating to the contrasting shapes of forest harvest with their surroundings (e.g., clear cuts) was so strong that it was explicitly addressed in the National Forest Management Act of 1976 calling for "cuts . . . shaped and blended to the extent practicable with the natural terrain" (16 USCA 1604g3Fiii). The Visual Resource Management Program of the BLM (1980) similarly places considerable focus on design techniques that minimize visual conflicts with features such as roads and power lines by aligning them with the natural contours of the landscape. For example, a straight road going through a landscape can be in marked contrast to the background environment, whereas a road that winds through a landscape along the natural contours (e.g., along hills, vegetation patterns) can be perceived much more positively, and can even be favored (Kaltenborn and Bjerke 2002) (Figure 4.1.2-15).

Based on these characteristics of contrast, we used three categories for how well individual man-made features blend into or contrast with their surroundings (Table 4.1.2-4). We considered the color of a feature in relative harmony with the landscape if it closely matched the surrounding environment, or if the color tended to be darker relative to its environment which, as described previously, tends to make the feature less conspicuous. We considered the shape of a feature in relative harmony with the landscape if it was not in marked contrast to the environment, for example, if a linear feature followed natural contours.

Noise and/or Movement Characteristics: Are there conspicuous noises or movements associated with the man-made features?

Motion and sound can both have an influence on how a landscape is perceived (Hetherington et al. 1993), particularly by attracting a person's attention to a particular area of a viewshed. Movement and noise parameters can be perceived either positively or negatively depending on the source and context. For example, the motion of running water generally has a very positive influence on perception of the environment (Carles et al. 1999), whereas noise from vehicles on a highway may be perceived negatively. In Carles et al.'s (1999) study, sounds were perceived negatively when they clashed with a person's aspirations for a particular site,

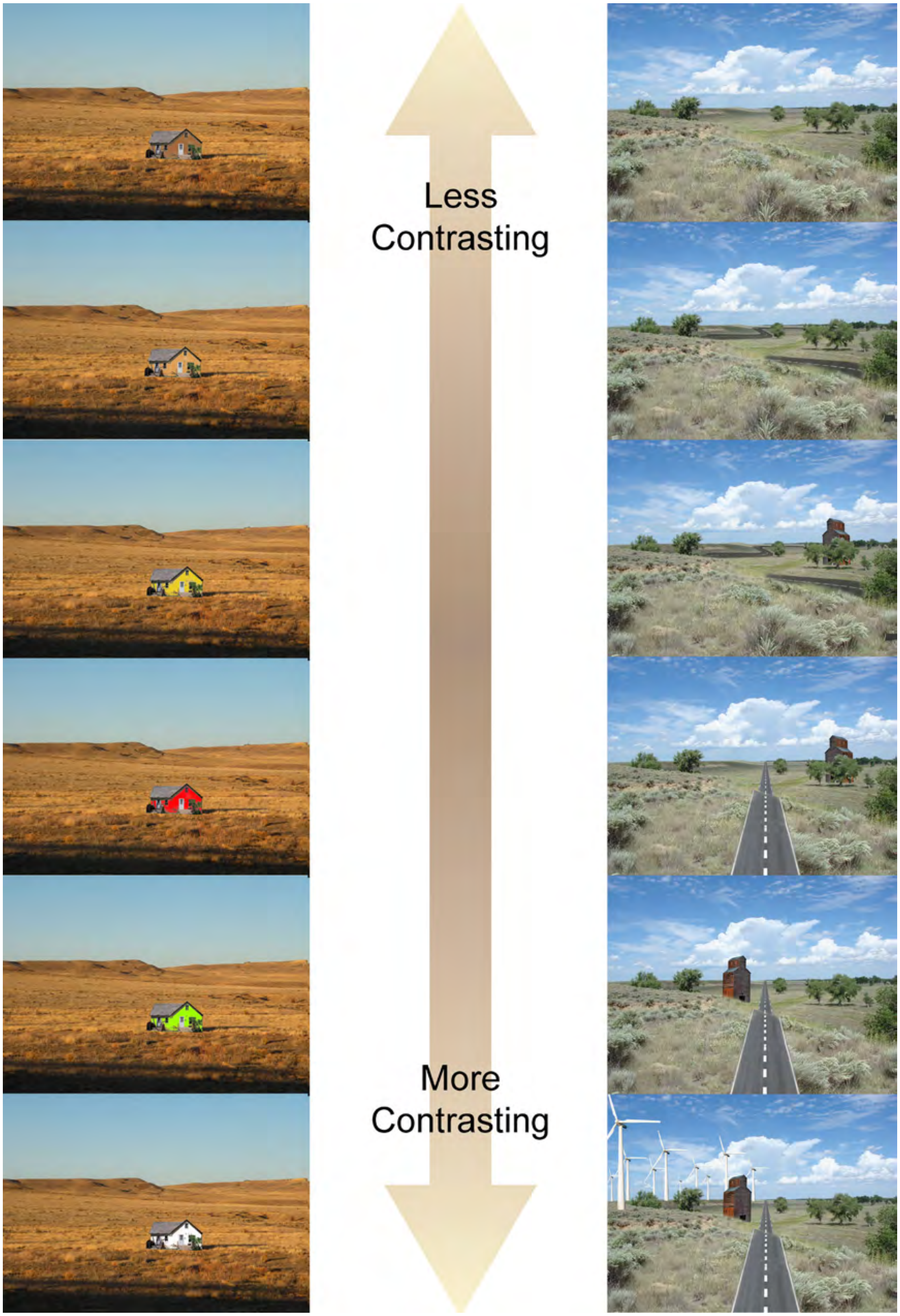

Figure 4.1.2-15. Graphic illustration showing how color (left panel) and shape (right panel) can influence how man-made features blend or contrast with their surroundings. Note the influence of vegetation screening on the grain silo and the difference when the road follows the natural contours (upper right photos) or deviates from the natural contours (lower right photos).

Table 4.1.2-5. Categories used to describe conspicuousness of noise or movement associated with a man-made feature

Degree of Conspicuous Noise or Movement Associated With a Man-made Feature		
Not Conspicuous	Moderately Conspicuous	Conspicuous
Little or no conspicuous noise or movement asssociated with the feature	Moderate degree of conspicuous noise or movement associated with the feature	Conspicuous noise or movement associated with the feature

such as tranquility. We used three categories for this assessment to describe the level of conspicuous noise or movement associated with a man-made feature (Table 4.1.2-5).

4.1.3 Reference Conditions

The essence of our reference condition is that the monument's viewshed has maintained its natural and rural character. There is a strong foundation of studies that have shown that, in general, natural landscapes are preferred over anthropogenic landscapes. However, there are also a number of studies indicating that man-made features that seem to fit with a perceived rural environment (ranch houses, winding dirt roads, etc.), do not evoke the negative response as commercial or industrial developments do, and may even add positively to the perceptions of the landscape (Kearney et al. 2008).

For the housing density indicator, the reference condition is that the density is sufficiently low to maintain the rural character of the landscape. If housing densities were high and perceived as transitioning to an urban or suburban character, then the perceived quality of the viewshed would likely diminish, as would our assessment of the condition. Similarly, for the road density indicator, the density, particularly of higher traffic volume paved roads, does not cause people to perceive the landscape as a travel route.

For the condition related to the man-made feature indicators, our good reference condition parallels our descriptions for pristine and minimally developed landscapes (Table 4.1.3-1).

Additionally, most of the man-made features that are visible will need be relatively inconspicuous to be considered in good condition. Once again, a low density of man-made features that are perceived as being consistent with the rural character does not diminish the overall condition of the viewshed, but the addition of commercial and industrial developments (e.g., factories, shopping centers) within a given viewshed would likely diminish perceptions of that viewshed as well as our assessment of condition.

4.1.4 Condition and Trend

Housing Density

Housing densities within Capulin Volcano NM's viewshed are very low. Greater than 99% of the areas visible from the monument have densities <1.5 units per square km (Table 4.1.4-1), and those remaining areas with higher densities are concentrated in or around the villages of Capulin, Des Moines, and Folsom, NM (Figure 4.1.4-1). Furthermore, of the 99% with the lowest housing densities, virtually all are ranches or rural homes. As previously described, these structures did not evoke a

Table 4.1.3-1. Condition Classes of Proportion of Viewshed That is Natural vs. Man-made visible landscape

Condition	Class	Description
Good	Pristine	No man-made structures or developments are visible within the viewshed.
Good	Minimally Developed	Man-made structures or developments are present, but the vast majority of the landscape is dominated by natural features.
Moderate	Moderately Developed	Man-made structures or developments occupy a moderate portion of the landscape.
Significant Concern	Highly Developed	The vast majority of the landscape is dominated by man-made structures or developments.

Table 4.1.4-1. Housing densities within 30 km of Capulin Volcano NM in 2010 as estimated using NPScape (Budde et al. 2009 and Gross et al. 2009), that have been screened to include only areas visible from Volcano Road

Density Class	Area (km^2)	Percent
Private undeveloped	2113.27	84.89%
< 1.5 units / square km	363.16	14.58%
1.5 - 6 units / square km	9.13	0.36%
> 6 units / square km	3.64	0.14%

Note: The source data from NPScape included some areas with missing data, which were excluded from these totals.

negative visitor perception (Schauman 1979; Sheppard 2001; Ryan 2006; Sheppard 2001). Our conclusion, with respect to housing densities, of the monument's viewshed condition is good.

Road Density

Road densities are also relatively low within the monument's viewshed (Figure 4.1.4-2). There is only one US Highway (US Highway 64/87) in the viewshed, which is approximately three miles away at its closest point. This highway also runs almost perpendicular to any line of sight from Capulin Volcano NM, which further lends itself to being less conspicuous, particularly at farther distances. In addition, there are three New Mexico State Highways within the monument's viewshed: Highways 72, 325, and 456. However, all but one of these (NM Highway 325) are at distances and/or angles that render them extremely inconspicuous from the monument. Thus, our conclusion of the condition of the viewshed from the monument, with respect to road densities, is good.

Proportion of the Viewshed That is Natural vs. Man-made Features

As previously discussed, there is a tendency for people to prefer landscapes that are natural versus man-made (Zube et al. 1982; Kaplan et al. 1989; Sheppard 2001; Kearney et al. 2008; Han 2010). The common exception to this is when man-made features are viewed as fitting into the landscape (Kearney et al. 2008). Based on our assessment of this indicator, the monument's viewshed contained <5% man-made features overall, with the highest percentage never exceeding 5% even in the most developed areas (e.g., visitor center, monument headquarters). Further, many of the features that are most frequently visible are rural homes or ranches, which tend to fall into the category of being perceived as fitting into the landscape (Kearney et al. 2008; Ryan, 2006). Most of the features that might be viewed less positively were at greater distances or angles from the monument's viewshed, making them highly inconspicuous. Consequently, for this indicator we consider the monument's viewshed to be minimally developed, therefore, in good condition.

Conspicuousness of Man-made Feature Characteristics

For our final indicator, we considered whether individual or groups of man-made features on the landscape exhibit characteristics that tend to make them more or less conspicuous. We summarize our results for this indicator in Table 4.1.4-2 and discuss each class of features in greater detail below.

Roads and Highways

U.S. Highway 64/87 is the major road bisecting the monument's viewshed. This highway receives a moderate level of traffic including commercial transports. From a standpoint of movement and noise, it could potentially be the most conspicuous feature on the landscape; however it is located either at the far end of the middle-ground or in the background distance classes, and its straight line shape is perpendicular to the viewing angles within the monument. Consequently, this potentially conspicuous feature is rendered relatively benign with respect to Capulin Volcano NM's viewshed.

All three of the New Mexico state highways receive considerably less traffic than U.S. Highway 64/87 with New Mexico Highway 325 present in all three distance classes, and the other two highways located in the background distance class, rendering them relatively inconspicuous. New Mexico Highway 325 is probably the most conspicuous of all the highways, but the low volume of traffic makes its impact relatively low. There are also numerous

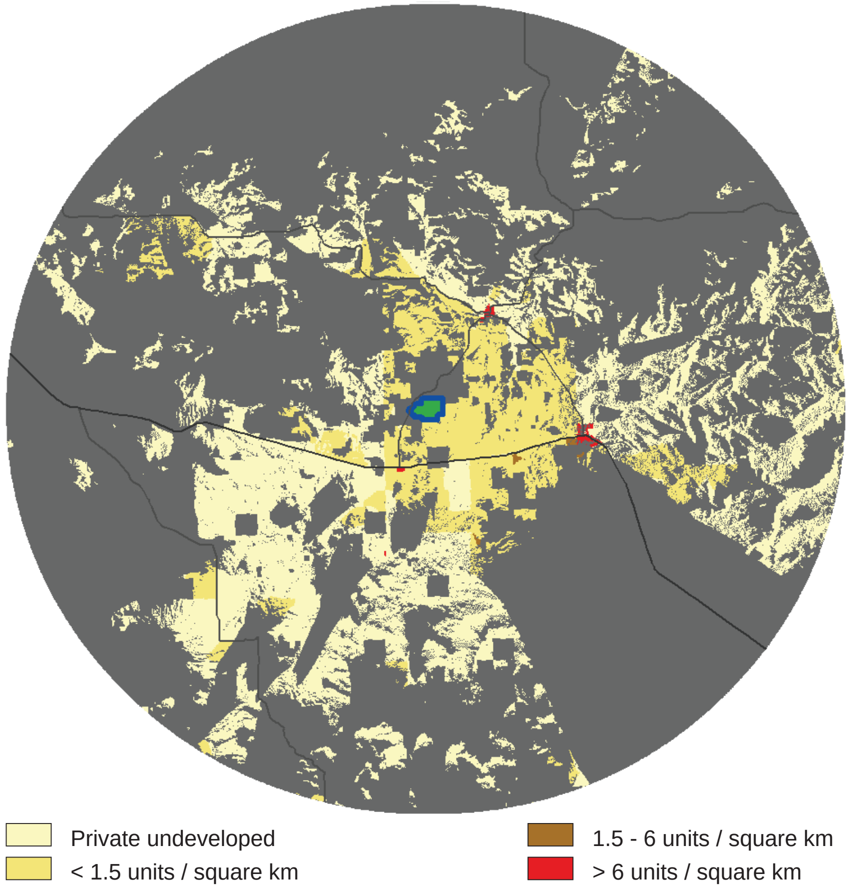

Figure 4.1.4-1. Housing densities within 30 km of Capulin Volcano NM in 2010 as estimated using NPScape (Budde et al. 2009). Data were screened to include only areas visible from the Volcano Road viewshed.

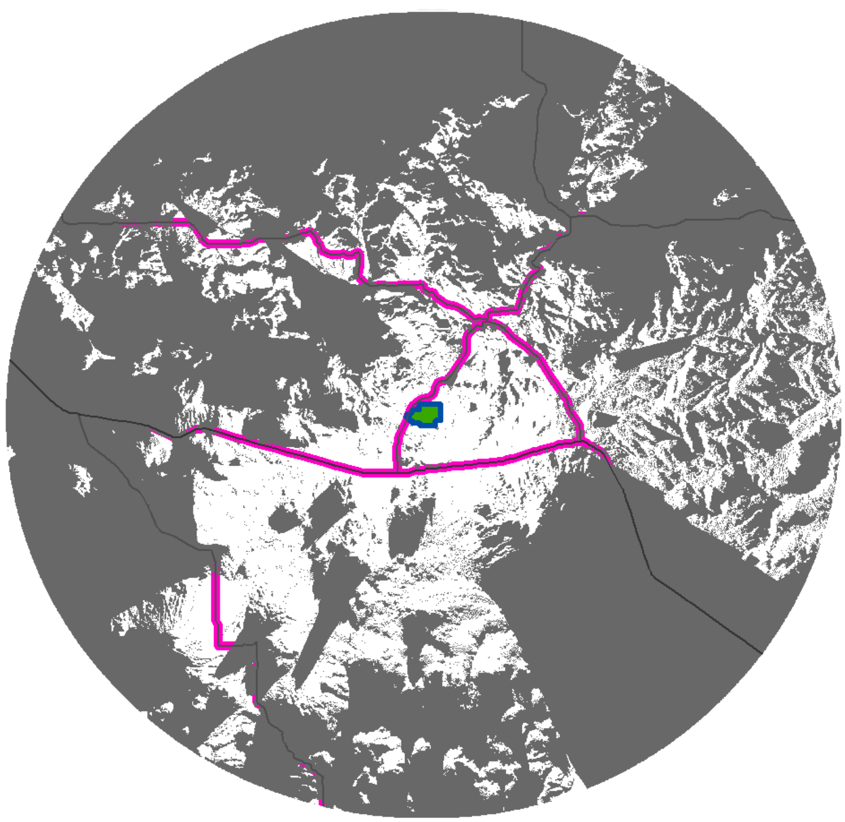

Figure 4.1.4-2. Road densities within 30 km of Capulin Volcano NM in 2010, as estimated using NPScape (Budde et al. 2009). Data were screened to include only areas visible from the Volcano Road viewshed.

Table 4.1.4-2. Summary of the characteristics, arranged by distance classes, that make man-made features within Capulin Volcano NM's viewshed more or less conspicuous

Structure(s) or Feature	Type of Feature	Distance Class	Size Class	Color and Shape	Noise and Movement
Foreground					
Monument Entrance Road	Road or highway	Foreground	Substantial length, but low volume	Somewhat contrasting	Moderately conspicuous
Capulin Volcano NM visitor center/ headquarters complex	Other development	Foreground	Low height, substantial volume	Contrasting	Moderately conspicuous
Cinder pits	Other development	Foreground and background	Low height, substantial volume	Somewhat contrasting	Moderately conspicuous
Volcano Road	Road or highway	Foreground	Substantial length, but low volume	Somewhat contrasting	Conspicuous noise and movement
Middle ground					
Capulin	Village	Middle ground	Low height, Substantial volume	Somewhat contrasting	Conspicuous noise and movement
US Highway 64/87	Road or highway	Middle ground and background	Substantial length, but low volume	Contrasting	Conspicuous noise and movement
Other rural homes, not in villages	Rural home or ranch	Middle ground and background	Low height and volume	Somewhat contrasting	Moderately conspicuous
Background					
Radio/cell phone towers	Other development	Background	Substantial height, but low volume	Contrasting	Not conspicuous
Folsom	Village	Background	Low height, substantial volume	Somewhat contrasting	Conspicuous noise and movement
Des Moines	Village	Background	Low height, substantial volume	Somewhat contrasting	Conspicuous noise and movement
New Mexico Highway 456	Road or highway	Background	Substantial length, but low volume	Somewhat contrasting	Moderately conspicuous
New Mexico Highway 72	Road or highway	Background	Substantial length, but low volume	Somewhat contrasting	Moderately conspicuous
All: Foreground, Middle ground, and Background*					
New Mexico Highway 325	Road or highway	All	Substantial length, but low volume	Somewhat contrasting	Moderately conspicuous
Rural Roads	Road or highway	All	Substantial length, but low volume	Somewhat contrasting	Moderately conspicuous
Power lines	Other development	All	Substantial length, but low volume	Contrasting	Not conspicuous
Fence lines	Other development	All	Substantial length, but low volume	Contrasting	Not conspicuous
Ranches	Rural home or ranch	All	Low height and volume	Somewhat contrasting	Moderately conspicuous

Note: Features are listed in a hierarchy of more contrasting to less contrasting based upon the distance classes. See Figure 4.1.2-8 and "Characteristics" section in "Data and Methods" for a discussion of this hierarchy.

* = Some of these features are located in the foreground, but are not prominent. The majority are located in the middle ground or background.

rural roads within the viewshed, but these too have low traffic volume and are generally too far away and/or of low height, blending with the surrounding landscape.

Villages/Rural Homes

There are three villages visible within the Capulin Volcano NM viewshed, two of which are in the background distance class (Folsom and Des Moines). Capulin Village is located in the middle-ground distance class. However, all three villages are small with limited contrasting characteristics. Even Capulin Village, the closest of the three, is quite inconspicuous. These features probably have a negligible impact on Capulin Volcano NM's viewshed.

Although there are numerous rural homes and ranches within the monument's viewshed, these too are generally quite inconspicuous. Only one ranch is visible within the foreground distance class, and its relatively low activity does not pose much, if any, impact on the viewshed. Further, as previously discussed, there have been several studies that indicate that rural homes, such as ranches, do not typically evoke much of a negative perception for viewshed quality and in many cases evoke a positive one (Schauman 1979; Sheppard 2001; Ryan 2006).

Other Developments

The Capulin Volcano NM visitor center and headquarters complex is probably the most conspicuous man-made features within the monument's viewshed. They are located in the foreground distance class, have colors that somewhat contrast with the surroundings, and exhibit moderate levels of noise and movement. However, even these most conspicuous features do not seem to illicit any major concerns by visitors.

There are both commercial and private cinder extraction pits within Capulin Volcano NM's viewshed. The commercial pit is located in the middle ground distance class and the private pits are both located within the foreground distance class. Commercial pit extraction is currently active, and we do not know the current activity of the private pits, which may or may not be intermittently active.

There are powerlines and fence lines scattered throughout the viewshed; however, from most vantage points they are not very conspicuous. There is one powerline in the foreground distance class that is relatively visible from the entrance road vantage point, but even this one is not very conspicuous from the other vantage point locations. Fence lines are also scattered throughout the viewshed, but they are most apparent from viewing the contrasting vegetation changes on either side of the fence, rather than from the fence material. However, like ranch houses, these are unlikely to evoke much of a negative response, as studies have shown they would likely be perceived as a fitting part of a rural landscape (Kaplan and Kaplan 1989; Gobster 1999; Kearney 2008).

Radio and cell phone towers can be quite intrusive on a landscape and have evoked negative responses in some studies (Kearney et al. 2008). However, the towers visible within the monument's viewshed are located on the top of Sierra Grande in the background distance class and are not very conspicuous from the monument's vantage points.

In summary, there are several man-made features within Capulin Volcano's viewshed that have been shown to evoke negative responses in some studies (e.g., highways, cell phone towers, mining/cinder pits). However, in this case, most of these are far enough away, relatively small, and/or inactive so as not to be very conspicuous within Capulin Volcano NM's viewshed. Thus, with respect to the conspicuousness of man-made features, we consider the monument's viewshed once again in good condition.

Overall Condition

For assessing the condition of viewshed, we used a variety of indicators/measures that were not mutually exclusive but were intended to be different ways of capturing the essence of what we thought represented the condition of the monument's viewshed. How a viewshed is perceived is obviously subjective, but many studies have shown that the perceived quality of a landscape is influenced by the a combination of factors such as whether or not it is a natural setting, whether the man-made features sharply contrast with that natural setting, and whether the man-made features represent some component of land stewardship, rather than merely utility. Thus, our indicators/measures for this resource were intended to capture different aspects of these contributing factors, and a summary of how they contributed to the overall viewshed condition is summarized in Table 4.1.4-3.

Table 4.1.4-3. Summary of the viewshed indicators/measures and their contributions to the overall viewshed natural resource condition assessment.

Indicator/Measure	Description of How the Indicator(s) Contributes to the Overall Resource Condition	General Contribution of this Indicator or Measure to the Overall Resource Condition.
Housing density	The features on a landscape represent a continuum such that an isolated feature might be perceived as a single unit, but as clusters of those isolated units increase in density, the clusters become the unit of perception. For example, the effect of a town on the landscape is not based on the individual houses, rather the cumulative effect of the town. Housing density helped us to assess this aspect.	Housing density is quite low in the region surrounding Capulin Volcano NM and is not considered to have a substantial degrading impact to the overall viewshed condition.
Road density	Same as for housing density	Road density is quite low in the region surrounding Capulin Volcano NM, and is not considered to have a substantial degrading impact to the overall viewshed condition.
Proportion of the viewshed comprised of natural vs. man-made features	As the proportion of man-made components of the landscape increases, the landscape quality shifts from being perceived as a natural setting, to a rural setting, to eventually an urban setting.	The proportion of man-made components of the landscape surrounding Capulin Volcano NM is very low; thus contributing to its perception as a natural or very rural setting, either of which are likely to be viewed positively by park visitors.
Conspicuousness of man-made feature characteristics	How conspicuous man-made features are on the landscape can dramatically influence the perception of that landscape. Studies have shown that features that tend to blend into their surroundings are generally favored over those that are contrasting. Our approach attempted to look at this indicator hierarchically based on attributes that have increasing effect (Figure 4.1.2-14).	Most features on the landscape are very inconspicuous, and with the exception of the monument's facilities, most of those features were at sufficient distance to render their negative impact quite small to the overall viewshed condition.

Our overall assessment of the condition of the viewshed at Capulin Volcano NM is that it is currently in good condition and stable (i.e., no known pending major developments). There are certainly some developments on the landscape, but most of those are either consistent with fitting into a rural landscape (e.g., ranches, single family dwellings) and/or are far enough away (e.g., U.S. Highway 64/87) that their impact on the monument's viewshed is minimal.

Level of Confidence

Probably the biggest uncertainty in assessing the monument's viewshed condition is the subjectivity in evaluating visitors' perceptions. There have been numerous studies evaluating preferences of scenic values ((Zube et al. 1982; Kaplan et al. 1989; Sheppard 2001; Kearney et al. 2008; Han 2010; Stamps and Nasar 1997; Kaltenborn and Bjerke 2002; Ratcliff 1972; O'Conner 2008), but no research can provide a definitive answer. However, in the case of Capulin Volcano NM, we think that we are relatively accurate in suggesting that the overall viewshed condition is quite good. There are currently very few man-made features on the landscape that are likely to evoke a widespread strong negative reaction.

Another viewshed perspective to consider is viewing the monument from outside its boundary toward the cinder cone-much as one does while driving to the volcano or driving along an adjacent highway. Due to the volcano steeply rising above the surrounding plains, the cinder cone itself becomes the prominent feature located within the monument. Two distinct man-made features located on the volcano are the road and the candy-cane striped vegetation patterns due to thinning and removal treatments.

As stated in section 4.1.2, features that sharply contrast with their surroundings (e.g. a straight road instead of one that is sinuous) can be less favored than features that blend (Kaltenborn and Bjerke 2002). Volcano Road is highly conspicuous as it spirals around the sides of the cinder cone, and may in fact negatively impact visitor perceptions. The other possibility is that visitors don't negatively perceive the road since it provides a means of access to the top of the volcano for sightseeing, which is the highest visitor-ranked activity within the monument (NPS 2003).

The candy-cane vegetation thin/cut pattern is also highly conspicuous. Picard and Sheppard (2002) have shown that the larger the extent of visual change (e.g. clear-cuts), the lower the level of public acceptance. Picard and Sheppard (2002) also found that the more natural the scenic view, the smaller percent alteration is allowed by the public. Since the monument's thinning and removal treatments occurred recently, they are in marked contrast to adjacent untreated areas. This contrast should diminish over time as shrubs and trees fill in; thus reducing the contrast to the adjacent habitat. But again, assessing the quality of a given viewshed is highly subjective and formal studies exploring visitor perceptions regarding the monument's viewshed have yet to be conducted.

Key Uncertainty

A few years ago, a wind power development was proposed to be built somewhere surrounding Des Moines, New Mexico (Christopher Moos, National Park Service, pers. comm.). To date, no additional information has been discovered pertaining to the proposed development. As stated earlier, the monument's viewshed is largely comprised of "borrowed land" (Johnson et al. 2008) making the future condition of the monument's viewshed largely dependent upon local and regional planning.

4.1.5 Sources of Expertise

Cheryl McIntyre, lead ecologist for the Sonoran Institute, provided information and performed the analysis pertaining to Capulin Volcano NM's viewshed analysis. She earned a master's degree in chemistry in 2001 and worked in the semiconductor industry before joining the Sonoran Institute in 2004. Cheryl leads a team of researchers who collaborate with land managers and communities to better understand the status and trends of natural resources in and around select locations in western North America. Since 2004, Cheryl has partnered with the NPS Inventory and Monitoring Program to monitor natural resources, track land-use changes, and to communicate results effectively.

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4.2 Night Sky

Indicators/Measures

- Bortle Dark-Sky Scale
- Limiting magnitude
- Sky brightness
    - Maximum Sky Brightness
    - Minimum Sky Brightness
    - Integrated Whole Sky
    - Integrated Sky Above 20 °

Condition - Trend

Good - Insufficient Data

4.2.1 Background and Importance

A natural lightscape is considered to be a valued resource within the NPS, and natural resource-based parks are mandated to preserve the scenery, which includes protecting a visible (i.e., low artificial light level) night sky (NPS 2006). As such, Capulin Volcano NM's General Management Plan identifies its night sky as a fundamental resource and value (NPS 2010a). National Park visitors also seem to agree that preserved night skies are important to their experience. A 2007 visitor survey conducted throughout Utah national parks found that 86% of visitors thought the quality of park night skies was "somewhat important" or "very important" to their visit (NPS 2010b). Additionally, in an estimated 20 national parks, stargazing events are the most popular ranger-led program (NPS 2010b).

Not only is the night sky's aesthetic and/or recreational appeal important, but natural light/darkness is also an important factor for maintaining health within biological systems. Natural light intensity varies during the day–night (diurnal) cycle, the lunar cycle, and the seasonal cycle. Organisms have evolved to respond to these periodic changes in light levels in ways that control or modulate movement, feeding, mating, emergence, seasonal breeding, migration, hibernation, and dormancy. Plants also respond to light levels by flowering, vegetative growth, and even their direction of growth (Royal Commission on Environmental Pollution 2009). Given the effects of light on living organisms, it is likely that introduction of artificial light into the natural light/darkness regime will disturb the normal routines of many plants and animals (Royal Commission on Environmental Pollution 2009), as well as diminish stargazing recreational opportunities offered to national park visitors.

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Figure 4.2.1-1. Capulin Volcano NM affords expansive night sky views.

4.2.2 Data and Methods

For our assessment of the monument's night sky condition, we used indicators and measures ranging from qualitative assessments commonly used by amateur astronomers to evaluate the potential quality for star gazing to quantitative measures of night sky brightness derived from charged coupled device (CCD) camera images developed by NPS Night Skies Program scientists.

Qualitative Indicators and Measures

Indicators/Measures

- Bortle Dark-Sky Scale

The Bortle Dark-Sky Scale, which has proven to be quite popular with amateur astronomers, was proposed by John Bortle (Bortle 2001) based on 50 years of astronomical observations. Bortle's qualitative approach uses a nine-class scale that requires no special equipment and only a basic knowledge of the night sky (Bortle 2001; Moore 2001) (Figure 4.2.2-1) (Table 4.2.2-1). The Bortle scale uses both stellar and non-stellar objects to distinguish among the different classes. Another advantage of the Bortle scale is that it is suitable for conditions ranging from the darkest skies to the brightest urban areas (Moore 2001). The Bortle scale also uses descriptors that will be more familiar to a broader audience- to which they can better relate to their own aesthetic experience (Moore 2001).

Indicators/Measures

- Limiting magnitude

Limiting magnitude (LM) is a qualitative measurement of the brightness of the faintest stars visible to the naked eye (Bortle 2001; Moore 2001). It is also a measure commonly used by amateur astronomers to judge the quality of the night sky because it is simple to measure and requires no special equipment (Bortle 2001). Estimates are made using star counts of 25 sample areas, each containing a field of mapped stars with known brightness values (Moore 2001). In addition to its wide use and simplicity, LM can be expressed in ways that are intuitively easy to understand. For example, increases in night sky brightness (e.g., from light pollution) reduces the contrast between stars and their background; thus reducing an observer's ability to see fainter stars (Moore 2001). Moore (2001) further expressed this graphically by showing the relationship between LM and the number of stars that are visible to the naked eye (Figure 4.2.2-2). The LM scale is located in Table 4.2.2-1, along with the Bortle Dark-Sky scale.

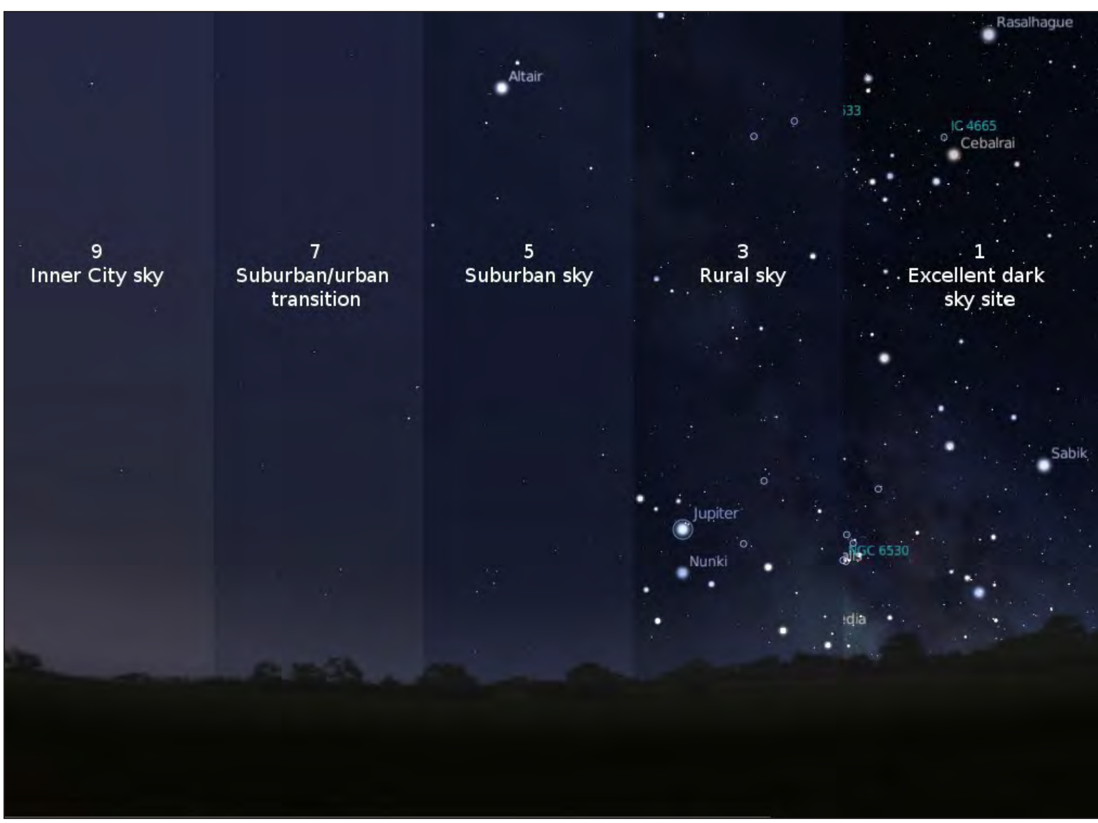

IMAGE GENERATED FROM STELLARIUM (WWW.STELLARIUM.ORG)

Figure 4.2.2-1. Composite image illustrating the range of night sky conditions based on the Bortle Dark-Sky Scale.

One drawback to using limiting magnitude as an indicator is that it does not perform well at the brighter and darker extremes compared to the Bortle Dark-Sky scale (Moore 2001). Another drawback of limiting magnitude estimates is that observer bias can skew results. However, it still provides a relatively easy measurement that can be used in conjunction with other night sky condition measurements.

Quantitative Indicators/Measures

The quantitative indicators and measures used to assess the monument's night sky condition are based on methodology developed by NPS Air Resources Division Night Skies Program scientists using CCD camera images. Detailed descriptions of their methodologies can be found in Duriscoe et al's. (2007) *Measuring night sky brightness with a wide field CCD camera,* and at the NPS Natural Lightscape website, along with additional night sky statistics and information for the monument and other national parks: (http://www.nature.nps.gov/air/lightscapes/index.cfm). The data we report for the monument's quantitative indicator/measures were collected as part of the Night Skies Program. The program's goals of measuring night sky brightness are to describe the quality of the nightscape, quantify how much it deviates from natural conditions, and how it changes with time due to changes in natural conditions, as well as artificial lighting in areas within and outside of the national parks (Duriscoe et al. 2007).

NPS scientists collected night sky data from one location in the monument, WGS84, latitude/longitude 36.78075, -103.96922. The data collection procedure used a CCD research grade digital camera, attached to a robotic mount and laptop computer. The computer choreographed the entire system, pointing the camera to pre-determined areas of the sky and captured a series of short exposures. These images were stitched together to form a mosaic of the entire sky that can be displayed in either a panoramic or hemispheric (fish-eye) view. Data were calibrated to stars of known brightness, allowing absolute brightness measures to be extracted from the images. The camera used a green filter, rejecting all other light from the infrared to the ultraviolet. This green or "V-band" filter approximates human night vision sensitivity. Data were displayed in V magnitudes, an astronomical brightness system. The metrics rely on the standard methods of astronomical photometry and its instrumentation and are a

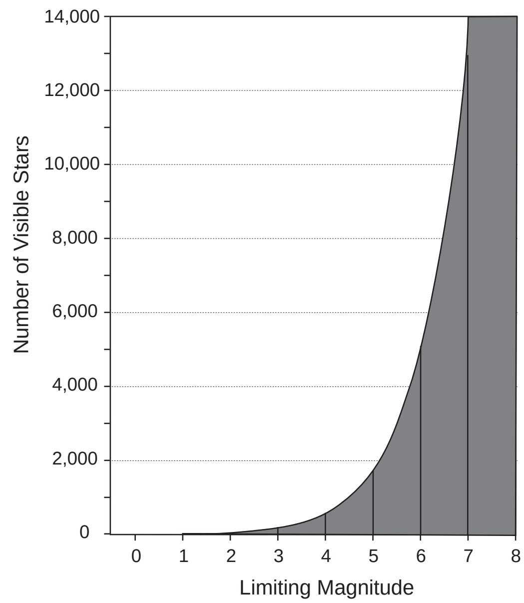

Figure 4.2.2-2. There is a sharp drop-off in number of visible stars as light pollution increases and the limiting magnitude decreases. (Adapted from Moore (2001)

novel attempt at quantitative descriptors that may be directly related to both visitor experience and ecosystem function.

For this assessment, we are using quantitative indicators/measures derived from the CCD camera images that assess brightness, including maximum sky brightness, minimum sky brightness, and two measures of integrated sky brightness.

The maximum sky brightness is typically found in the core of urban light domes (e.g. the semi-circular shaped light along the horizon caused by the scattering of urban light). The minimum sky brightness is typically found at or near the zenith (straight overhead). The integrated night sky brightness is calculated from both the entire celestial hemisphere as well as a measure of the integrated brightness masked below 20° altitude to avoid site-to-site variations introduced by terrain and vegetation blocking.

Indicators/Measures

- Sky Brightness:
  - Maximum Sky Brightness
  - Minimum Sky Brightness
  - Integrated Whole Sky
  - Integrated Sky Above 20 °

Brightness values are expressed as astronomical magnitudes per square arc second in the V-band. The astronomical magnitude scale is "upside down" with higher numbers correlating to darker conditions. An arc second is 1/3600th of an angular degree. Both are standard units in

Table 4.2.2-1. Bortle Dark-Sky and Limiting Magnitude Scales

Bortle Scale	LM	Milky Way	Astronomical Objects	Zodiacal Light/ Constellations	Airglow and Clouds	Nighttime Scene
Class 1 Excellent Dark Sky-Site	7.6-8.0	MW shows great detail, and Scorpio/ Sagittarius region casts an obvious shadow	Pinwheel galaxy (M33) is an obvious object	Zodiacal light has obvious color, and can stretch across entire sky.	Bluish airglow is visible near the horizon and clouds appear as dark blobs against stars.	Jupiter and Venus annoy night vision, ground objects are barely lit, trees and hills are dark.
Class 2 Typical Truly Dark Site	7.1-7.5	Summer MW shows great detail and has veined appearance	Pinwheel galaxy is an visible with direct vision, as are many globular clusters.	Zodiacal light bright enough to cast weak shadows after dusk and has apparent color.	Airglow may be weakly apparent, and clouds still appear as dark voids.	Ground is mostly dark, but object projecting into the sky are discernible.
Class 3 Rural Sky	6.6-7.0	MW still appears complex; dark voids and bright patches and a meandering outline are visible	Brightest globular clusters are distinct, Pinwheel galaxy visible with averted vision.	Zodiacal light is striking in Spring and Autumn, extending 60° above horizon.	Airglow is not visible, and clouds are faintly illuminated except at zenith.	Some light pollution evident along horizon, ground objects are vaguely apparent.
Class 4 Rural/ Suburban Transition	6.1-6.5	Only well above horizon does the MW reveal any structure. Fine details are lost.	Pinwheel galaxy is a difficult object, even with averted vision; Andromeda galaxy very visible.	Zodiacal light is clearly evident, but extends less than 45° after dusk.	Clouds are faintly illuminated except at zenith.	Light pollution domes evident in several directions, sky is noticeable brighter than terrain.
Class 5 Suburban Sky	5.6-6.0	MW appears washed out overhead, and is lost near the horizon	The oval of Andromeda galaxy is detectable, as is the glow in the Orion nebula.	Only hints of zodiacal light in Spring and Autumn.	Clouds are noticeable brighter than sky, even at the zenith.	Light pollution domes are obvious to casual observers, ground objects are partly lit.
Class 6 Bright Suburban Sky	5.1-5.5	MW only apparent overhead, and appears broken as fainter parts are lost to sky glow.	Andromeda galaxy detectable only as a faint smudge, Orion nebula is seldom glimpsed.	Zodiacal light is not visible, Constellations are seen, and not lost against a starry sky.	Clouds anywhere in the sky appear fairly bright as they reflect back light.	Sky from horizon to 35° glows with grayish color, ground is well lit.
Class 7 Suburban/ Urban Transition	4.6-5.0	MW is totally invisible or nearly so.	Andromeda galaxy and Beehive cluster are rarely glimpsed.	Zodiacal light is not visible, and constellations are most easily seen.	Clouds are brilliantly lit.	Entire sky background appears washed out, with a grayish or yellowish color.
Class 8 City Sky	4.0-4.5	MW not visible	Pleiades are easily seen, but precious few other objects are visible.	Zodiacal light not visible, and some dimmer constellations lack key stars.	Clouds are brilliantly lit.	Entire sky background has an orangish glow, and it is bright enough to read at night.
Class 9 Inner City Sky	<4.0	MW not visible	Only the Pleiades are visible to all but the most experienced observers.	Only the brightest constellations are discernible.	Clouds are brilliantly lit.	Entire sky background has a bright glow, even at the zenith.

the astronomical literature. The measurement process filters out the influence of bright stars, so that the measurement is of the sky background (e.g. the space between the stars). These preliminary data do not distinguish between natural light sources such as the Milky Way, and artificial light such as urban light scattering.

The methodology to measure night sky brightness across the entire celestial hemisphere is derived from NPS research. As a new scientific frontier, the methods and metrics are developing rapidly, and we anticipate further refinements and a published report in lieu of the preliminary data presented below.

4.2.3 Reference Conditions

The ideal night sky reference condition, regardless of how it's measured, is one devoid of any light pollution. However, results from night sky data collection throughout 90+ national parks suggest that a pristine night sky is very rare (NPS 2010b). The natural brightness of a night sky can be calculated and modeled, and current scientific efforts are addressing the subtraction of natural sky features. Modeling, combined with actual data captured from pristine sites, will eventually enable a measure of departure from natural reference conditions.

Bortle Dark-Sky Scale and Limiting Magnitude

A night sky with a Bortle Dark-Sky Scale class of 1 (LM > 7.6) is considered an observer's "nirvana" (Bortle 2001); unfortunately, a sky that dark is so rare that few observers have ever witnessed (Moore 2001). Thus, we considered a sky in Bortle's class 2, with a limiting magnitude value between 7.1-7.5 (typical truly dark skies) to be in good condition and class 3, with a limiting magnitude value between 6.6-7.0 to be of a moderate condition. Class 4 and below and a LM of 6.5 have a significantly degraded aesthetic quality and may introduce ecological disruption as well. At Class 4 and worse many night sky features important to observers are being lost from view due to the reduction in contrast from artificial lights. It is important to note that such degraded conditions can be restored toward a more natural state via improvements in outdoor lighting. Limiting magnitudes do not always correspond directly with the Bortle Dark-sky Scale, as a suite of visual observations comprise the determination of the Bortle Class.

Sky Brightness

Reference conditions for night sky brightness can vary somewhat based on the time of the night, the position of the Milky Way, and the activity of the sun which can increase "airglow," a kind of faint aurora. For the minimum night sky brightness measure, the darkest part of a natural night sky is generally found near the zenith. A value of 22.0 magnitudes per square arc second (msa) is considered to represent a pristine sky, though it may vary by more than ±0.3 depending on natural conditions. Lower (brighter) values indicate increased light pollution and a departure from natural conditions. The astronomical magnitude scale is logarithmic, so a change of 2.50 magnitudes corresponds to a 10x difference (1000%); thus a 19.5 msa sky would be 10x brighter than natural conditions. Minimum night sky brightness values of 21.5 to 22.0 msa, are generally considered to represent natural (unpolluted) conditions (Walker 1970, 1973, as cited in Duriscoe et al. 2007).

The maximum night sky brightness is often found in within the Milky Way of a natural sky. A typical measurement from the Sagittarius region of the Milky Way in a natural sky yields 19.2 msa. Other regions of the Milky Way are somewhat dimmer, or around 20.0-21.0 msa. A value brighter than 19.0 msa will result in impairment to human night vision and may be noticeable by casting faint shadows or causing glare. A value lower (brighter) than 17.0 represents a very bright areas of the night sky and would significantly impair human night vision and cast obvious shadows. Values for the brightest portion of the sky are of interest to the NPS because they represent unnatural intrusions on the nightscape, will prevent human dark adaptation, and may have effects on wildlife (Duriscoe et al. 2007). Maximum night sky brightness values of 21.0 to 21.5 msa, exclusive of the Milky Way, are generally considered to represent natural (unpolluted) conditions (C. Moore, NPS, pers. comm.). .

Integrated brightness of the entire sky background (excluding stars and planets) is an excellent index of sky quality, as it is a quantity that is site-specific and has significant relevance to the human visual experience. As more datasets are gathered by NPS scientists, the integrated brightness values will be placed into qualitative categories representing sky quality (Duriscoe et al. 2007). To allow site-to-site comparison among locations that have varying terrain or vegetation, a measurement can be made to integrate sky brightness only above 20° altitude. Values for integrated sky brightness (whole) of ~ -7.00 represent natural conditions. Values for integrated sky brightness (above 20°) of ~-6.20 represent natural conditions (C. Moore, NPS, pers. comm.).

4.2.4 Condition and Trend

Bortle Dark-Sky Scale and Limiting Magnitude

Based on the four site visits between 2004 and 2009, the Bortle Class is estimated at 2. Capulin Volcano NM is at the low end of this classification, and certain natural and atmospheric conditions are likely to result in an estimation of Bortle Class 3 on some nights. A limiting magnitude estimation made on the night of November 18, 2009 (selected as the reference

Table 4.2.4-1. Sky brightness values from Capulin Volcano NM recorded by the NPS Night Skies Program on 11/18/2009, third dataset of the night, indicating values of the darkest area (near Zenith), brightest area of the sky, and for integrated brightness (whole sky and sky above 20°)

Darkest (mag/sq arc-sec)	Brightest (mag/sq arc-sec)	Integrated Whole Sky (mag/sq arc-sec)	Integrated Sky above 20°(mag/sq arc-sec)
21.89	19.83	-7.18	-6.55

conditions) yielded 7.1. This value corresponds to the low end of Bortle Class 2, though there are many factors confound an exact translation of one system to another. These values represent a truly dark sky and are considered indicators of good condition.

Sky Brightness

The night sky brightness values at the monument are presented in Table 4.2.4-1. These are consistent with a night sky in good condition, though the data also show the notable impact of light pollution along the horizon. This section will be expanded when we receive NPS night sky report .

Overall Condition

For assessing the condition of the monument's night sky, we used two qualitative and one quantitative indicators/measures. These indicators/measures captured different aspects of factors contributing to a night sky, and a summary of them is listed in Table 4.2.2-2. The overall condition of the monument's night sky is good and represents a truly dark sky.

Condition Relative to Regional Context

Capulin Volcano NM's night sky range of influence is 250 km, which includes light pollution from cities as far away as Denver and Colorado Springs, Colorado, and Amarillo, Texas, and as close as Raton and Clayton, New Mexico (C. Moore, NPS, pers. comm.). It is one of the darkest locations within the "lightshed" that is discerned in Figure 4.2.4-1. However, the monument is situated within a relatively

Table 4.2.4-2. Summary of the night sky indicators/measures and their contributions to the overall night sky natural resource condition assessment.

Indicator/Measure	Description of How the Indicator(s) Contributes to the Overall Resource Condition	General Contribution of this Indicator or Measure to the Overall Resource Condition.
Bortle Dark-Sky Scale	This is a qualitative measure that uses a scale divided into nine classes. This is a relatively easy measure to use for night sky conditions and requires no special equipment. The scale is based upon how viewable certain features of the night sky, including the Milky Way, constellations, and even the nighttime scene are for astronomers.	The monument's night sky is considered to be a "truly dark site" when assessed using the Bortle Dark-Sky scale. It was ranked in the top 20 dark night skies out of 90+ measured national park skies.
Limiting magnitude	This is also a qualitative measure that local astronomers use to assess the brightness of the faintest stars to the naked eye. The limiting magnitude scale closely follows the Bortle Dark-Sky scale.	The limiting magnitude yielded a value 7.1, which is consistent with the value assigned using the Bortle scale, suggesting once again that the monument's night sky is dark.
Sky brightness • Maximum sky brightness • Minimum sky brightness • Integrated whole sky • Integrated sky above 20	This is a quantitative measure that assesses the sky brightness using four different parameters, including night light pollution along the horizon.	The monument's night sky brightness values are consistent with a night sky in good condition. However, there is notable impact from light pollution along the horizon.

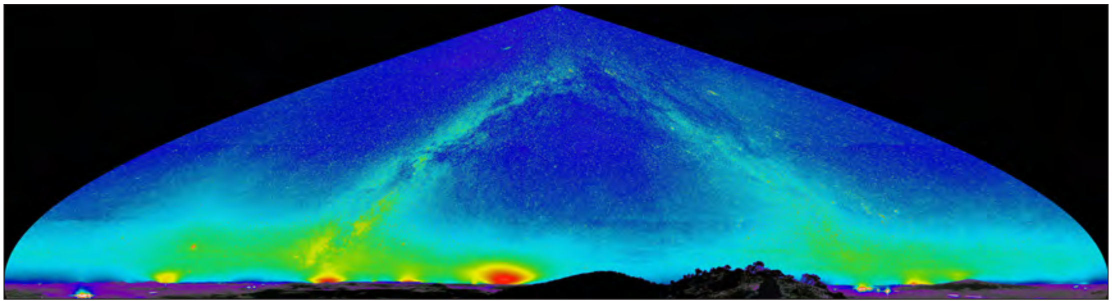

Figure 4.2.4-1. Image of Capulin Volcano NM's Night Sky.

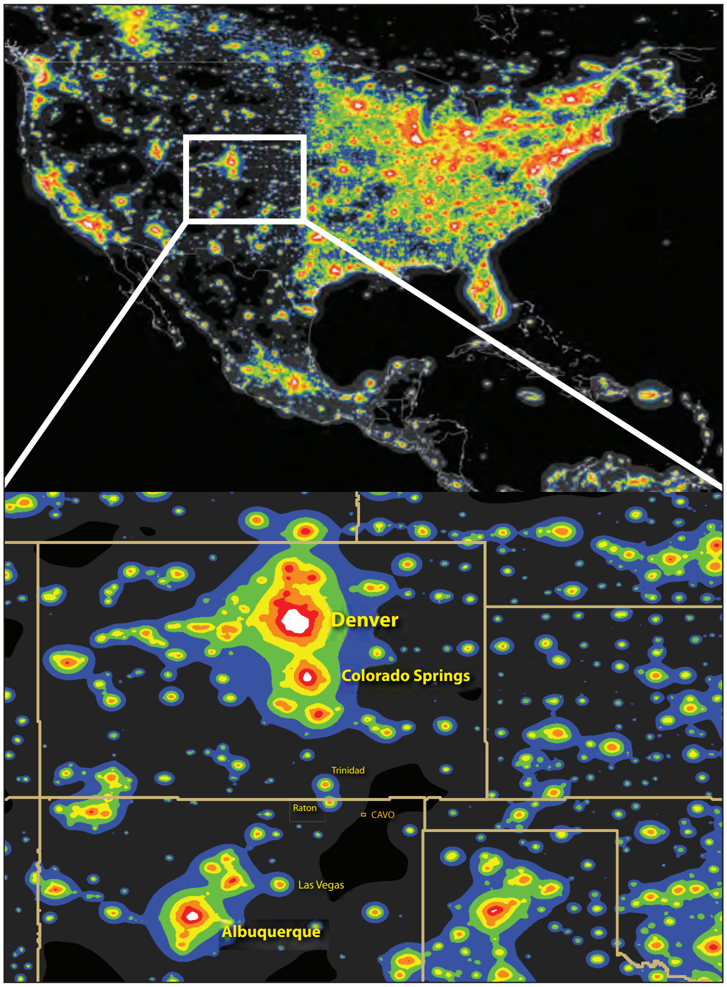

Figure 4.2.4-2. Artificial sky brightness in North America (Cinzano 2001).

dark hole compared to much of the surrounding region (Figure 4.2.4-2). The lack of artificial lighting and dark sky immediately surrounding Capulin Volcano NM provides the darkness necessary for star, planet, and moon visibility during clear nights. Although the monument's night sky condition is not pristine, it is very good and is among the top 20 darkest night skies measured throughout 80 national parks.

Trend

Even though the monument is at the edge of a dark hole that extends southwest of La Junta, CO to northeast of Las Vegas, NM, characterized by a lack of nighttime light pollution, light pollution appears to be a global-scale problem affecting nearly every country of the world. Light pollution in the monument's data is visible from cities as far away as Denver, CO. There is general widespread recognition that a continued degradation of night sky condition occurred over the past several decades (Cinzano 2002), and the night sky appears more seriously endangered than commonly believed (Cinzano et al. 2001). Furthermore, it is not surprising that the overall problem is more severe in the United States, Europe, and Japan, given their developed status. Although problems of light pollution might be perceived as primarily an urban problem, even our most pristine national parks are experiencing or are imminently threatened by light pollution (Duriscoe 2001).

Additionally, Cinzano (2002) examined changes in night sky brightness based on published measurements taken between 1947 and 2000. His analysis indicates a rapid increase in artificial night sky brightness; although he points out this conclusion is based on an overall average that cannot reliably be extrapolated to a specific rate of change at a given location. It is for this reason that we have listed the trend for Capulin Volcano NM as having insufficient data, but it should be recognized that this is within a context of overall global declines in the quality of our night sky. Without landscape-scale conservation efforts and a much higher awareness of the problem of light pollution, night sky degradations is likely to track with (or in excess of) population growth.

Key Uncertainty

The Bortle Dark-sky Scale and Limiting Magnitude estimations have the principle drawback in that they rely upon human visual observers and have the attendant bias. Differences in visual acuity as well as time and effort expended can influence the estimates of LM (Bortle 2001; Moore 2001). The CCD camera system and photometric measurement of night sky brightness is highly precise, but is nevertheless affected by vagaries in the atmosphere and in fluctuations in natural night sky brightness. Research is underway to minimize the influences of these factors upon the quantification of artificial light; and existing data can eventually be post-processed to this new standard (C. Moore, NPS, pers. comm.).

4.2.5 Sources of Expertise

Chad Moore, Program Manager for the NPS Natural Resources Program Center, Air Resources Division, Night Sky Program provided information pertaining to Capulin Volcano NM's night sky methodology and results. Moore earned a master's degree in earth science in 1996 and began working for the NPS shortly thereafter. Moore is the program manager for a small team of scientists that measure, restore, and promote the proper management of the night sky resource. He and team member, Dan Duriscoe, have developed an automated all-sky camera capable of precise measurement of light pollution. For the past few years they have been inventorying and monitoring the night sky at several US national parks.

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4.3 Soundscape

Indicators/Measures

- Noise Level
- Temporal Patterns of Noise

Condition - Trend

Good - Unknown

4.3.1 Background and Importance

The National Park Service considers a park's natural sounds to be comprised of physical resources, including natural (i.e., wind, water sounds, bird songs, leaves rustling, etc.) (Figure 4.3.1-1) and/or cultural (i.e., battle reenactments, quiet reverence, living history, etc.). These natural sounds are a park's acoustical resources and are essential to wildlife survival and visitor experiences (Lynch et al. 2011).

The preservation of the monument's acoustical environment is vitally important to overall ecosystem health. The peer reviewed literature widely documents that sound plays a critical role in intra-species communication, courtship and mating, predation and predator avoidance, and effective use of habitat. Additionally, similar studies have shown that wildlife can be adversely affected by sounds and sound characteristics that intrude on their habitats. While the severity of the impacts varies depending on the species being studied and other conditions, research strongly supports the fact that wildlife can suffer adverse behavioral and physiological changes from intrusive sounds (noise) and other human disturbances. Documented responses of wildlife to noise include increased heart rate, startle responses, flight, disruption of behavior, and separation of mothers and young (NPS 1995, US Department of Agriculture 1992, Barber et al. 2010).

Some large herbivores have been observed to habituate to acoustic stimuli (Krausman et al. 1998; Weisenberger et al. 1996). Habituation is a decreased responsiveness to a stimulus upon repeated exposure. There are many reasons why reports of habituation to noise should be interpreted with caution. A reduction in one form of response may represent a shift to another, unobserved mode of response rather than development of complete tolerance. Observation of more tolerant populations may be the result of sensitive individuals leaving the area (Bejder et al. 2006). Animals that remain may not have other viable options. Lastly, a

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Figure 4.3.1-1. Singing Western meadowlark completely habituated animal has learned to ignore a class of stimuli, some of which may signal biologically significant conditions.

While not necessary for survival, national park visitors also prefer sounds of nature and natural quiet while visiting parks. During a 2003 Capulin Volcano NM visitor study, visitors were asked to rate the importance of selected monument resources and qualities. Sounds of nature/natural quiet were rated 87% of time as important out of 258 groups surveyed, however, only 38% out of 253 visitor groups indicated that solitude was their most common activity while visiting the monument (NPS 2003). During a broader national park study, 72% of visitors said that one of the most important reasons for preserving national parks is to provide opportunities to experience natural peace and the sounds of nature (Haas and Wakefield 1998).

The natural ambient sound level (i.e., baseline condition) refers to the acoustical conditions that exist in the absence of human-caused noise, and the acoustical environment encompasses all of the physical resources that permit and affect sound transmission, as well as sounds present in the monument. Noise, on the other hand, is any human-created sound, aside from culturally relevant sounds, that degrades or masks these natural sounds, and is therefore considered undesirable. A person's ability to detect and hear sounds (i.e., audibility) of both natural and human-generated sounds, and how these sounds are perceived by visitors, comprises a park's "soundscape".

Natural quiet—the sounds of nature uninterrupted by human-caused noise—has been identified by Congress and the NPS as an important resource in national parks that must be protected (National Parks Overflights Act of 1987 ; National Parks Air Tour Management Act of 2000 ; NPS Management Policies 2006). Furthermore, NPS' Organic Act of 1916, Management Policy 4.9 for Soundscape Management (2006), and Director's Order 47 (2000), mandates the preservation of the acoustical environment and states that natural soundscapes will be restored if degraded, as well as protected from unacceptable impacts.

4.3.2 Data and Methods

The NPS Natural Sounds Program scientists conduct acoustical monitoring throughout parks to determine the status and trend of acoustical resources, but since the monument has not had any acoustical data collected, we will assess its soundscape in general terms based upon the sources, levels, and most common periods of audibility of sounds generated throughout each of the monument's acoustical environments. These aspects may be greatly influenced by the acoustical environments in which they occur.

Primary Sources of Sound at the Monument

The most common natural sounds that are heard from within the monument include weather related sounds (i.e., wind, rain, thunder), wildlife sounds, primarily bird songs or calls, and at times complete stillness (i.e. natural quiet).

The most common human-produced sounds heard throughout the monument include traffic noise from motorcycles, RVs, and buses, but most commonly from standard cars or trucks. Human voices/ conversations and monument staff activities, including operations, can be heard at different locations throughout the monument. And depending upon the time of year, different projects occur throughout the monument including snowplowing throughout the winter months. Periodic aircraft sounds, from both commercial airliners and military overflights, can also be heard in the monument. Even though one major highway (U.S. 64/87) provides access to the monument, it is located 3 miles away, which means that only the faintest highway traffic noise can be heard but most often no noise is detected from this highway. State highway NM325, runs along the western side of the monument's boundary and vehicles using this highway can be heard from some areas within the monument, but they are general not excessive.

Management Zones and their Associated Acoustical Environments

The condition of the monument's acoustical environment, as we have assessed it here, is based on both noise levels that might be detrimental to monument resources (e.g., wildlife), as well as human perception of the acoustical environment, as it relates to a visitor's experience. Both of these are likely heavily influenced by the acoustical environments within which they occur.

Based on the Alternative B, the preferred alternative, in the monument's draft General Management Plan (NPS 2010), the monument

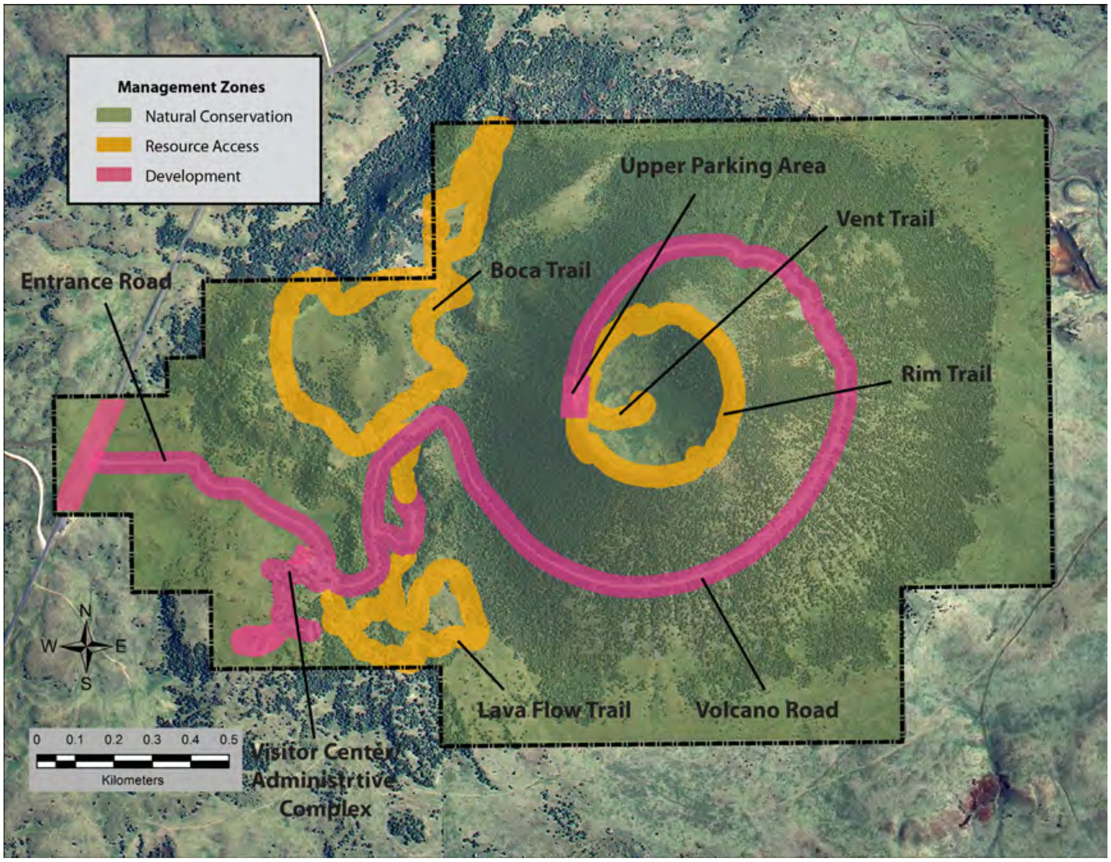

Figure 4.3.2-1. The management zones identified in Alternative B, the preferred alternative, of the draft Capulin Volcano NM General Management Plan (NPS 2010).

is divided into three management zones: (1) natural conservation, (2) resource access, and (3) park development (Figure 4.3.2-1). The type of designated activities within these management zones are described in greater detail below and greatly influence their acoustical environments and their ambient sound levels.

Natural Conservation Zone

The natural conservation zone encompasses the majority of the monument acreage and was established to provide visitors an opportunity to experience the natural features and solitude within the monument's landscape. In the natural conservation zone, the predominant sounds heard include those generated by nature. These include bird songs and calls during the spring and summer months, sounds of weather, including wind (and vegetation rustling from the wind), and rain, as well as times of silence. However, Capulin Volcano NM is a relatively small park, and the closer a visitor is to the road or a development, while in the natural conservation zone, the louder a human-generated noise will most likely be. But overall, this acoustical environment in this zone is very close to the monument's natural ambient sound level.

Resource Access Zone

The resource access zone includes all trails and provides visitors an opportunity to experience close contact with both natural and cultural resources and opportunities to learn about the monument through self-discovery and exploration. Although the resource access zone includes all the trails located in the monument, not all trails are equal with respect to their acoustical environment. The Boca and Lava Flow Trails are primarily adjacent to the natural conservation zone where the quietest conditions can be found, with the exception of occasional voices from fellow hikers. In contrast, the Rim and Vent Trails, which are hiked by many visitors, are located immediately adjacent to the upper parking area. Sounds carry very easily at the top of the volcano and sometimes, depending upon the weather conditions, a voice can be heard from the parking area to the other side of the Rim Trail. However, when it is windy, which is common at the monument and especially so at the top of the volcano, noises can be significantly masked.

Park Development Zone

The park development zone includes the entrance and Volcano Roads, visitor center/ administration complex and parking area, the picnic area, and upper parking lot (NPS 2010). This zone is where visitors stop at the visitor center to pay a fee, which produces stopping and starting of vehicles, as well as where they receive an orientation to the monument through programs and services. The monument maintenance yard, administrative offices, and visitor service operation locations and activities are concentrated in this zone as well.

Visitor Expectation of the Acoustical Environments

How a visitor perceives the acoustical environment, is at least in part dependent on their expectations for that environment (Benfield et al. 2010; Carles at al. 1999). One would not likely go into a busy shopping mall and be annoyed because they could not hear the birds singing outside. In contrast, a visitor going to a given park for solitude might very well be annoyed if human noises masked their ability to hear birds singing. Even within a given park, there are differences in both the acoustical environments as well as expectations for these environments. For example, the expectations of natural quiet are likely to be far less at a visitor center than they are at a pristine area of the park away from roads and human development.

Depending upon the acoustical environment (e.g., management zone) in which noise occurs, the condition may or may not be more negatively perceived. For example, the acoustical environment throughout the natural conservation zone is expected to be quieter for the majority of time compared to the resource access areas (i.e., along trails), and even more so compared to the monument development acoustical environments. Therefore, there is most likely less expectation from visitors that the developed areas, such as parking lots, and picnic area provide quiet and solitude.

Indicators/Measures

- Noise Level

For this indicator, we focus on noise levels. The complete absence of natural sounds would of course be considered as being a deteriorated condition, as the author Rachael Carson so effectively expressed as a symbol of a dying environment in her book Silent Spring. However, such an extreme condition is nowhere near the case at Capulin Volcano NM. Thus, we focus on the anthropogenic source of noise that may negatively influence visitor experience or other park resources (e.g., wildlife). We focus on noise levels because the response to sounds even from the same source may differ depending on its volume. A visitor yelling on a trail is more likely to be perceived negatively than that same visitor talking in a quiet voice.

Table 4.3.2-1. The dB levels of some familiar sounds.

Source	dB(A)
Human breathing at 3m	10
Whispering at 5m	20
Residential area at night	40
Busy restaurant	60
Curbside of busy street	80
Jackhammer at 2m	100
Train horn at 1m	120

Sound is perceived in terms of amplitude (loudness/volume/strength of sound), which is measured in decibels (dB) and in terms of frequency, which is related to the pitch of a sound and measured in Hertz (Hz). Like a temperature scale, the decibel scale goes below zero, and the average person can hear sounds to approximately 0 dB. Frequency is the number of times per second that the sound wave repeats itself and people with normal hearing can detect sounds between 20 Hz and 20,000 Hz and as low as 0 dB at 1,000 Hz. A common method for adjusting sound levels in relation to human hearing is A-weighting, and these values are denoted by dB(A). In Table 4.3.2-1, we have presented the dB levels of some familiar sources of nose in order to get an idea of the magnitude of the dB levels.

Indicators/Measures

- Temporal Patterns of Noise

For this indicator we focus on the temporal patterns of noise. A loud noise is much more likely to be perceived negatively if it is of long duration and/or occurs frequently. The honking of a horn would likely annoy some visitors, but a car alarm that is stuck on while the owner is off hiking would likely be dramatically more annoying.

4.3.3. Reference Conditions

From an ideal perspective, a good reference condition for the monument's acoustical environment would be that ambient sounds are predominant, if not exclusive, throughout the entire monument, despite the management zone designation. However, this is not possible since NPS also has a mandate to provide visitor opportunities, which is why areas throughout the monument have been specifically prescribed a certain type of management zone where more noise is acceptable and sometimes may even be the prominent sound depending upon time of day and season. For this reason, it is important to view indicators in the context of not only how loud, long, or frequently they occur, but also where and when they occur (Rossman 2004).

The most common natural sounds that are heard from within the monument include weather related sounds (i.e., wind, rain, thunder), wildlife sounds, primarily bird songs or calls, and at times complete stillness (i.e. natural quiet). These sounds tend to be below approximately 40-50 dB, with an obvious exception being thunder (Table 4.3.3-1).

In contrast much of the human generated noise is > 50 dB (Table 4.3.3-2). As we have previously indicated, it is not possible to maintain a purely natural acoustical environment, since NPS has a mandate to provide visitor opportunities, which is why areas throughout the monument have been specifically prescribed a certain type of management zone where more noise is acceptable. Thus, some sources of human generated noise are acceptable depending on how loud they are, where they are, and when they are heard (Table 4.3.3-3).

In general, we consider the soundscape to be in good condition when the sound expectation is met (or exceeded) most of the time for the acoustical environment. A moderate concern is when the sound expectation is not consistent with an environment's designated activity. A significant concern for the acoustical environment, is when noise is consistently more prominent than the natural sounds at any given area and time (Table 4.3.3-4).

Table 4.3.3-1. Approximate sound levels for common natural ambient sounds expected to be heard at Capulin Volcano NM.

Source	dB(A)s
Natural Quiet	0 -10
Rustling Leaves	20
Crickets (at Zion NP at 5 m [16 ft])	40
Birds Singing	30 - 60
Thunder (depends on distance)	100 – 120

Footnotes for sources in progress

Table 4.3.3-2. Approximate sound levels for common human generated sounds (noise) likely to be heard at Capulin Volcano NM.

Source	dB(A)s
Conversation at 5m	60[1]
Car (25/35 mph)(Germany)	64/67[2]
Light Truck or Van (25/35 mph) (Germany)	68/70[2]
Mowing (1m / 10m)	107/60
Snowplowing (< 35 mph)	83
Commercial Flights (Boeing 707 at 1 mi)	90
Military Overflights	100 – 120

1

2 Source: Steven (2005), summarized in Silent Project (2011).

Footnotes for sources in progress

4.3.4 Condition and Trend

Noise Level

Of all human generated noise heard in the monument, ones generated from military overflights are probably the loudest. Although not as loud because they are generally at higher altitudes, flights of all types affect all areas within the monument. The Piñon Canyon Maneuver Site (PCMS)-a 235,896 acre U.S. Army base training site for Fort Carson- is located in southeastern Colorado. The purpose of PCMS is "to provide critical maneuver lands" for soldiers from Fort Carson and other military bases, and is the second largest area in the United States devoted to maneuver training. Army aircraft flyovers do occur occasionally in the area surrounding the monument and the noise is loud but very short in duration. A visitor study was conducted at White Sands National Monument to determine visitor response to military aircraft overflights since an Air Force base is adjacent to White Sand's boundary. In general, visitors became annoyed by the jet

Table 4.3.3-3. The acoustical environments associated with each management zone indicating the types of appropriate and inappropriate sounds that might be experienced for that environment.

Management Zone	Actual and Expected Acoustic Environment
Natural Conservation	In this zone, the dominant sounds, as well as the expectation of sounds by visitors are comprised of the natural ambient sounds such as wind, leaves rustling, birds singing, thunder claps, etc. Sometimes faint human-generated noises can be heard but are typically infrequent. Noise levels that interfere with wildlife behavior or auditory signals are rare. The sound levels are almost exclusively comprised of the low decibel producing sounds, with the exception of thunderclaps. Inappropriate noises in this zone include hikers using excessively loud voices (e.g., talking loudly or yelling), vehicles that are driving at excessive speeds or without properly functioning mufflers such that they can be heard more prominently, and low to high flying aircraft.
Resource Access	In this zone, the dominant sounds, as well as the expectation of sounds by visitors are comprised of the natural ambient sounds such as wind, leaves rustling, birds singing, thunder claps, etc., but appropriate noises include occasional voices from recreational activities including hiking and interpretive programs along the trails, occasional traffic noises, and occasional mechanized equipment noises, although, if audible, are distant. Noise levels that interfere with wildlife behavior or auditory signals are infrequent to rare. The sound levels are almost exclusively comprised of the low-infrequently moderate decibel producing sounds. Inappropriate noises in this zone include hikers using excessively loud voices (e.g., talking loudly or yelling), vehicles that are driving at excessive speeds or without properly functioning mufflers such that they can be heard more prominently, and or increased starting and stopping or engines and car doors shutting, frequent mechanized equipment noise, and low to moderately low flying aircraft.
Park Development	In this zone, the dominant sounds are natural sounds when human-created sounds are absent (typically during low visitation), however, appropriate noises and expectation of noise for this zone include normal conversation voices, motorized vehicles driving by, short-duration idling, or starting/stopping of vehicles, periodic use of motorized tools and heavy equipment. Noise levels that interfere with wildlife behavior or auditory signals are generally infrequent but sometimes common. The sound levels are mostly comprised of the low-moderately high decibel producing sounds. Inappropriate noises in this zone include excessively loud voices (e.g., talking loudly or yelling), vehicles that are driving at excessive speeds or without properly functioning mufflers such that they can be heard more prominently, car horns, long durations of bus idling, and low flying aircraft.

Table 4.3.3-4. The reference conditions used to determine whether the condition of the soundscape at Capulin Volcano NM is good, of moderate concern, or of significant concern.

Good	Moderate Concern	Significant Concern
Natural sounds dominate the landscape in natural conservation and resource access zones, and noises in the development zone are mostly appropriate for that area. Inappropriate noises, if they occur are short in duration and very infrequent. Noise levels that interfere with wildlife behavior or auditory signals are infrequent to rare.	Natural sounds dominate the landscape in natural conservation and resource access zones. Noises in the development zone are usually appropriate for that area. Inappropriate noises, are mostly short in duration and relatively infrequent, but enough that some visitors might be annoyed. Wildlife may exhibit some response (e.g., fleeing from noises), but this is not enough to influence their survival or reproduction.	Inappropriate sounds are frequently heard in the natural conservation and resource access zones. Noises in the development zone are the dominant sounds and inappropriate noises are too frequent and/or often of long duration. Inappropriate noises, are long enough or frequent enough than many visitors are likely annoyed. The survival and/or reproduction of wildlife is negatively impacted.

noise if it was frequent, in close succession, and severe enough (Miller et al. 1999). The overflight frequency that visitors experience at White Sands versus at Capulin Volcano is significantly different, therefore, it is relatively safe to assume that even though the overflight noise is one of the loudest noises ever heard throughout the monument, it is also very short in duration and infrequent.

But overall, we believe that there is probably general concordance between the actual acoustical environments and the expectations for those environments within (1) the Natural Conservation Zone, (2) the Boca and Lava Flow Trails for the Resource Access Zone, and (3) the Entrance Road, Volcano Road, and Visitor Center/Administration Complex within the development zone. Even though the latter is probably the noisiest area of the monument, visitors are more likely to expect this and are unlikely to pull into the parking lot of an administrative complex for solitude. Rather, they are using this as a stopping point to pay fees, gather information, or use services such as the restrooms or bookstore before going to

Figure 4.3.4-1. The visitor center parking lot is the largest and accommodates more vehicles than others in the monument.

other areas of the monument where a greater expectation for the lack of noise is more likely. In many ways, concentrating the monument's operational activities and developments adjacent to the primary visitor services area creates one central location where the majority of noise is generated. Also, visitors do not typically spend prolonged periods of time in this area unless they are in the visitor center looking at exhibits, browsing the bookstore, or watching the monument's film instead of being outside. Similarly, the picnic area attracts visitors who are looking for a place to relax and eat their lunch/snacks versus participating in noisier activities. Although, depending upon the size and energy level of the group, conversations may rise to a level where visitors may experience sound levels to be annoying.

Noises generated from visitors and monument operations are much more prevalent in the development zone, but are also localized. The visitor center parking lot area and park administration and maintenance operations is where the greatest number of noise-generating activities can be heard. This is due to the fact that everyone entering the monument must stop at the visitor center to pay a fee, which produces stopping and starting of vehicles, as well as increased monument staff activity due to the maintenance yard, administrative offices, and visitor service operation locations concentrating in this acoustical environment. The visitor center parking lot is the largest in the monument, accommodating more vehicles than at the picnic area or upper parking lot area (Figure 4.3.4-1). Therefore, it is more likely that the 'stop/go' vehicle movements increase the noise levels (United Kingdom Noise Association n.d.).

In the monument's visitor study (National Park Service 2003), survey participants were asked to include the number of people in their group. From this information, we extrapolated that during July 2003 (one of the busiest months during a relatively high visitation year) there were an estimated 3,545 vehicles, with approximately 18% of those being larger than a standard vehicle and approximately 2% representing motorcycles. Thus, during the busiest times, one may expect to find vehicles arriving at an approximate rate of 26 vehicles per hour, with arrivals and departures likely unevenly spaced.

The road and picnic area are also located within the park development zone, but unlike the visitor center area, do not create the same acoustical environment even though the same activities are permitted. This is largely due to the fact that there is less starting and stopping of vehicles, and the speed limit along the entrance and Volcano Roads is 25 mph. Lower speeds reduce noise levels, and research from the Conservation Law Foundation, showed that a 12-15mph increase in speed results in noise levels rising by 4-5 decibels. An increase of 5 decibels causes noise to travel almost 80%

farther so the spatial noise footprint increases by more than a factor of three (K. Fristrup, pers. comm.).

Out of all developed areas in the monument, the upper parking lot may be the one location where sound expectations vary from the actual experience, at least during peak visitation. Even though the upper parking lot is limited in vehicle capacity, and throughout a portion of the summer, managed by monument staff to ensure vehicle overcrowding does not occur, it is a highly concentrated area. For example, as one drives to the top of the volcano, the upper parking lot is immediately reached, creating space for parking only. This is the first location where visitors are able to get out of their vehicles to take in the sweeping views of the surrounding landscape. As a result, often times, visitors are walking around the parking area, conversing, and vehicles are starting and stopping, sometimes creating a noisy and congested environment.

There is probably less concordance between the actual acoustical environment and the expectation for that environment along the Rim and Vent Trails within the resource assess zone and at the upper parking area within the development zone. The upper parking area is probably a location where sound expectations vary most from the actual experience, at least during peak visitation. Although visitors are likely to expect the presence of other visitors, the upper parking area is a very popular destination and even though the number of vehicles is limited by the allotted number of parking spaces, it can be very busy, and consequently noisy. The Rim and Vent Trails are adjacent to the upper parking area and visitors may be surprised to see how well noises from the upper parking area can be heard along those trails. In contrast, the Boca and Lava Flow Trails are primarily adjacent to the natural conservation zone where natural sounds do dominate the acoustical environment, although sometimes voices from hikers or interpretive talks can be heard but are typically at a conversational level.

Finally, the monument's natural conservation zone is primarily comprised of the natural sounds including wind blowing, vegetation rustling, and birds singing. Some areas within this zone are adjacent to the entrance and Volcano Roads, which may briefly mask the natural sounds with noises such as vehicles driving by. But relatively speaking, this zone is one where visitors can truly experience solitude with minimal noise intrusions.

Temporal Patterns of Noise

The loudest noises in the monument are generated from aircraft overflights and monument operations. However, at this time, both of these sources are also infrequent and short lived.

Snowplowing, mowing, and heavy equipment operation are some of the most frequent sources of noise from monument operations, and these are intermittent and change, depending on the season.

Commercial airlines do fly over the monument in their flight path for landing at Colorado Springs, Denver, or Santa Fe. Informal observations made by a former monument maintenance worker (L. Thwaite, pers. comm.) indicated that commercial flight frequency increased between the years of 2009 and 2010, making overflights more frequently heard at the monument. Commercial overflights at higher altitudes have presented issues for other parks' soundscape condition (L. Marin, pers. comm.).

Military overflights are rare (typically less than once per month on average), but they often fly at lower altitudes and are extremely loud. Low level tactical training maneuvers can sometimes fly as low as 200 feet from the ground surface. Thus these flights can be quite disruptive, but at this point are rare and of short duration.

In addition, private planes do on rare occasion fly near the monument, but at present are infrequent.

Noise from traffic and human conversations are far more common at the monument. Both of these sources are typically generated from park visitors and both exhibit strong seasonal and daily patterns.

Seasonal and Daily Visitation Patterns

Most of the human-generated sounds that can be heard in the monument are produced within the monument with the exception of aircraft noise. In addition, the majority of human-generated sounds result from visitation, which exhibits a strong seasonal pattern. Data on monument visitation by month from 2000 – 2010 indicate that visitation peaks during the months of June-August (Figure 4.3.4-2). On average, approximately 60% of the total visitation (597,766 visitors during this period) occurred during this time period alone and 76% occurred from May-September (National Park Service Public Use Statistics Office 2011).

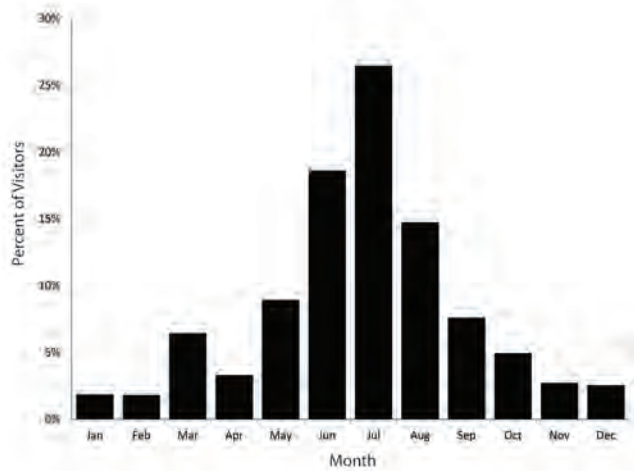

Figure 4.3.4-2 Monthly patterns of visitation from 2000 – 2010 based on the National Park Service Public Use Statistics Office (2011).

In addition to the seasonal nature of visitation, there is a strong daily pattern as well. In the monument's 2003 visitor study (National Park Service 2003), 31% percent of visitors surveyed arrived between noon and 2 pm (Figure 4.3.4-3a), and 32% depart between 1 pm-3 pm (Figure 4.3.4-3b). Also, based on an informal assessment of hourly visitation between Memorial Day and Labor Day 2007-2009, monument staff discovered the highest number of visitors arrived between the hours of 10 am-2 pm, which supports the 2003 visitor study results.

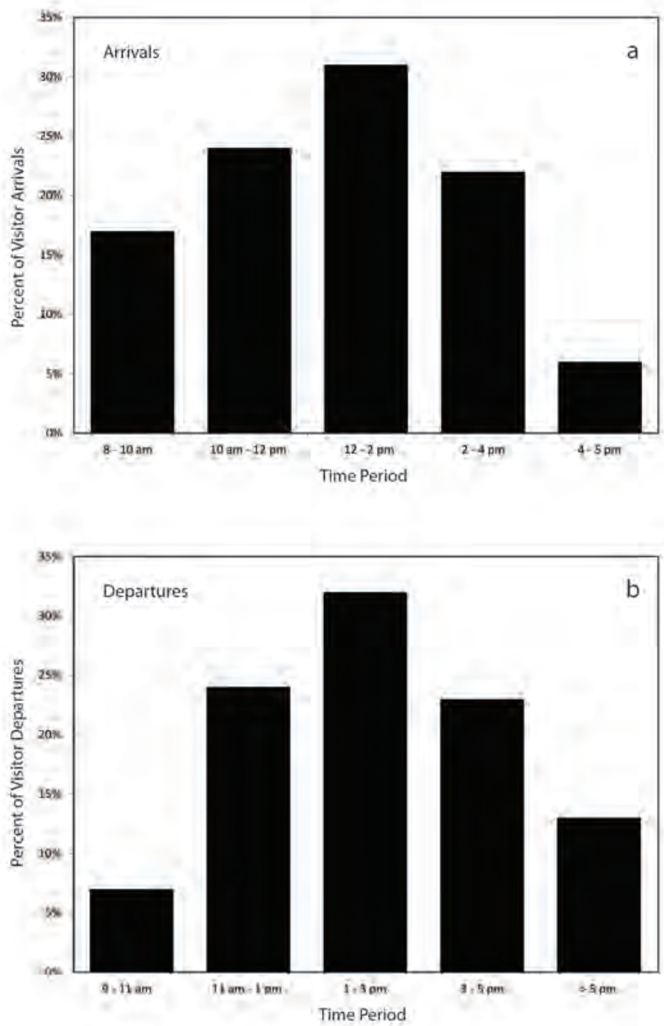

Figure 4.3.4-3. Daily patterns of arrival (a) and departure (b) of visitors based on a National Park Service Visitor Study (National Park Service 2003).

Overall Condition

For assessing the condition of soundscape, we two indicators/ measures, which are summarized in Table 4.3.4-4. There may be times when areas of the monument are primarily comprised of human generated noises, particularly during busy summer days from late morning to early afternoon, or when school buses transport high numbers of students for various educational/interpretive programs at the monument. However, these occurrences are relatively infrequent and concentrated, creating an acoustical environment, that is often characterized by its natural sounds. Furthermore, monument visitation is at a level that even during those busiest times in summer, visitors have an opportunity to find natural quiet along the trails that are adjacent to the natural conservation zone, as well as throughout most of the monument the majority of the year. An additional advantage to the monument's acoustical environment is that it is located in a rural environment, and even though a major highway is in the vicinity, it is located 3 miles south of the monument's boundary, and on extremely rare occasions, can only be faintly heard when it is completely quiet. Therefore, we consider the monument's acoustical environment, to be in good condition but trend is unknown at this time.

Table 4.3.4-4. Summary of the soundscape indicators/measures and their contributions to the overall soundscape natural resource condition assessment.

Indicator/Measure	Description of How the Indicator(s) Contributes to the Overall Resource Condition	General Contribution of this Indicator or Measure to the Overall Resource Condition.
Noise level	The types of noises can impact the condition of a soundscape, but the levels of those noises also dramatically influence the soundscape condition. A person speaking at a conversational level may not be annoying, whereas a person yelling may become extremely annoying.	The loudest noises that occur in the monument, such as aircraft and monument maintenance operations, are also the least frequent. The most common noises generated result from traffic and human conversation, which exhibit strong temporal patterns. The noise levels tend to occur in specific areas of the monument, and as a result, exhibit a characteristic of containment.
Temporal patterns of noise	The duration and timing of noises also greatly influence the condition of a soundscape. The monument's visitation patterns suggest that patterns of noise follow the overall visitation pattern, with a few notable exceptions.	The busiest time at the monument, therefore, most likely the loudest, is typically on a Saturday during the months of June-July between the hours of noon-3 p.m. A few exceptions to this pattern include snowplowing during the winter months and noises from aircraft which occur throughout the year but relatively infrequently.

Level of Confidence and Key Uncertainties

Assessing the quality of a soundscape is highly dependent upon visitor interpretation of the sounds that are heard and their expectation for their national park experience. In general, studies have shown that visitors prefer sounds of nature, specifically while visiting a nature-based area (Benfield et al. 2010; Carles et al. 1999). It is less clear what the visitor threshold of tolerance for noise, especially when different park zones are managed for different activities. So one key uncertainty is knowing what sounds and in what areas monument-specific visitors deem acceptable versus annoying.

A proposed plan by the Air Force to create a low-altitude training range that would include most of southern Colorado and northern New Mexico has recently been cancelled. The cancelling of the proposed low altitude tactical training area undoubtedly benefits the monument's acoustical environment,, but may present some concern if the Air Force reconsiders the plan at a future date. The monument is required to have an Air Tour Management Plan developed due to the existing or potential for air tour activity. It is expected that with aircraft activity on the rise in many parks, and without Federal Aviation Administration assistance in regulating the increases, the amount of uninterrupted time available for visitors to notice, appreciate and contemplate quiet will decrease proportionately. (NPS 1995).

4.3.5 Sources of Expertise

The NPS Natural Sounds Program scientists help parks manage sounds in a way that balances the various expectations of park visitors with the protection of park resources. They provide technical assistance to parks in the form of acoustical monitoring, data collection and analysis, and in developing acoustical baselines for planning and reporting purposes.

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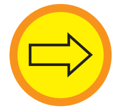
4.4 Air Quality

Indicators/Measures

- Visibility haze index
- Level of ozone
- Atmospheric wet deposition in total N and total S

Condition - Trend



Moderate Concern - Stable Trend

4.4.1 Background and Importance

Under the direction of the NPS' Organic Act, Air Quality Management Policy 4.7.1, and the Clean Air Act (CAA) of 1970, the NPS has a responsibility to protect air quality and any air quality related values (e.g., scenic, biological, cultural, and recreational resources) that may be impaired from air pollutants.

One of the main purposes of the CAA is "to preserve, protect, and enhance the air quality in national parks" and other areas of special national or regional natural, recreational, scenic or historic value. The CAA includes special programs to prevent significant air quality deterioration in clean air areas and to protect visibility in major national parks and wilderness areas (NPS-ARD 2011a).

Different categories of air quality areas have been established through the authority of the CAA: Class I, II, and III. Like most National Park Service areas, Capulin Volcano NM is designated as a Class II airshed (Figure 4.4.1-1). These classes are allowed different levels of permissible air pollution, with Class I receiving the greatest protection and strictest regulation. The CAA gives federal land managers responsibilities and opportunities to participate in decisions being made by regulatory agencies that might affect air quality in the federally protected areas they administer (NPS-ARD 2011b).

It's important to note that even though the CAA gives Class I areas the greatest protection against air quality deterioration, NPS management policies do not distinguish between the level of protection afforded to any unit of the National Park System (NPS 2006).

Air Quality Standards

Air quality is deteriorated by many forms of pollutants that either occur as primary pollutants, emitted directly from sources such as power plants, vehicles, wildfires, and wind-blown dust, or as secondary pollutants, which result from atmospheric chemical reactions. The CAA requires the Environmental Protection

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Figure 4.4.1-1. Capulin Volcano NM is designated as a Class II airshed.

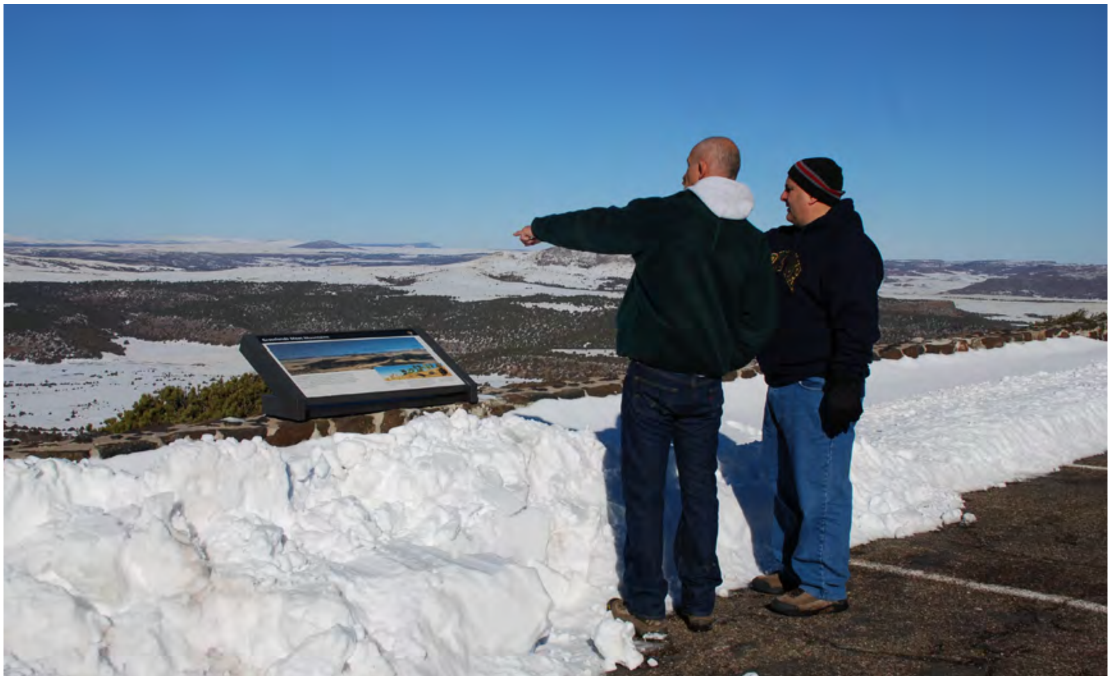

Figure 4.4.1-2. Visitors viewing the scenic vistas from Capulin Volcano NM.

Agency (EPA) to establish National Ambient Air Quality Standards (NAAQS) (40 CFR part 50) to regulate these air pollutants that are considered harmful to human health and the environment (EPA 2011a). The two types of NAAQS are primary and secondary, with the primary standards establishing limits to protect human health, and the secondary standards establishing limits to protect public welfare from air pollution effects, including decreased visibility, damage to animals, crops, vegetation, and buildings (EPA 2011a).

The NPS' Air Resources Division (NPS-ARD) air quality monitoring program uses EPA's NAAQS, natural visibility goals, and ecological thresholds as benchmarks to assess current conditions of visibility, ozone, and atmospheric deposition throughout park service areas.

Visibility affects how well (acuity) and how far (visual range) one can see (NPS-ARD 2002), but air pollution can degrade visibility. Both particulate matter (e.g. soot and dust) and certain gases and particles in the atmosphere, such as sulfate and nitrate particles, can create haze and reduce visibility.

Visibility can be subjective and value-based (e.g. a visitor's reaction viewing a scenic vista while observing a variety of forms, textures, colors, and brightness) (Figure 4.4.1-2) or it can be measured objectively by determining the size and composition of particles in the atmosphere that interfere with a person's ability to see landscape features (Malm 1999). The viewshed section (4.1) of this assessment addresses the subjective aspects of visibility, whereas, this section addresses measurements of particles and gases in the atmosphere affecting visibility.

Ozone is a gaseous constituent of the atmosphere produced by reactions of nitrogen oxides (NO_x) from vehicles, power plants, industry, and fire and volatile organic compounds from industry, solvents, and vegetation in the presence of sunlight (Porter and Biel 2011). It is one of the most widespread air pollutants (NPS-ARD 2003), and the major constituent in smog. Ozone can be harmful to human health, and it is also phytotoxic, causing foliar damage to plants (NPS-ARD 2003). The foliar damage requires the interplay of several factors, including the interaction of the plant to the ozone, the level of ozone exposure, and the exposure environment. The highest ozone risk exists when the species of plants are highly sensitive to ozone, the exposure levels of ozone significantly exceed the thresholds for foliar injury, and the environmental conditions, particularly adequate soil moisture, foster gas exchange and the uptake of ozone by plants (Kohut 2007).

Ozone penetrates leaves through stomata (openings) and oxidizes plant tissue, which alters the physiological and biochemical processes (NPS-ARD 2011c). Once the ozone is inside the plant's cellular system, the chemical reactions can cause cell injury or even death (NPS-ARD 2011c), but more often reduces the plant's resistance to insects and diseases, reduces growth, and reduces reproductive capability (NPS-ARD 2011d).

Air pollutants can be deposited to ecosystems through rain and snow (wet deposition) or dust and gases (dry deposition). Nitrogen and sulfur air pollutants are commonly deposited as nitrate, ammonium, and sulfate ions and can have a variety of effects on ecosystem health, including acidification, fertilization or eutrophication, and accumulation of toxins (NPS-ARD 2010a). Atmospheric deposition can also change soil pH, which in turn, affects microorganisms, understory plants, and trees (NPS-ARD 2010a). Certain ecosystems are more vulnerable to nitrate or sulfate deposition than others, including high-elevation ecosystems in the western United States, upland areas in the eastern part of the country, areas on granitic bedrock, coastal and estuarine waters, arid ecosystems, and some grasslands (NPS-ARD 2010b).

According to the EPA, in the United States, roughly ⅔ of all SO_2 and ¼ of all NO_x come from electric power generation that relies on burning fossil fuels. Sulfur dioxide and nitrogen oxides are released from power plants and other sources, and ammonia is released by agricultural activities, feedlots, fires, and catalytic converters. In the atmosphere these transform to sulfate, nitrate, and ammonium and can be transported long distances across state and national borders, impacting resources in remote areas, including Capulin Volcano NM (EPA 2011b).

4.4.2 Data and Methods

The approach we used for assessing the condition of air quality within Capulin Volcano NM's airshed was developed by the NPS-ARD for use in Natural Resource Condition Assessments (NPS-ARD 2010b,c). Interpolated values generated by NPS-ARD, averaged over 5 years were used to assess condition. NPS-ARD used all available data from NPS, EPA, state, tribal, and local monitors to generate the interpolated values across the contiguous U.S., with a specific value assigned to the center of each park. These values provided estimates for visibility and ozone in the absence of onsite monitoring. The atmospheric wet deposition interpolated values for the monument are virtually identical to the measured values, because of the way the interpolation is computed (distance-weighted). Even though the data are derived from all available monitors, the data from the closest monitor will "outweigh" the rest. For the monument, the interpolations are virtually identical to the monitored values, keeping in mind that the interpolated values represent a 5-year average.

Indicators/Measures

Visibility Haze Index

Visibility is monitored by the Interagency Monitoring of Protected Visual Environments (IMPROVE) Program (NPS-ARD 2010a). The NPS-ARD assesses visibility based on the deviation of the current Group 50 visibility conditions from estimated Group 50 natural visibility conditions; (i.e., those estimated for a given area in the absence of human-caused visibility impairment (EPA-454/B003-005). Group 50 is defined as the mean of the visibility observations falling within the range of the 40th through the 60th percentiles, as expressed in terms of a Haze Index in deciviews (dv). A factor of the haze index is light extinction, which is used as an indicator to assess the quality of scenic vista and is proportional to the amount of light lost due to scattering or absorption by particles in the air as light travels a distance of one million meters (NPS-ARD 2003). The haze index for visibility condition is calculated as follows:

Visibility Condition/Haze Index (dv) =
current Group 50 visibility – estimated Group 50 visibility
(under natural conditions)

The deciview scale scores pristine conditions as a zero and increases as visibility decreases (NPS-ARD 2010b).

Indicators/Measures

Level of Ozone

Ozone is monitored as part of the NPS Gaseous Pollutant Monitoring Program, in partnership with the EPA's CASTNet Program (Porter and Biel 2011). The assessment for ozone levels at the monument was made by referencing NPS ARD's 5-year interpolated value average tables.

Indicators/Measures

Atomospheric wet deposition in total N and total S

Atmospheric deposition can be monitored in both wet and dry forms, but for the purposes of this assessment, we will use wet deposition

NPS

Figure 4.4.2-1. Wet deposition monitoring station at the monument..

monitoring data only because most areas of the country do not have dry deposition data available, including the monument.

Wet deposition is monitored across the United States as part of the National Atmospheric Deposition Program/National Trends Network (NADP/NTN; NPS-ARD 2003). The values for wet deposition condition are expressed as the average amount of nitrogen (N) or sulfur (S) in kilograms deposited over a one-hectare area in one year (kg/ha/yr) (NPS-ARD 2003).

Wet deposition data have been collected on-site at the monument since 1984 following the protocols set forth by the NADP/NTN. The protocol changed in 1994, however, the change did not affect NH_4 and only slightly affected NO_3 and SO_4, (NADP 2011a) so data pre and post 1994 can be compared (NPS-ARD 2010a). The monument's wet deposition monitoring station is equipped with a standardized precipitation collector and rain gauge (Figure 4.4.2-1).

Weekly samples are collected and processed following a standard operating procedure established by Dossett and Bowersox (1999). The samples are sent to the Central Analytical Laboratory (CAL), Illinois State Water Survey for processing, and data from the field observer report forms are entered into a relational database. The results of the analyses are then loaded into NADP's database, merged with descriptive information and posted at http://nadp.sws.uiuc.edu/sites/siteinfo.asp?id=NM12&net=NTN (NADP 2011b).

4.4.3 Reference Conditions

The reference conditions against which current air quality indicators are assessed are identified by NPS ARD (2010b) for NRCAs and listed in Table 4.4.3-1.

Visibility

A visibility condition estimate of less than 2 dv above estimated natural conditions indicates "good" condition, estimates ranging from 2-8 dv above natural conditions indicate "moderate" condition, and estimates greater than 8 dv above natural conditions indicate "significant

Table 4.4.3-1. Reference conditions for air quality indicators.

Air Quality Indicator	Significant Concern	Moderate	Good
Visibility	>8 dv	2-8 dv	< 2 dv
Ozone	≥ 76 ppb	61-75 ppb	≤ 60 ppb
Wet deposition (total N and total S)	>3 kg/ha/yr	1-3 kg/ha/yr	< 1 kg/ha/yr

Source: NPS-ARD 2010b

concern." Although the dv ranges of these categories were selected somewhat subjectively, the NPS-ARD chose them to reflect the variation in visibility conditions across the monitoring network as closely as possible.

Ozone

The ozone standard set by the EPA at a level to protect human health, 75 parts per billion (ppb) averaged over an eight-hour period, is used as a benchmark for rating current ozone condition. The three-year average of the fourth-highest daily maximum eight-hour average ozone concentrations measured at each monitor in an area must not exceed 75 ppb in order to be in compliance with the EPA standard.

The NPS-ARD rates ozone condition as "good" if the ozone concentration is less than or equal to 60 ppb, "moderate" if the concentration is between 61 and 75 ppb, and of "significant concern" if the concentration is greater than or equal to 76 ppb.

Wet Deposition

The NPS-ARD considers parks with less than 1 kg/ha/yr of atmospheric wet deposition of nitrogen or sulfur compounds to be in "good" condition, those with 1-3 kg/ha/yr to be in "moderate" condition, and parks with wet deposition greater than 3 kg/ha/yr to be of "significant concern."

4.4.4 Condition and Trend

Condition for all air quality indicators are listed in Table 4.4.4-1.

Visibility

All visibility data were derived from NPS ARD Air Atlas interpolated 5-year average values (2005-2009 and 2001-2005) (NPS-ARD 2011e). All interpolated values for the monument's visibility condition fell within the moderate condition rating, which indicates visibility is degraded from the good reference condition of <2 dv above the natural condition. No visibility trend was reported specifically for the monument, but in considering the overall trend of visibility throughout national parks, NPS-ARD analyzed visibility data for 157 parks during the period of 2008-1999. Only five of the parks showed a significant degrading trend on either clear or hazy days, with none of those parks located west of the Mississippi River, except for Hawaii (NPS-ARD 2010a). The majority of the parks measured during the haziest days revealed no visibility trend (NPS-ARD 2010a).

Ozone

All ozone data for the monument were derived from interpolated values analyzed by NPS-ARD (2011f), reported in the Air Atlas tables. All of the 5-year interpolated averages from the Air Atlas tables (2005-2009 and 2001-2005) resulted in a moderate ozone condition ranking for the monument.

Six plant species found within the monument have been identified as ozone-sensitive (NPS-ARD 2006) and four of those are ozone bioindicators (Table 4.4.4-2). In order to be considered as an ozone bioindicator most of the following criteria must be met:

Table 4.4.4-1. Condition results for air quality indicators at Capulin Volcano NM

Data Span	Ozone	Visibility	Total N (kg/ha)	Total S (kg/ha)
2009-2005	Moderate	Moderate	Moderate	Good
2005-2001	Moderate	Moderate	Moderate	Moderate

Source: NPS-ARD 2011e,f,i

Table 4.4.4-2. Ozone sensitive plants found at Capulin Volcano NM (NPS-ARD 2006).

Scientific Name	Common Name	Bioindicator
Apocynum androsaemifolium	Spreading dogbane	Yes
Apocynum cannabinum	Indianhemp	No
Artemisia ludoviciana	Louisiana sagewort	Yes
Populus tremuloides	Quaking aspen	Yes
Prunus virginiana	Common chokecherry	No
Rhus trilobata	Skunkbush	Yes

- species exhibit foliar symptoms in the field at ambient ozone concentrations that can be easily recognized as ozone injury by subject matter experts
- species ozone sensitivity has been confirmed at realistic ozone concentrations in exposure chambers
- species are widely distributed regionally
- species are easily identified in the field (NPS-ARD 2011g).

An example of skunkbush foliar damage from ozone is shown in Figure 4.4.4-1 (NPS-ARD 2011h). Plants in the monument have not been assessed for ozone injury, but a risk assessment concluded that the risk of plant injury from ozone was low at the monument based on the fact that exposure levels were relatively low and soil moisture was low when ozone was higher (Kohut 2007).

Wet Deposition

The data for atmospheric wet deposition condition were derived from NPS-ARD's interpolated values (2005-2009 and 2001-2005) (NPS-ARD 2011i), which incorporated the monument's onsite NADP wet deposition monitoring results. All reported values resulted in moderate condition ratings.These interpolated values developed by NPS-ARD resulted in the same air quality condition ratings as what the on-site wet deposition monitoring results revealed.

Figure 4.4.4-1. Ozone Injury to Skunkbush Leaf

Source: http://www.nature.nps.gov/air/Pubs/bioindicators/skunkbush.cfm

Sullivan et al. (2011 a,b), studied the risk from acidification (from nitrogen and sulfur) or nutrient nitrogen effects (from nitrogen) for the monument. They took a slightly different approach with their assessment by considering three factors that influence nutrient enrichment and acidification from atmospheric deposition: pollutant exposure, ecosystem sensitivity, and park protection mandates. Pollutant exposure included the type of deposition (i.e., wet, dry, cloud, fog), the oxidized and reduced forms of the chemical, if applicable, and the total quantity deposited. The ecosystem sensitivity considered the type of terrestrial and aquatic ecosystems present at the monument and their inherent sensitivity to the atmospherically deposited chemicals. And finally, the park protection mandates considered whether and area had a special air protection designation due to being a wilderness area or a Class I airshed, as well as the NPS Organic Act. Based upon these three factors, an overall risk summary rating for each national park was assigned.

For all three wet deposition chemicals, the monument was considered to be at a low risk for damage related to acidification from sulfur and nitrogen deposition and at a very low risk for enrichment effects from atmospheric nitrogen, compared with parks nationwide. Because these are relative, not absolute, rankings of risk, the condition estimates should also be considered when evaluating overall risk to resources at the monument from deposition.

In general, nitrate, sulfate, and ammonium deposition levels have changed over the past 20 years throughout the United States (Figure 4.4.4-2). Regulatory programs that mandated a reduction in emissions have proven effective for decreasing both sulfate and nitrate ion deposition primarily through reductions from electric utilities, vehicles, and industrial boilers, although a rise in ammonium ion deposition has occurred in large part due to the agricultural and livestock industries (NPS-ARD 2011j). However, a new study conducted by Lehmann and Gay (2011), indicated an increase in nitrate precipitation concentrations from 1985-2009 in the southwestern states, including most of Arizona, and portions of New Mexico and Texas. The observed increase in nitrate at the monument was not statistically significant, but

Table 4.4.4-3. Summary of the air quality indicators/measures and their contributions to the overall air quality natural resource condition assessment.

Indicator/Measure	Description of How the Indicator(s) Contributes to the Overall Resource Condition	General Contribution of this Indicator or Measure to the Overall Resource Condition.
Visibility haze index	Visibility affects how well and how far one can see and is negatively affected by air pollution. Particulate matter, gases, and particulates can create haze thereby reducing visibility. NPS visitor studies have shown the importance visitors place on their ability to view the scenic vistas within and throughout national parks.	Five-year averages of interpolated visibility values were derived to determine that the condition of visibility is of moderate concern at the monument.
Level of ozone	Ozone is an atmospheric gas that is produced by reactions of nitrogen oxides and is one of the most widespread air pollutants. Ozone can be harmful to human heath as well as to vegetation by causing foliar damage, which sometimes leads to the death of the affected plant(s).	Five-year averages of interpolated visibility values were derived to determine that the condition of ozone is of moderate concern at the monument. In addition, a total of six plants have been identified as ozone sensitive, four of which serve as bioindicators.
Atmospheric wet deposition in total N and total S	Air pollutants can be deposited to ecosystems through rain and snow, which is referred to as atmospheric wet deposition. Nitrogen and sulfur air pollutants are commonly deposited onto ecosystems sometimes resulting in acidification, fertilization, eutrophication, or accumulation of toxins.	Five-year averages of interpolated atmospheric wet deposition values were derived to determine that the condition of both total nitrogen and total sulfur deposition is of moderate concern at the monument. The long term trend indicates that ammonium is degrading, and there are no trends for both NO3 and SO4.

increases in the region are cause for concern.

It seems reasonable to expect a continued improvement in sulfate deposition levels because of Clean Air Act requirements, however, at this time, ammonium levels are not regulated by the EPA and may continue to rise as a result (NPS-ARD 2010a).

Overall Condition and Trend

For assessing the condition of air quality, we used three air quality indicators/measures. Our indicators/measures for this resource were intended to capture different aspects of air quality, and a summary of how they contributed to the overall condition is summarized in Table 4.4.4-3. We consider the overall condition of air quality at Capulin Volcano

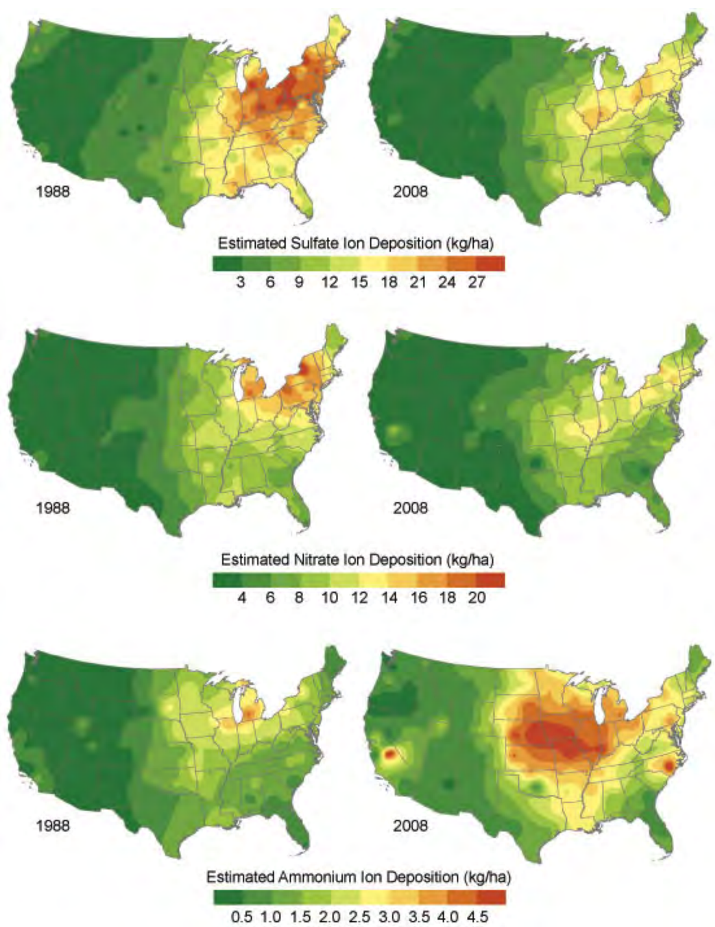

Figure 4.4.4-2. Change in wet deposition levels From 1998-2008 throughout the United States

Source: http://www.nature.nps.gov/air/Monitoring/wetmon.cfm.

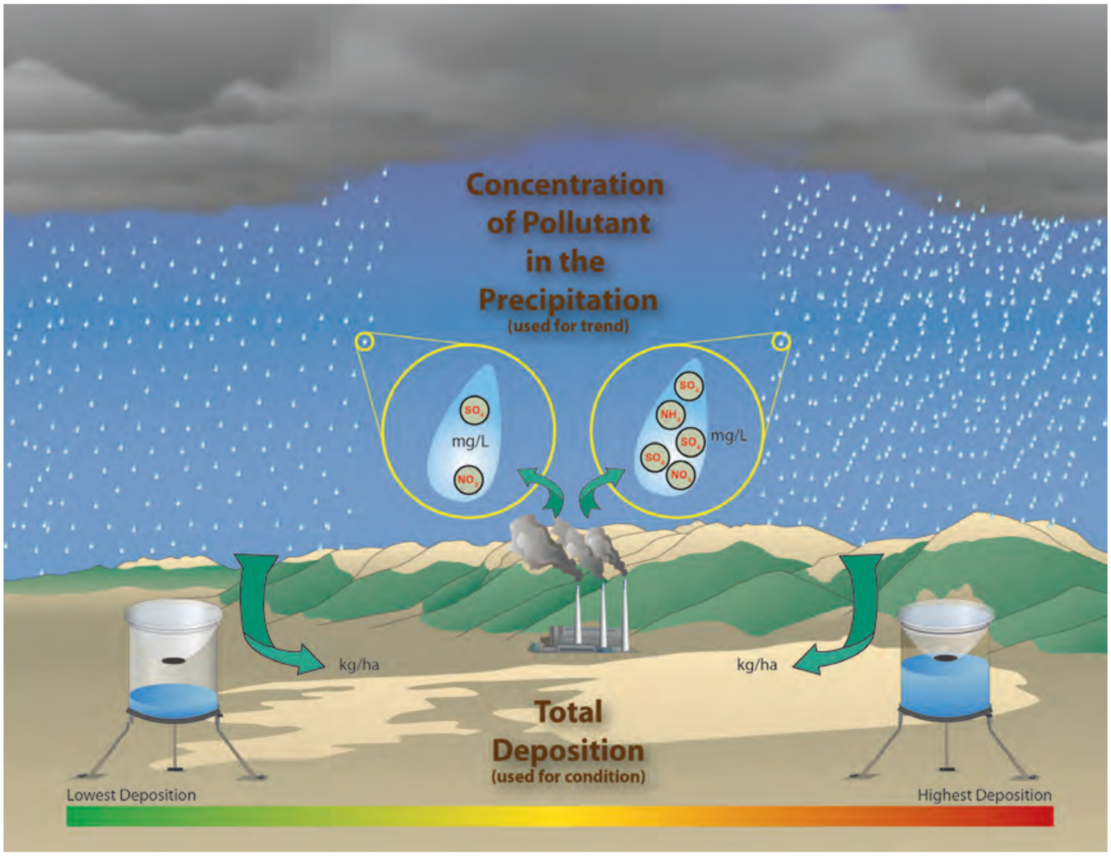

Figure 4.4.4-3. Atmospheric wet deposition conditions and trends are assessed differently.

Table 4.4.4-4. Air Quality Trend Results (concentrations of pollutants in rain and snow)

Data Span	NO_3 (mg/L)	NH_4 (mg/L)	SO_4 (mg/L)
1999-2008* (10-year)	No trend	No trend	No trend
1990-2008* (Long term)	No Trend	Degrading Trend	No Trend**

*NPS ARD 2010a

**Indicated possible improvement but not statistically valid

NM to be of a moderate concern and because there are numerous monitors for all three parameters, the interpolations for condition are likely very representative.

Trends for air quality indicators can only be derived if a monitor considered representative of the park is located near enough and/or onsite monitoring occurs. A monitor is considered representative if it is located within 10 miles for ozone and within 100 km for visibility. The only trend data available for the monument are for atmospheric wet deposition.

It is important to note that air quality trends and conditions are derived differently (Figure 4.4.4-3). Atmospheric wet deposition condition is based on total nitrogen and total sulfur deposited on ecosystems and measured in kg/ha to reflect the total deposition that the ecosystem is receiving. The condition values are based on a 5-year average of interpolated values. Whereas, air quality trends can only be determined for parks where onsite monitoring occurs or monitors are located within the required distances. The metrics for trend data are measured in the concentrations of nitrate, ammonium, and sulfate in mg/L as opposed to deposition in kg/ha, to remove variability caused by very high or very low precipitation years.

Of the air quality trends reported by NPS-ARD from 1999-2008 for the monument's atmospheric wet deposition, there were no trends for all three ions (NPS-ARD 2010a). For NPS-ARD's longer term trend period (1990-2008), there were no trends for NO_3, and SO_4' and a degrading trend for NH_4 that reflect trends in atmospheric concentrations of NO_x, SO_2, and NH_3 (E. Porter, pers. comm.). The trend results for NH_4, NO_3, SO_4 are summarized in Table 4.4.4-4.

Level of Confidence/Key Uncertainties

The key uncertainty of the air quality section is knowing the effect(s) of air pollution, especially nitrogen deposition, on ecosystems at the monument.

4.4.5 Sources of Expertise

The National Park Service's Air Resources Division oversees the national air resource management program for the NPS. Together with parks and NPS regional offices, they monitor air quality in park units; provide air quality analysis and expertise related to all air quality topics.

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4.5 Geology

Indicators/Measures

- Presence/absence of accelerated erosion
- Severity of erosion

Condition - Trend

Significant Concern - Declining

4.5.1 Background and Importance

Capulin Volcano NM was initially established by presidential proclamation in 1916 as "a striking example of recent extinct volcanoes", which was deemed "of great scientific and especially geologic interest" (Presidential Proclamation 1340 [39 Stat. 1792]) (Figure 4.5.1-1). Visits to the top of the volcano provide panoramic views of the Raton-Clayton Volcanic Field(RCVF) and the Sangre de Cristo Mountains. Approximately 50,000 people per year visit the monument to see this unique feature and its impressive setting (NPS Public Use Statistics Office 2010). The intact cinder cone, crater, lava flows, and other volcanic and geologic features are all explicitly identified as fundamental resources of the monument, as are the unobstructed views seen from the top of the volcano (NPS 2010). Spectacular views are made easily accessible to visitors via Volcano Road, which ends at the rim of the crater. Volcano Road is eligible for inclusion in the National Register of Historic Places, thus establishing the road's historical significance in accordance with 36 CFR 800. While the road is unique in its offering of accessibility for scientific, education, and public enjoyment opportunities, it also offers challenges related to its destabilization of soils and slopes and potential threats to the volcano from resulting erosion.

The Raton-Clayton Volcanic Field

Capulin Volcano NM is located within the RCVF, the easternmost Cenozoic volcanic field in the United States (Aubele and Crumpler 2001). This volcanic field, oriented northwest to southeast, stretches from Raton (and Springer) to Clayton and covers nearly 7,500 square miles (19,425 km^2) of northeastern New Mexico (Figure 4.5.1-2). The RCVF contains hundreds of other cinder cones and basaltic lava flows, rhyolite volcanic domes, and a large andesitic shield volcano (Sierra Grande).

The RCVF is an example of an inverted topographic valley, where the oldest lava flows occupy the areas of highest local elevation (Stroud 1997). This inversion results from an erosion process called "volcanic inversion relief" (Cotton 1969) or inverted topography.

NPS

Figure 4.5.1-1. Capulin Volcano NM

ROBERT BENNETTS

Figure 4.5.1-2.
A view of the RCVF looking southwest from Capulin Volcano NM.

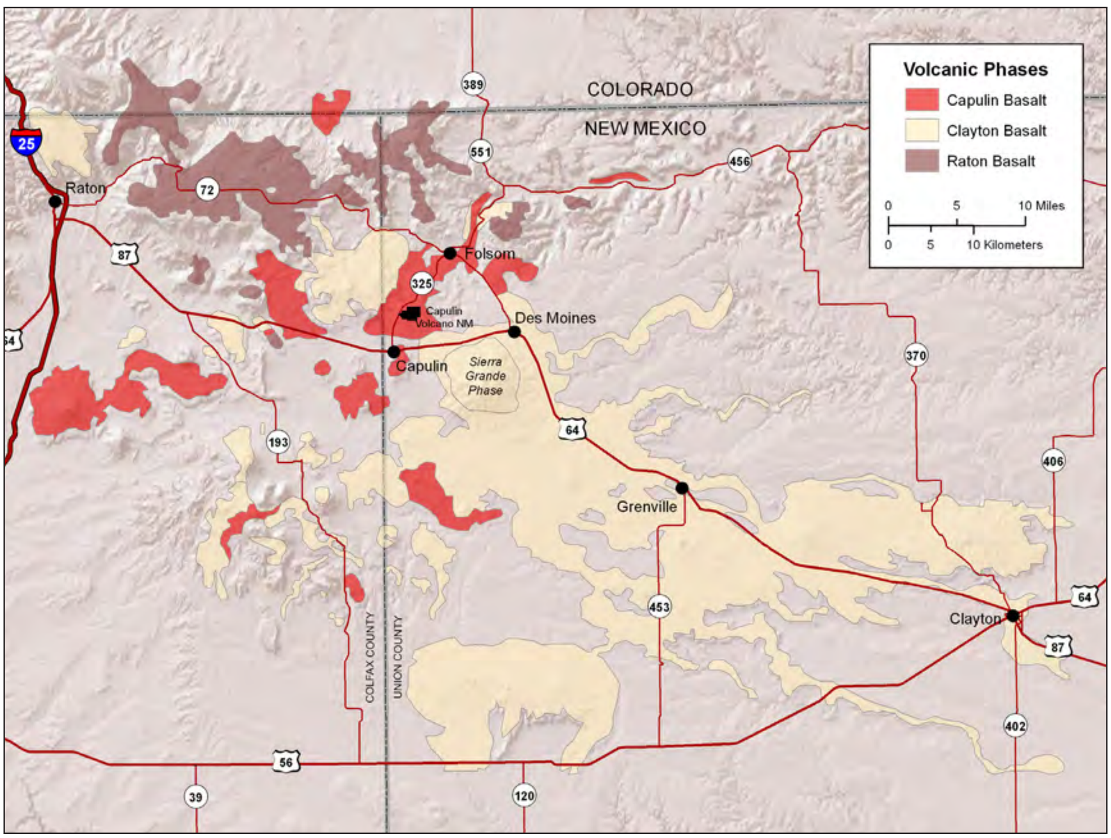

Figure 4.5.1-3.
Map of RCVF volcanic phases. Adapted from Muehlberger et al. (2005)

It is generally agreed that volcanic activity in the RCVF can be separated into three phases: the Raton, Clayton, and Capulin Phases (Stormer 1972; Calvin 1987; Stroud 1997) (Figure 4.5.1-3). These phases span a period from approximately 9 million years ago to less than 60,000 years ago (Sayre and Ort 2011). The oldest pulse was the Raton phase, represented by Raton basalts that cap the mesas east of Raton, New Mexico (Stroud 1997) . The second pulse was the Clayton phase, consisting of Clayton basalts and covering the area from Sierra Grande east to Clayton, New Mexico. Capulin Volcano is located near the center of the RCVF and formed during the third and last phase of volcanic activity. The last known eruptions, including the formation of Baby Capulin, just north of Capulin Volcano NM, occurred as recently as 30,000 to 40,000 years ago (NPS 2008).

Geologic Resources

The geologic resources of Capulin Volcano NM include the scoria cone, lava flows, and associated geologic features (Table 4.5.1-1). Many of these features were identified and located by Sayre and Ort (2011) during their 1999 field work, which were later refined and updated by Richman (2010) as part of a geologic inventory of Capulin Volcano NM. Currently, the Geologic Resources Inventory (GRI) Program, administered by the Geologic Resources Division, is providing further assistance to the monument by identifying geologic mapping coverage and needs, distinctive geologic features and processes, resource management issues, and potential monitoring and research needs (KellerLynn 2011).

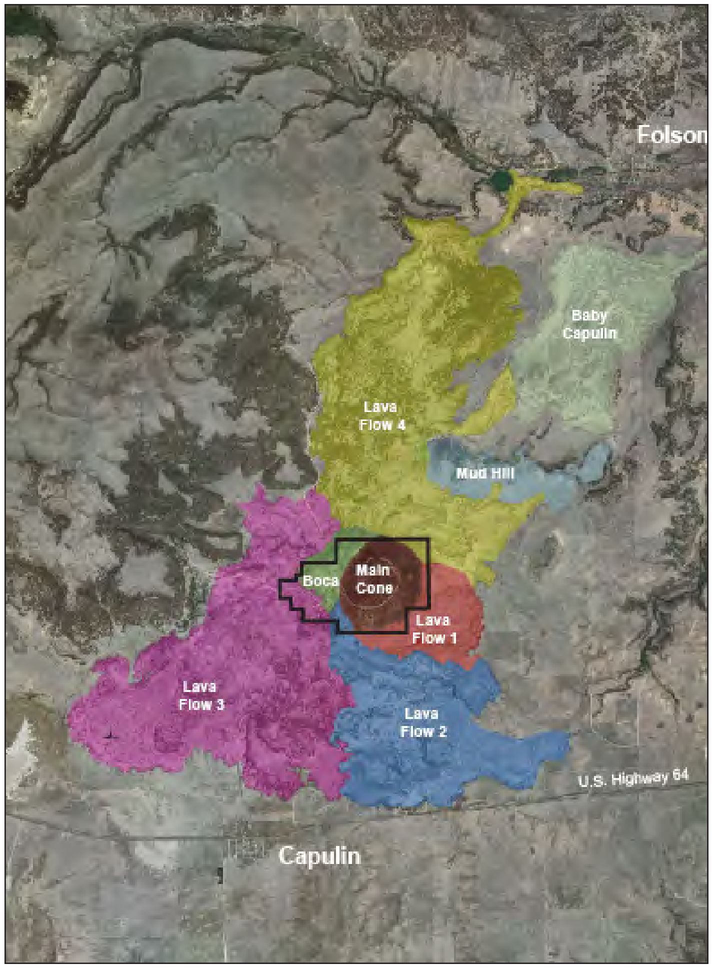

Figure 4.5.1-4 Capulin Volcano lava flows.

Capulin Volcano: Scoria/Cinder Cone

Capulin Volcano is a classic scoria/cinder cone type volcano, but is rare in that it has a nearly perfect cone shape with a summit crater that has not been breached (Crumpler and Aubele 2001). Capulin Volcano is also uncommon because of its size; most cinder cones only reach a height of about 900 feet (274 m), but Capulin Volcano reaches about 1,300 feet (396 m). The scoria cone is nearly 1 mile (1.6 km) across at its base, and it has a summit crater more than 300 feet (91 m) deep. Capulin Volcano rises more than 1,000 feet (308 m) above the plains to 8,182 feet (2,494 m) above sea level.

Although there have been different estimates over time, the most recent evidence suggests that Capulin Volcano erupted approximately 59,100 years ago (± 6,000 years) ago (Sayre and Ort 1995). The scoria cone was produced by the eruption and is the simplest type of volcano, forming from particles and masses of solidified lava ejected from a single vent. It remained symmetrical during its eruption because lava did not flow from the main crater but from secondary vents located at the base of the cone, thus preserving the shape. As with Capulin Volcano, most cinder cones have a bowl-shaped crater at the summit. The cone consists mainly of loose cinders, scoria, ash, and other rock debris.

Lava Flows

During the volcanic eruption, the first lava flow series flowed eastward (Figure 4.5.1-4). The next flows erupted from the cone's boca, or mouth, an area at the base of the cone along its western side. The second lava flow series flowed to the south, the third flowed to the southwest, and the fourth flowed to the north and northeast. The lava flows cover almost 16 square miles (41 km^2) and are mostly located outside of the monument's boundary. Although, small portions of each lava flow, as well as the boca and most of the scoria cone, except for 8 acres (3.2 ha), are located within the boundary.

The presence of eolian dust on lava flows, dust infilling, is used as a relative-dating method by

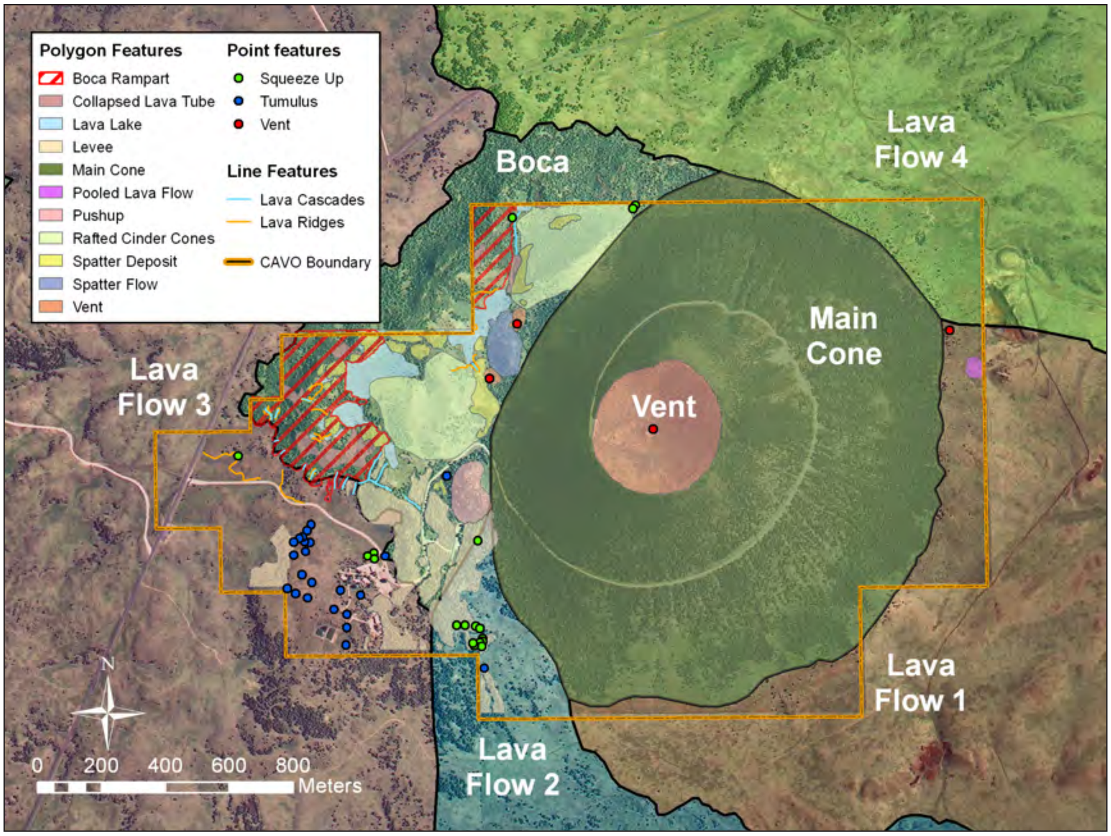

Figure 4.5.1-5. The geologic features within Capulin Volcano NM mapped by Richman (2010) as part of a geologic inventory of the monument. Adapted from Richman (2010).

geologists. The dust fills in cracks and vesicles on the flows and "ages" them. As explained by the New Mexico Bureau of Geology and Mineral Resources (N. Dunbar, pers. comm.), a clean, silt-free surface indicates young age, depressions filled with silt indicate moderate age, and removal of topographic highs by silt indicates old age. Furthermore, infilling is the first stage in eventual soil development on the lava flows. As a lava flow fills in and attains a smooth surface, vegetation augments sedimentation by influencing moisture content and trapping sediment. Bauman (1999) studied the influences of climate, provenience (source of sediment), and surface cover types on soil formation within the Carrizozo lava flow in central New Mexico. A significant finding from this M.S. thesis was that the soils on the flows are of eolian origin and not basalt weathering products. This study's findings may be applicable to Capulin Volcano NM's lava flows.

Additional Geologic Features

Some of the many features related to the lava flows include pressure ridges, tumuli, squeeze-ups, pushups, lava tubes (collapsed), and levees (Figure 4.5.1-5). Pressure ridges, with a wrinkled surface, were produced when moving lava developed a cooler surface crust compared to the lava flowing beneath it. Tumuli, or lava mounds, are small, dome-shaped mounds on the surface of a lava flow formed where the lava crust broke and lava was forced out under pressure. Squeeze-ups are small, bulbous, linear, or irregularly-shaped accumulations of lava formed by the extrusion of viscous lava through an opening in the solidified crust of a flow. Push-ups are hardened surface areas of a lava flow that were pushed up and tilted by molten lava within the flow. Lava tubes formed beneath the lava's crust, as the lava drained away (Table 4.5.1-1).

Volcano Road

Although no monument resources are currently listed on the National Register of Historic Places, the Cultural Landscape Inventory (NPS 2003) determined that certain resources at the monument warrant listing. Volcano Road, which allows visitors to appreciate the cinder cone and its setting, is noted as an important part of the monument's cultural landscape. The road was built in 1925, primarily due to the efforts of Homer Farr, the second custodian of the park, who drove the first car to the top of the volcano. The dirt road had an average width of 20 feet (6 m) and a grade of 6% (NPS 1977). About 30 years after construction, portions of a retaining wall (5 feet [1.5 m] tall and 18 inches [46 cm] thick) were constructed along the road

Table 4.5.1-1. The type, number, and description of geologic features within Capulin Volcano NM reported and mapped by Richman (2010) as part of a geologic inventory (adapted from Richman [2010])

Feature Type	Number	Description
Point Features		
Cave*	3	A natural opening in the ground extending beyond the zone of light and large enough to permit the entry of an average human.
Squeeze-up	23	Small, bulbous, linear, or irregularly-shaped accumulations of lava formed by the extrusion of viscous lava through an opening in the solidified crust of a flow.
Tumulus	18	A doming or small mound on the crest of a lava flow caused by pressure due to the difference in the rate of flow between the cooler crust and the more fluid lava below.
Vent	4	The opening at the earth's surface through which volcanic materials issue forth.
Line Features		
Lava cascade	16	The eruption of lava that plunges over a precipice creating a waterfall like feature of ejected material(s).
Lava ridge	18	The accumulation of erupted volcanic material that is contained along a linear feature, building up to form a ridge.
Polygon Features		
Boca rampart	2	An area that is fused with volcanic materials creating a "wall-like" structure.
Collapsed lava tube	6	Lava tubes are formed when the surface of a lava flow cools and solidifies while the still-molten interior flows through and drains away.
Lava lake	19	A lake of molten lava, usually basaltic, contained in a vent or crater.
Levee	15	A broad, low embankment built up along a channel.
Main Cone	1	Cylindrical feature formed by lava accumulation around a vent.
Pooled lava flow	1	A less defined lake feature of molten lava.
Push-up	1	A hardened surface area of a lava flow that was pushed up and tilted by molten lava within the flow.
Rafted cinder cone	2	A breached portion of the cone that is located on the surface of the flow as rafted mounds of materials.
Spatter deposit	24	Accumulation of molten volcanic slag and cinders ejected in a more liquid form.
Spatter flow	1	Accumulation of molten volcanic slag and cinders ejected in a more liquid form that moved across the surface..
Vent (main)	1	The primary opening/place of origin where volcanic materials were ejected.

* Not shown on map due to sensitivity of the resource.

to keep cinder material from falling or washing onto its surface (NPS 2003; Table 4.5.1-2).

The road to the volcano's summit was constructed by benching into the natural slope of the mountain. The cut slopes were not stabilized at the time of construction (NPS 1977). The monument's Cultural Landscape Inventory notes that the road was a maintenance challenge almost from the start (NPS 2003). In the spring and after severe rain storms, the road was often closed while monument personnel repaired it (Figures 4.5.1-6, -7, -8). Plans to build a retaining wall to keep material off of the road

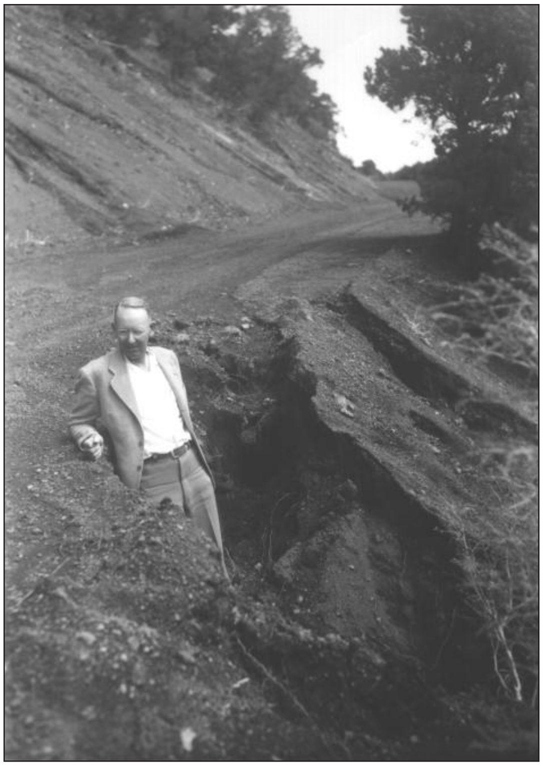

Figure 4.5.1-6. Erosion along the road shoulders after a storm (July 1950).

Figure 4.5.1-7. Washout along the road shoulders (July 1967).

Figure 4.5.1-8. Erosion below a culvert (July 1967).

were formulated about a decade after the road's construction. A 1977 environmental assessment that examined alternatives for controlling existing erosion problems noted that

> ". . .the steepness of cut slopes on the up-hill side of the roadway and the differences in resistance of the cinder material to erosion (i.e., some fused, some loose cinders) result in a condition where the bottom slope cinders are constantly eroded, causing the cinders at the top of the slope to break off and slide downhill. The scar on the mountain slope increases in size every year thereby destroying more trees and other vegetation. . . ". (NPS 1977). (see Figure 4.5.1-9).

Table 4.5.1-2. Major events associated with the Volcano Road

Year	Event
1916	The national monument was established.
1925	The dirt road to the top of the volcano was constructed.
1954	Portions of the 5-foot-tall retaining wall were constructed along the road.
1960s–1980s	Additional work was done on the retaining walls. Wall heights were raised to 8–12 feet (FHWA 2005).
1986	The road was paved.
Late 1980s–90s	A debris flow on the south side of the volcano washed out the road.
2002	Culvert 24 was restored and larger culvert inlets were installed.
2010	Culverts 13, 14, and 15 were repaired (but NPS judged the work to be incomplete).
2010	There was a debris flow between culverts 22–28 on July 15 that trapped vehicles along the road for approximately one hour.
2011	Road construction and improvements are planned (including finalizing work done on culverts 13–15 in 2010.

When the road was paved in 1986, problems with erosion continued (and probably increased due to the new surface's impermeability). The Draft Statement for Management for Capulin Volcano NM (1989) identified the erosion problem and stated that it needed to be studied to determine control measures. The report noted that erosion at that time was primarily a problem on the downhill side of the road. This downhill erosion is discussed in a number of trip reports and memoranda from NPS geologists in the late 1990s and early 2000s. One of those is a 1998, five-page memorandum from Dave Steensen, a geologist and current Chief of the Geologic Resources Division (formerly the Science and Technical Services Branch), to the superintendent of Capulin Volcano NM (Steensen 1998). The memorandum, based on a site visit and information provided by monument staff, summarizes the erosion problems at the time:

> *"The Mountain Road is causing significant acceleration of erosional processes on Capulin Mountain. Downslope effects are greater than upslope effects, except in a few localized areas. In a general sense, the road affects the natural rates of erosion in four ways: 1) cutbanks undercut natural slopes and low-order stream channels; 2) surface runoff intensity and frequency is increased; 3) misplaced culverts direct runoff onto unsuitable slopes; and 4) diversion of surface runoff disrupts natural hydrologic patterns. "*

Efforts to mitigate some of these erosion problems, particularly as they relate to the integrity of the road, have been made. Work was conducted in 2002 (e.g., installing larger culvert inlets) and in spring 2010 (Table 4.5.1-2).

The larger culverts that were installed in 2002 convey greater discharge (theoretically, they were enlarged to handle greater sediment). A large enough storm may plug the culvert inlets at least in their current configuration. Since the next downroad culvert that is open (during that storm) can also convey more discharge, they is a real potential to increase discharge onto unprotected slopes below culvert outlets (D. Steensen, pers. comm.).

One of the most recent discussions of erosion problems at the park is found in a scoping report (Federal Highway Administration 2005). Similar to past reports, this one discusses erosion above cut slopes (up-hill of the road, where several of the cut slopes experienced localized failures), and focuses on erosion down-slope of the road. Erosion near culvert outlets was described as "severe" at several locations and as threatening the road. The explanation given is the combination of the steep slope, outlet velocity, and lack of soil cohesion. Another drainage problem described in the 2005 report is surface flow coming off the pavement, which flows over the outside edge of the pavement and erodes the slopes adjacent to the road edge. In the mid-2000s, some problem areas were the outlets of culverts 15 and 18. The outlets had eroded 5–6

Figure 4.5.1-9. Trees uprooted on Capulin Volcano due to erosion. Photos from 1977.

feet (1.5–1.8 m) in elevation below the end of the outlet, and the erosion gullies had moved up-hill towards the road. Both culverts were deemed "close to catastrophic failure." According to the Federal Highways Administration (2005), a 1993 engineering study on the road rated culverts 15 and 24 as having moderate erosion.

Work to mitigate continuing and more recent erosion problems was conducted in May 2010, prior to field work for this condition assessment. The work was conduced at culverts 13, 14, and 15 and included extending the length of culvert outlets, adding retaining walls (with gabion baskets) above culvert outlets, and backfilling associated eroded areas. The work was determined by the NPS to be incomplete and deficiencies were to be corrected in 2011. Additionally, a meeting with the Federal Highways Program Manager and engineers, along with NPS staff, was held in July 2010 to begin the development of a comprehensive scope of work that would address the ongoing erosion issues. The monument was awarded over $3 million to complete the necessary work and is planned to begin during 2011.

4.5.2 Data and Methods

Erosion is arguably the most significant threat to the geologic resources at Capulin Volcano NM. Erosion is a natural process that has been occurring over the past 60,000 years; however, significant acceleration and severity of erosion processes are the result of human developments. Additionally, the combination of steep slopes, generally between 40% and 60% approaching the crater (Weindorf et al. 2008), and highly erodible soils add to the severity of the issue.

Erosion problems on the cinder cone related to Volcano Road are certainly the most obvious. However, additional erosion-related issues, although less severe than that occurring on the cone, exist in other areas of the monument. Sections along both the Lava Flow Trail and Fire Road in the southern part of the monument are experiencing erosion. The Rim Trail may also pose some erosion risk to geologic resources, particularly because it has an impervious surface that, like Volcano Road, can concentrate runoff. Work along the Rim Trail occurred during the summer 2010 to restore the eroded areas and, if possible, to mitigate future erosion of the cinder cone. Erosion within lava flow 4 has occurred due to cinder mining activities adjacent to the monument's northeast boundary. Several years ago, Geologic Resources Division staff assessed the site and recommended the restoration of this area, although work has yet to begin on this restoration project.

Even though these areas show evidence of erosion, the erosion related to the cinder cone itself will be the primary focus for this assessment due to its significance to the monument (i.e., the reason it was proclaimed a monument) and due to the presence of accelerated erosion and the severity.

We used two indicators/measures to assess the condition of the cinder cone, which include the presence/absence of accelerated erosion and the severity of the erosion. Erosion is a meaningful indicator because it can affect the integrity/stability of the cone, as well as the aesthetic appearance to visitors, neighbors, and other members of the public; other resources at the monument, such as vegetation, wildlife, and wildlife habitat; and the existence or condition of Volcano Road.

Indicators/Measures

- Presence/absence of accelerated erosion

The measure we used for the presence/absence of accelerated erosion indicator was the proportion of culverts at which erosion, beyond what would be expected naturally (e.g., in the absence of the road) is occurring. This was determined by counting the number of culverts at which accelerated erosion is occurring, relative to the total number of culverts present. Data collected by NPS staff and Service Organization for Youth (SOY) group during the summer of 2010 were used to assess this indicator, along with a rapid assessment of the cinder cone's site/soil stability conducted by Pete Biggam in November 2010, a soil scientist with NPS Geoscience and Restoration Branch of the Geological Resources Division. Although much of his visit focused on grasslands, he evaluated one site approximately two-thirds up the cinder cone to assess the soil/site stability, based on the approach presented by Pellant et al. (2005).

Table 4.5.2-1. The length and source of erosion gullies at each Volcano Road culvert.

Culvert #	Erosion Length (ft)	Source[1]
7	543	Digitized
8	906	GPS
9	1373	GPS
11	1219	GPS
12	No data	Digitized
13	637	Both
14	1130	GPS
15	753	Digitized
16	264	Digitized
17	618	Digitized
18	265	GPS
19	571	GPS
20	802	GPS
21	709	GPS
22	422	GPS
23	309	GPS
24	670	GPS
25	54	GPS
29	34	GPS

[1] GPS refers to smoothed lines from the GPS data collected in the field. Culverts 1–6, 10, and 26–28 do not show any evidence of accelerated erosion.

Indicators/Measures

- Severity of erosion

The second indicator used to assess the condition of the cinder cone was the severity of erosion occurring on the cone. NPS and SOY measured the overall length of the erosion gullies down-slope of the road (measured from the culvert outlet or other beginning point to the down-slope end of the erosion gully). However, we augmented this measure with an ancillary measure of the width of the erosion gully, but this measure was only taken at a subset of the culverts with erosion, therefore, is not comprehensive.

The erosion gullies were mapped using Global Positioning System (GPS). The collected data were straightened, using GIS, to obtain the distances the erosion gullies extended down the slopes from the road. There were some culverts that could not be examined (the culverts could not be located or time did not allow for the work); in these cases, 2009 aerial imagery was used to assess and digitize the occurrence and linear extent of erosion. The method used to obtain information pertaining to each erosion gully is listed in Table 4.5.2-1.

Ancillary information on the occurrence of invasive, exotic plants was also collected by NPS and SOY staff at more than half of the culvert sites (11–27 and 29). Because the information was not collected at every culvert, it is used only as a general reference to point out one of the concerns with areas of ground disturbance—they are areas conducive for the establishment of invasive plants. At the culverts examined, the number of exotic plant stems (by species) was estimated within the eroded area (or gully) and 5 feet (1.5 m) on each side, up to 200 feet (60 m) down-slope from the road. A full assessment and discussion of the monument's exotic plants *is* in section 4.9 of this report.

NPS

NPS

Figure 4.5.3-1. Erosion above (top) and below (bottom) Volcano Road at culvert 13 shows he disparity between what might be expected in the absence of the road.

4.5.3 Reference Conditions

The absence of erosion in many cases could be considered as an appropriate reference condition. However, because of the steep slopes and highly erodable soils, some erosion would be expected regardless of the presence of the road. Thus, the reference condition for the monument's cinder cone, with respect to erosion, is the presence and degree of natural erosion that would occur in the absence of the road. Given the steepness of slopes and loose soils, some rills (small gullies a few inches deep) and gullies would be expected (Pete Biggam, pers. comm.). However, the concentration of water that is channeled through the culverts, along with other drainage issues related to the road, has greatly amplified the presence and severity of erosion on the cinder cone. Comparisons of erosion above and below the road were used to help determine the reference condition and whether erosion was accelerated. Although upslope erosion due to the road occurs in a few localized areas, downslope effects are generally substantially greater (Steensen 1998) (Figure 4.5.3-1).

4.5.4 Condition and Trend

Presence/Absence Of Accelerated Erosion And Severity Of Erosion

Based on the field data and follow-up office assessment (e.g., examining 2009 imagery), accelerated down-slope erosion occurs at 19 of the 29 culverts along the road (66%). There is no evidence of accelerated down-slope erosion at 10 of the culverts (i.e., culverts 1–6, 10, and 26–28). Thirty-four percent of the culverts are currently free from erosion problems (Figure 4.5.4-1).

Comparisons between the conditions of culverts with erosion versus those without erosion were not made, but vegetation (both amount and

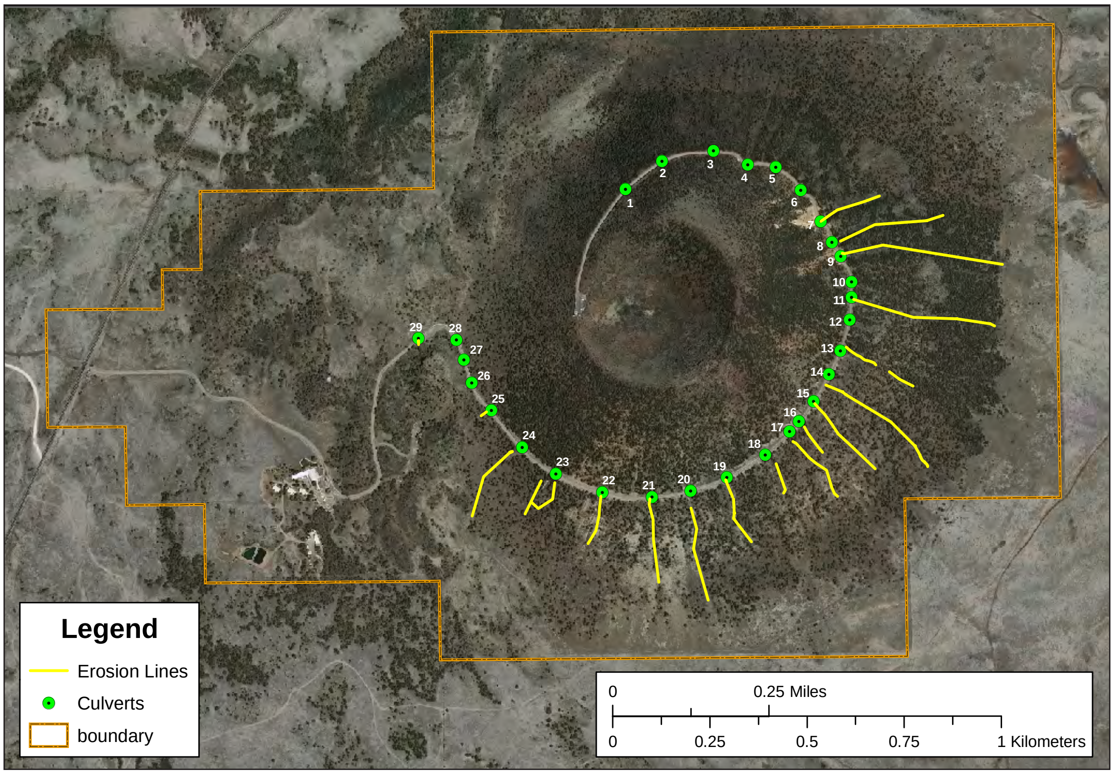

Figure 4.5.4-1. Accelerated erosion (gullies) associated with culverts along the Volcano Road. Culvert numbers are shown for reference.

NPS

NPS

Figure 4.5.4-2. Erosion below culvert 22 as seen from the Volcano Road (top) and the base of the cinder cone (bottom).

type), lack of concentrated runoff at the upper culverts 1-6 and lower culverts 26-28, and less slope at the lower culverts may be contributing factors, although this information has not been confirmed and is simply anecdotal.

For those 19 culverts experiencing accelerated erosion (some severely), erosion gully lengths ranged from 34 feet (10 m) to 1,373 feet (419 m), and averaged 647 feet (197 m). Culverts with the longest erosion gullies are 9 (1,373 feet [419 m]), 11 (1,219 feet [372 m]), and 14 (1,130 feet [345 m]). Several of the gullies extend halfway or more down-slope through the piñon-juniper habitat, and a few of the gullies extend all the way down-slope to the piñon-juniper/grassland ecotone (Figure 4.5.4-2). Gully width measurements were available for only five of the 19 culverts experiencing erosion (Table 4.5.2-1). Of these, width measurements were taken along the entire, or nearly entire, length at three culverts (8, 14, and 19). At three of the five culverts where erosion widths were recorded, the areas of widest erosion were located close to the culvert outlets (Figure 4.5.4-3). A complete set of photos showing the severity of erosion along the culverts is presented in Appendix C.

Biggam's rapid assessment of the soil/site stability at the location above the road on the upper portion of the cinder cone revealed that natural erosion processes are occurring on the volcano.

NPS

Figure 4.5.4-3. Erosion at culvert 9 was the highest level of erosion recorded with a 390 ft (119 m) stretch 60 ft (18 m) wide.

The site was located in an area of soil map unit Bd – Bandera association, with a designated Ecological Site of Cinder (R070XA011NM) (NRCS 2007). Cinder land is a term used to denote areas that have little or no soil and vegetation, are best described as areas of loose cinders and other scoriaceous ejecta, and have a very low water holding capacity (Biggam 2010). Biggam further noted that in this particular area, the Cinder land component was higher than the normal 20% composition described in the soil map unit. Biggam's assessment of the erosion above the road demonstrated that the combination of loose substrates, lack of vegetation, and steep slopes create favorable conditions for accelerated erosion to occur naturally. Even though moderate to extreme formation of rills and gullies were present at this location, the amount and severity of erosion below the road, due to concentrated runoff, is still substantially more extensive than what is naturally occurring above the road (Figure 4.5.3-1).

Ancillary information: Invasive Exotic Plants

Information on the occurrence of invasive, exotic plants was collected at culvert sites 11–27 and 29. Mullein (*Verbascum thapsus*), hore-hound (*Marrubium vulgare*), houndstongue (*Cynoglossum officinale*), yellow sweet clover (*Melilotus officinalis*), Russian thistle (*Salsola tragus*), lambsquarter (*Chenopodium album*), field bindweed (*Convolvulus arvensis*), and salsify (*Tragopogon* sp.) were present. Yellow sweet clover and field bindweed were only observed at two culverts each, while Russian thistle, mullein, and horehound were observed at most of the culverts surveyed. The culvert areas that appeared to have the highest estimated number of exotic plant stems were 12–14, 16–18, 19, and 22–23.

Overall Condition

For assessing the condition of geology, we used two indicators/measures, and a summary of how they contributed to the overall geology condition is in Table 4.5.4-1 Based on the high proportion of culverts exhibiting accelerated erosion (66%), as well as the severity of that erosion, we consider the condition of the cinder cone to be of significant concern. Because erosion is expected to continue until solutions are found and implemented, we have also listed the trend as declining. It is important to note that this assessment does not apply to the geologic resources over other areas/geologic features of the monument.

Level of Confidence

The assessment of the condition of the scoria cone is based on the field data (from summer/fall 2010), on-the-ground photographs, and 2009 aerial imagery. As described above, there is a long history of erosion due to the road and its associated drainage structures. This history is documented in photographs, which date from 1936 to the present, various federal agency

Table 4.5.4-1. Summary of the geology indicators/measures and their contributions to the overall geology natural resource condition assessment.

Indicator/Measure	Description of How the Indicator(s) Contributes to the Overall Resource Condition	General Contribution of this Indicator or Measure to the Overall Resource Condition.
Presence/absence of accelerated erosion	Natural erosion is expected for the geologic resources at the monument, but it is the accelerated erosion, specifically on the cinder cone resulting from Volcano Road, that affects its integrity and stability, as well as its appearance.	Accelerated erosion occurs downslope at 66% (19/29) of the culverts located along the monument's cinder cone.
Severity of erosion	The increased presence and frequency of erosion begins to define the severity of erosion at a given location. The length and width of eroded gullies were measured along the cinder cone to determine severity of erosion.	Gully lengths averaged 647 feet, with some extending all the way to the base of the cinder cone into the grassland that surrounds the cone. The widest gully measured 390 feet across, indicating that severe erosion is occurring at some culvert locations.

reports (e.g., Federal Highways Administration 2005), and memoranda and trip reports from NPS geologists. A substantial amount of erosion at some locations has been documented over the years.

Some uncertainty exists, however, with regard to the degree of natural erosion that would occur in the absence of the road. As discussed previously, with the steep slopes and soil types that occur on the cone, some degree of erosion would be expected even in the absence of the road. Because no assessment of the level of natural erosion has been conducted at Capulin Volcano NM, we based the reference condition of the scoria cone on the relative appearance/degree of erosion of the cone above the road. Because some of the past trip reports from NPS geologists noted that the road and its retaining walls were leading to some erosion problems above the road (overall, less significant than below the road), using the above-the-road slopes for the reference condition can be viewed as a conservative comparison.

There is also some uncertainty regarding the culverts that were not visited in the field during the summer of 2010 (or were only visited to take photographs). Due to time constraints, data could not be collected on the occurrence of erosion at all culverts. In cases where there was evidence of accelerated erosion (e.g., in recent photographs), the aerial imagery was used to estimate the extent of erosion (i.e., the length of the erosion gully), and the erosion lines were digitized using GIS. Steensen (1998) noted that several "low order" drainage channels are crossed by the road in the vicinity of culverts 3 to 10, and we determined that the linear features extending down-slope from the road at culverts 4–6 were these drainage channels rather than road-induced erosion gullies. There may however, be some small level of accelerated erosion that is also occurring at culverts 4–6. Due to the uncertainties discussed here, the approach that has been taken in this report is to focus the discussion of erosion on the areas with known, photographed, and measured erosion problems caused by the road and its drainage structures.

Key Uncertainty

A key uncertainty regarding the acceleration of erosion to the cinder cone may result from previous vegetation management treatments. As discussed in greater detail in the chapter on piñon-juniper vegetation, thinning treatments have occurred on a substantial portion of the cinder cone. When these treatments were planned, it was thought that "prescribed fire and mechanical thinning [were] ways to manage vegetation and control erosion on the slopes of the cinder cone."(NPS 2004). The basis of this idea was that mechanical treatments to reduce canopy cover would allow grasses to "return to subunit" (it was previously thought that the cinder cone was historically a grassland; see section 4.7 on piñon-juniper vegetation) that would in turn reduce erosion (NPS 2004). However, Pete Biggam noted in his site visit report, "Although erosion was occurring prior to thinning, opening up the canopy exposes the site to influences of raindrop impact, sheet, rill, and gully erosion, and loss of existing herbaceous material, litter, and organic matter." Evidence suggests that some increases in grasses and herbaceous vegetation would likely follow thinning, but it is not clear whether any such benefits that would occur would be substantial enough to outweigh the concerns. Both, Vegetation Ecologist, Brian Jacobs, and former geologist with the Geologic Resources Division, Deanna Greco, further describe the potential erosion that could occur if these treatment areas were subsequently burned, as was originally planned (Deanna Greco and Brian Jacobs, pers. comm.).

4.5.5 Sources of Expertise

A Geologic Resources Inventory scoping meeting was held at Capulin Volcano NM in May 2011 to discuss the 2010 mapped geologic features and to review this section of the assessment. Bruce Heise, Geologist with the Geologic Resources Division, served as the primary reviewer.

Work on this assessment was conducted in consultation with Deanna Greco (NPS Geologic Resources Division), and Pete Biggam (NPS Geologic Resources Division). In addition to the field assessment, critical information sources were historical and contemporary NPS photographs, Geologic Resources Division trip reports and memoranda, and agency reports discussing erosion at the monument.

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4.6 Groundwater

Indicators/Measures

- Change in Groundwater Level

Condition - Trend

Good - Insufficient Data

4.6.1 Background and Importance

Groundwater accounts for 1.7% of Earth's total water and 30.1% of Earth's freshwater (USGS 2011a). The overall trend in the United States is that as population increases, the amount of groundwater withdrawn also increases (Figure 4.6.1-1).

Long-term water-level declines caused by sustained groundwater pumping are a key issue associated with groundwater use, and many areas of the United States are experiencing groundwater depletion. New Mexico's ground-water is no exception. In addition to the semi-arid to arid environment, demand for New Mexico's groundwater is increasing and recent population projections indicate that by 2060 New Mexico's population of 1.97 million in 2005 will nearly double to 3.68 million people (Alcantara 2008). Additionally, New Mexico is ranked as the top western state that relies on groundwater to supply its drinking water needs (Ground Water Protection Council 2007).

An environmental consequence to groundwater depletion is land subsidence, which is the settling or sinking of the Earth's surface. The increasing development of land and water resources threatens to exacerbate existing land-subsidence problems and initiate new ones throughout the United States, including many areas of the arid Southwest (USGS 2011b).

NPS Management Policy 4.6.1 states that the NPS will perpetuate surface waters and groundwaters as integral components of park aquatic and terrestrial ecosystems (NPS 2006). It is the policy of the NPS to determine the quality of park surface and groundwater resources and avoid, whenever possible, the pollution of park waters by human activities occurring within and outside of parks (Figure 4.6.1-2).

<u>*Groundwater Basin Characteristics*</u>

New Mexico Office of the State Engineer delineated and described underground water basins throughout the state to help manage underground water resources. Capulin Volcano NM is associated with minor aquifers and is not part of a larger groundwater system such as the High Plains Aquifer (the Ogllala), which lies to the south and east of the monument (Figure 4.6.1-3). Only one aquifer is known to be present within the monument-the Capulin basin, which was partially mapped by Trauger and Kelly (1987). They mapped the occurrence of groundwater throughout the basin while investigating potential sites for a new electric generating plant in the area. The basin is believed

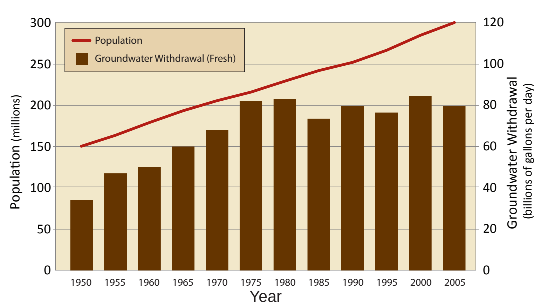

Figure 4.6-1-1. Groundwater withdrawals for the United States, 1950–2005.

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Figure 4.6.1-2. Capulin Volcano NM only has one known groundwater basin and no naturally occurring surface water.

to underlie an area of at least 105 square miles in parts of Colfax and Union counties, however, the exact extent of the aquifer is unknown. The eastern boundary includes the western side of the volcano, extending to the west, north, and south (Figure 4.6.1-4). Capulin Volcano NM's well draws from this aquifer at 207 m (680 ft).

The geologic formations around Capulin Volcano NM that pertain to the groundwater resource include Quaternary alluvium and extrusive/igneous rocks (Daniel B. Stephens & Associates 2007). The Capulin basin is characterized by relatively flat to gently sloping alluvial plains, shallow closed basins, and scattered playas. The alluvium consists mainly of well sorted fine to medium sand and fine gravel, and the volcanic rock consists mainly of scoria and cinders. Both of theses materials are highly transmissive and make up the principal aquifer of the Capulin groundwater basin (Trauger and Kelly 1987).

The numerous volcanic rocks/features rise above the plains and are underlain by a thick sequence of shale and fine-grained sandstone, which forms a relatively impermeable barrier to the downward movement of groundwater. There are no perennial streams in the basin although numerous springs exist due to the clay lenses that act as confining beds and result in artesian conditions at the lower east end of the basin (Trauger and Kelly 1987).

The highly jointed, rough-surfaced basalt flows and areas underlain by the scoria, as well as the alluvium layer, serve as recharge conduits by rapidly transmitting significant quantities of precipitation to the water table. These substrate types are highly porous, which results in large storage capacities and high transmissivity when precipitation is available.

Limited data indicate that the maximum aquifer thickness is approximately 55 m (180 ft) thinning to less than 6 m (20 ft). Because the volcanic rocks are highly receptive to infiltration of precipitation, recharge to the groundwater body may be as much as 20% of the annual precipitation. However, the recharge capability in the alluvial plains' soil and grass cover zone reduce recharge rates to approximately 5% (Trauger and Kelly 1987). The major sources of recharge are from higher elevation snow melt during the spring and the monsoonal rains during the summer months (Daniel B. Stephens & Associates 2007), but the majority of the precipitation is lost to evaporation and transpiration (Trauger and Kelly 1987). Additionally, temperatures throughout New Mexico have increased on average by 1.5 degrees since the 1960s (NM OSE 2006). Increased temperatures lead to high evapotranspiration, lower soil moisture, and a greater potential for drought. Prolonged drought could lower recharge rates and increase groundwater pumping needed for agriculture and irrigation

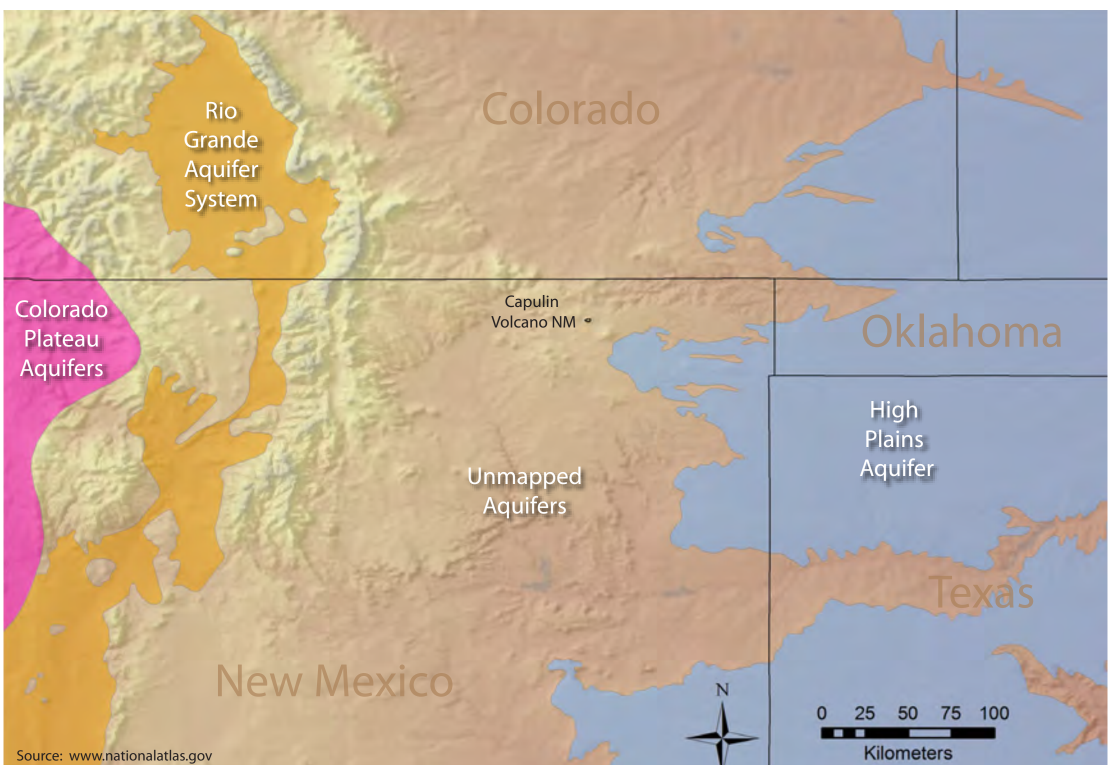

Figure 4.6.1-3. Major aquifer systems in the region surrounding Capulin Volcano NM

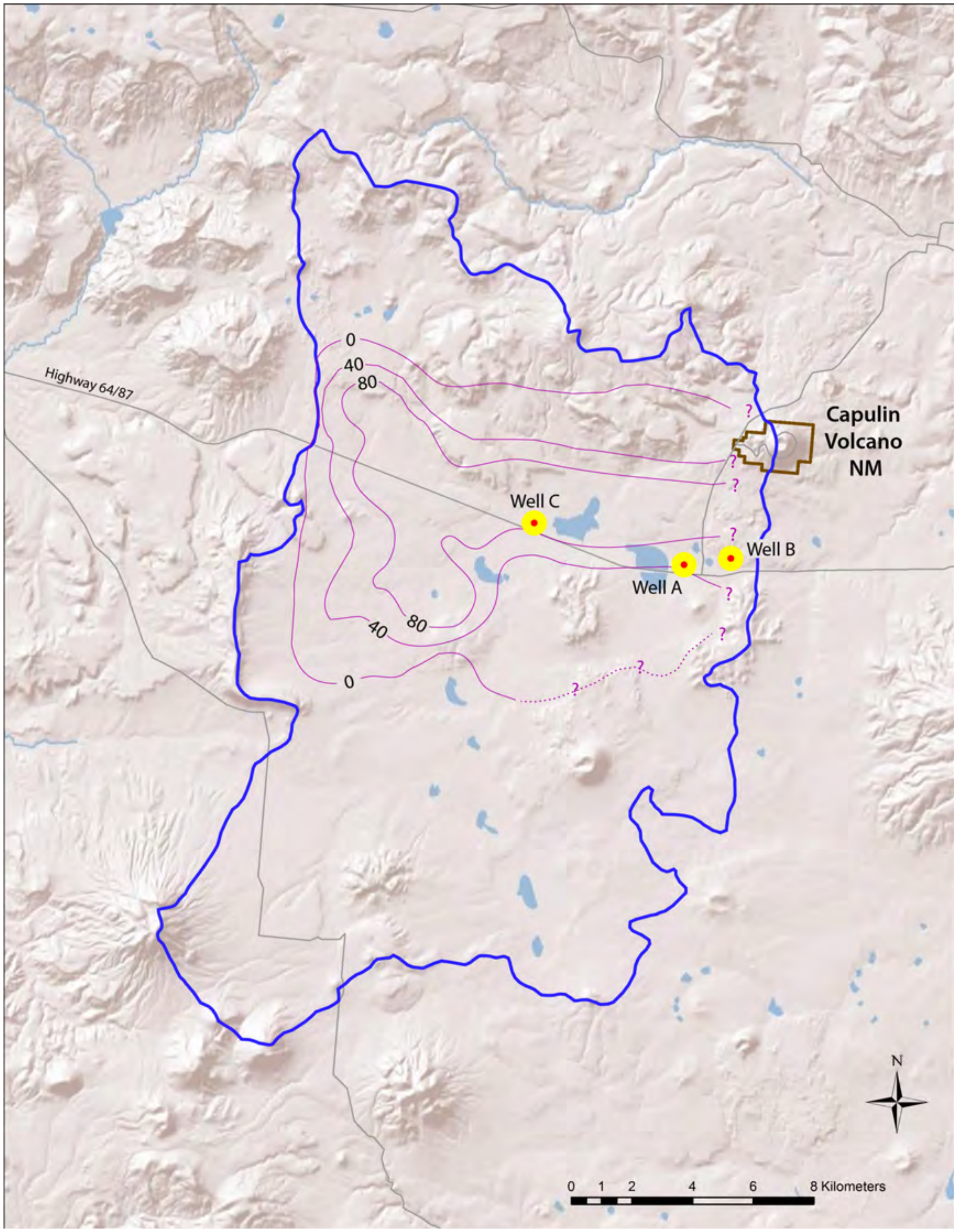

Figure 4.6.1-4. The boundary of the Capulin groundwater basin showing 40 ft (12 m) contour intervals for estimated thickness of the aquifer (adapted from Trauger and Kelly (1987). Also shown are three wells within the basin used to monitor groundwater as part of the U.S. Geological Survey National Water Information System.

purposes as a result of the drought. These two factors in combination will hasten the rate of aquifer depletion (Daniel B. Stephens & Associates 2007).

An additional basin that may be present within the monument was declared by the New Mexico Office of State Engineers in 2005 as the Clayton Groundwater Basin, however, it has not been fully mapped to determine its extent (Daniel B. Stephens & Associates 2007) and at this point is unknown if it includes any area within the monument.

4.6.2. Data and Methods

Data used for the groundwater indicator were obtained from the US Geological Survey (USGS) National Water Information System (http://nwis.waterdata.usgs.gov/usa/nwis/gwlevels/) (USGS 2011c), a national water database, including groundwater levels.

Indicators/Measures

- Change in Groundwater Level

Groundwater storage is determined by aquifer characteristics and water levels within the aquifer. Changes in storage are directly associated with changes in water levels. Rising water levels indicate increased storage resulting from greater inflow than outflow, while declining water levels indicate that outflow exceeds inflow. Thus, change in groundwater level was used as the measure/indicator, using the depth to groundwater or water level elevation as our primary measurement.

Groundwater Wells in the Capulin Basin

Three USGS monitored wells are located near the monument, one in Colfax County and two in Union County (Figure 4.6.1-4). The water level elevations and depths to water levels have been monitored at all three wells since the 1950s. Information pertaining to each well is listed in Table 4.6.2-1 and data collected from each well are presented in graphs in Figures 4.6.2-1, -2, -3, showing both the depth to water on the y-axis, located on the left, and the water level elevation on the y-axis, located on the right.

Well A has a period of record from August 14, 1958 to the most recent reading (at the time of writing) taken on August 25, 2010. The highest depth to water measurement, 8.54 m (28.01 ft), was taken on 2/8/1974, omitting a measurement taken during pumping of the well, and the lowest water level at Well A was recorded on 7/20/1994 at 11.51 m (37.76 ft) (n=88).

Well B has a period of record from 7/11/1951 through 8/25/2010. The most recent reading recorded depth to water of 8.56 m (28.09 ft), the highest water level on record. The lowest measured water level at Well B was a depth to water of 12.21 m (40.06 ft) recorded on 1/23/1975 (n=35).

Well C has been monitored from 1957 to present with the last reading occurring on 1/25/2011. The highest water level was measured on 2/3/1960 and 8/24/1960 with a depth to water of 1.42 m (4.65 ft) and the lowest water level was measured on 8/5/2008 at a depth to water of 6.37 m (20.89 ft) (n=96).

4.6.3 Reference Conditions

The reference condition we used for change in groundwater level is one of sustainability; where on average, supply meets demand. When supply meets demand, we expect variability that reflects annual variation in environmental conditions (e.g., rainfall, evapotranspiration, pumping), but lacks an overall long-term declining water level trend.

4.6.4 Condition and Trend

As shown in Figures 4.6.2-1 and 4.6.2-2, water levels in two of the three wells, Well A and Well C, show trends in depth to groundwater (increasing depth to water, decreasing water level elevation) over the period of record. At Well A, the rate of decline has been more or less consistent since measurements began in the 1950s. At Well C, the rate of decline has accelerated substantially since 2000. The sustained declines in water level at these wells indicate that long-term overdraft has been occurring and continues to take place in these areas, (i.e., more water is being removed from the aquifer than is being replaced). This condition is known as groundwater mining, and it is unsustainable in the long term. Furthermore, continuation of declining water levels can be expected to eventually result in a loss of flow at springs that are reported to be present in the southeast end of the basin.

The water level at Well B, shown in Figure 4.6.2-2, appears to have increased 10 feet between 1996 and 2008. Without further investigation it is not possible to identify specific reasons for this increase, which appears to be localized.

Table 4.6.2-1. Groundwater wells located in the Capulin basin

Well	US Geological Survey ID	County	Depth of Well (ft)	Local Aquifer Description
Well A	364444104000201	Union	78	Undefined Aquifer - Alluvium, Bolson Deposits and other Surface Deposits
Well B	364444103591301	Union	41.1	Undefined Aquifer - Alluvium, Bolson Deposits and other Surface Deposits
Well C	364522104034501	Colfax	120	Undefined Aquifer

Table 4.6.4-1. Summary of the groundwater indicators/measures and their contributions to the overall groundwater natural resource condition assessment.

Indicator/Measure	Description of How the Indicator(s) Contributes to the Overall Resource Condition	General Contribution of this Indicator or Measure to the Overall Resource Condition.
Change in groundwater level	Water level can indicate depletion of an aquifer if the level continues to lower. This can be a result of supply exceeding demand and/or from a recharge rate that cannot maintain a degree of sustainability for the aquifer. On the other hand, if water level increase occurs that may be a result of retired wells that drew from a particular area within the basin or from recharge rates exceeding extraction.	Two of the three well water level recordings of the Capulin basin indicate a decline in water level, but the third well record indicates an increase in water level, most likely from a localized change in usage. Overall, the water level in the Capulin basin is good, especially given the current supply and demand.

Localized water level rises can occur when pumping wells are retired and water supplies are obtained from other sources, or when irrigated fields are no longer irrigated.

In determining condition for the monument's groundwater, it must be considered that the boundaries of the Capulin basin, as mapped by Trauger and Kelly (1987) are particularly uncertain in the vicinity of the monument itself. Data from the immediate monument area are not available, and data from the wells shown in Figures 4.6.2-1 to 4.6.2-3 are relatively distant from the monument. However, our conclusion regarding resource condition is that there is a definite indication of declining groundwater levels in the area surrounding the monument, but there is also an indication of increasing water level from at least one well. Also, at this time, on the land surface, there is no empirical evidence of secondary effects from changes in groundwater levels (e.g., reduction in flow to springs or vegetation change), although declining water levels in the Well A area are near the depth below which vegetation effects may soon be seen.

Water Use in Colfax and Union Counties

According to the Union County water planning officials, groundwater supplies all of the communities in Union County (Daniel B. Stephens & Associates. 2007), whereas surface water supplies 95% of the water needs in Colfax County (Daniel B. Stephens & Associates 2003). In both counties, the majority of the water is used for irrigation purposes, however, cattle ranching is one of the largest agricultural commodities surrounding the monument, but requires minimal water use compared to cropland production (Daniel B. Stephens & Associates 2003, 2007). Officials believe aquifer sustainability is not as much of a concern in the Capulin area, however, if high growth occurs in the area, aquifer sustainability issues will most likely occur as well (Daniel B. Stephens & Associates. 2007).

For assessing the condition of groundwater, we one indicator/measure, which is summarized in Table 4.6.4-1. Three wells that draw from Capulin basin have been monitored by USGS since the 1950s, providing information about the groundwater level in the area.

Thus, based on the limited data available, we conclude that the groundwater condition is good for the Capulin basin, but at this time, there is insufficient evidence to make a definite conclusion regarding the trend of the groundwater resource. From a regional perspective, there is evidence of declining water levels and overdraft of the Capulin basin, providing weak evidence for a declining trend.

Key Uncertainties

A key uncertainty is the unknown extent of the Capulin basin and the surrounding basins. Additionally, we do not know the supply and demand for groundwater in this area and cannot predict future development throughout the area. Another key uncertainty, although not discussed as an indicator for this assessment, is the quality of the groundwater. Currently no groundwater quality monitoring is occurring.

4.6.5 Sources of Expertise

Colleen Filippone is the NPS Intermountain Region hydrologist and specializes in groundwater. She provided valuable information

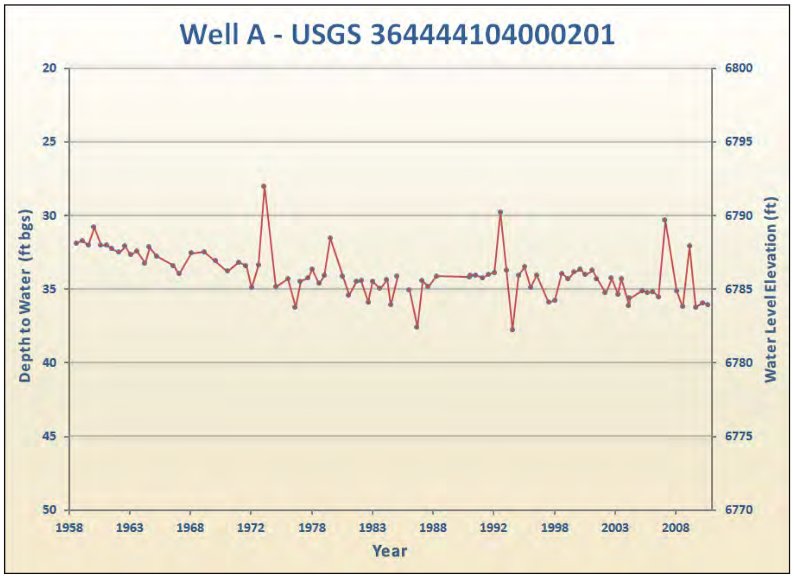

Figure 4.6.2-1. Depth to water level and water level elevation for well A

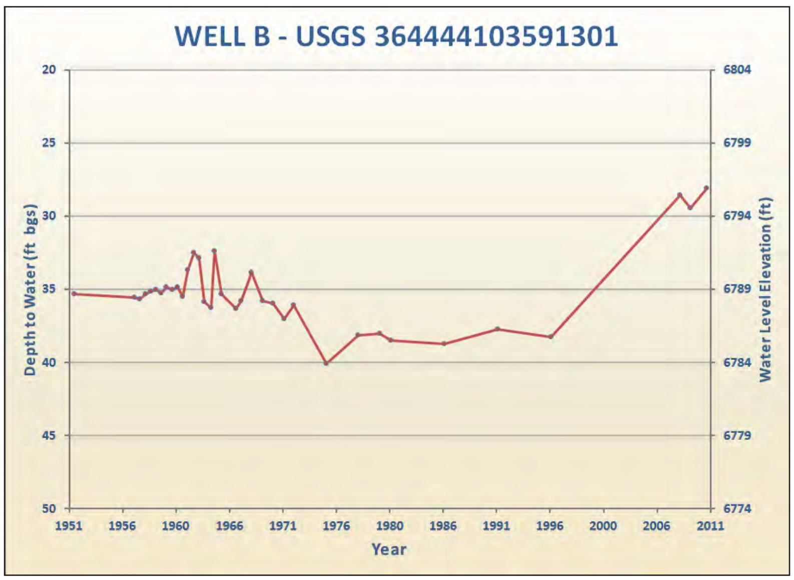

Figure 4.6.2-2. Depth to water level and water level elevation for well B

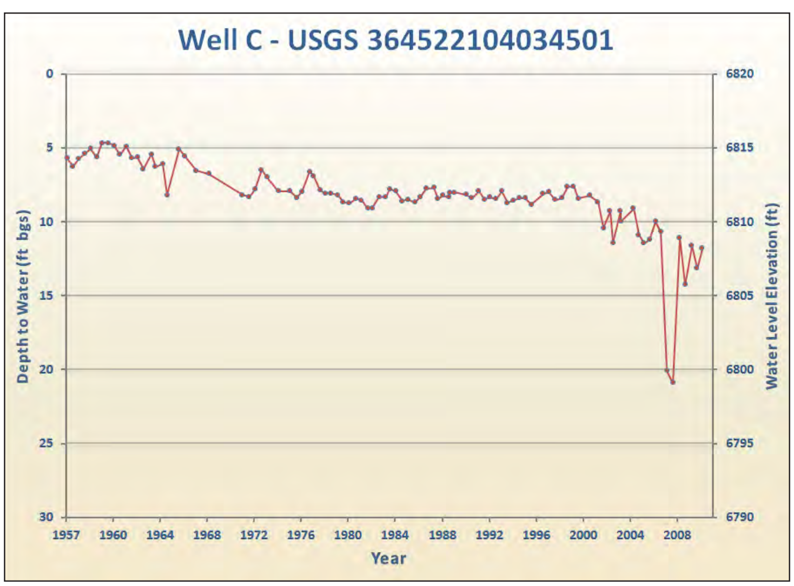

Figure 4.6.2-3. Depth to water level and water level elevation for well C

pertaining to groundwater and reviewed this section of the condition assessment

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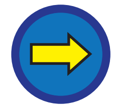
4.7 Piñon-Juniper

Indicators/Measures

- Are the species present and their distribution consistent with supply and demand of light, water, nutrients, and growing space and, within their natural range of variability?
- Are stands densities within their range of natural variability for their growing conditions?
- Are the age class distributions of piñons and junipers consistent with the expected range of variability for this site/ecosystem type?
- Do the trees and understory plants appear vigorous and healthy for this site/ecosystem type?
- Are ecological processes (e.g., fire) operating within the natural range of variation?
- Are the current levels of insects and/ or disease within the normal range for this ecosystem type?

Condition - Trend



Good - Stable

4.7.1 *Background and Importance*

Piñon pine (*Pinus edulis*) and Rocky Mountain juniper (*Juniperus scopulorum*) (piñon-juniper) is one of the major habitat types found within the boundaries of Capulin Volcano NM and comprises approximately 59% of the total area of the monument according to recent vegetation mapping efforts by Muldavin et al. (2011) (Figure 4.7.1-1). Piñon-juniper habitats have considerable value to wildlife. Piñon-juniper woodlands serve an important role as cover, particularly thermal cover during winter, for large mammals such as mule deer (*Odocoileus hemionus)* and elk (*Cervus elaphus*) (Fairchild 1999; Gillihan 2006). They also provide food sources for many wildlife species. Piñon nuts are consumed by a variety of both mammal and bird species, of which some, such as Piñon Jays

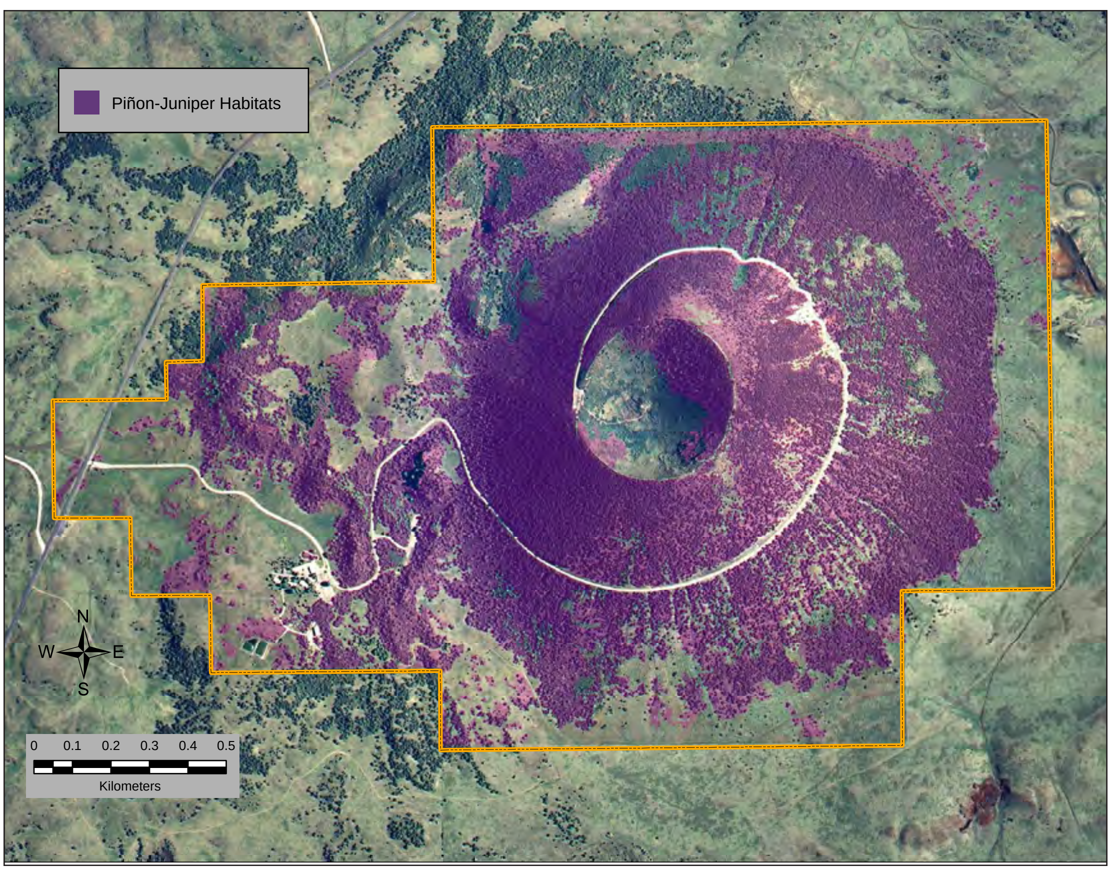


Figure 4.7.1-1. Piñon-juniper habitats comprise approximately 59% of the total area of Capulin Volcano NM (Muldavin et al. 2011)

(*Gymnorhinus cyanocephalus*), even specialize on this food source (Balda 2002) (Figure 4.7.1-2). Juniper berries also provide a food source for a variety of wildlife such as Townsend Solitaires (*Myadestes townsendi)*, which winter in areas of juniper (Bowen 1997). In addition to providing food, piñons and junipers provide nesting habitat for a variety of species (Gillihan 2006). Because of their food and other values, piñon-juniper woodlands support a higher abundance and diversity of birds than many other forest types as well as one of the highest proportions of obligate or semi-obligate bird species (Gillihan 2006; Paulin et al. 1999).

Piñon-juniper habitats contribute to biological diversity in other ways too. For example, trees along the east rim of the crater are covered with a distinctive community of well-developed foliose lichens (Figure 4.7.1-3). These lichens are a relatively uncommon feature found on a few isolated mountain tops in New Mexico where clouds and mist provide sufficient moisture to support the growth of epiphytic plants (see Romme comments in Appendix D).

Historic Perspective of Piñon-Juniper Habitat Condition

Until recently, the prevailing view of the current condition of piñon-juniper habitat at Capulin Volcano NM was that it was in a deteriorated state of grassland/savanna habitat that unnaturally filled in with piñon-juniper (NPS 2004; NPS 2005). This view was expressed in NPS (2004):

> "pre-settlement woodlands in this region were usually savanna-like or confined to rocky outcrops, not typically susceptible to fire."

This perspective included additional views related to the mechanisms for such deterioration, particularly changes in fire regimes, and that detrimental change (i.e., piñon-juniper "infill") has largely occurred over the past century as a result of fire suppression. Thus, a Fire Management Plan (2004; 2005) was developed for the monument, which prescribed thinning of piñon-juniper trees/shrubs, along with other woody vegetation , as well as burning treatments throughout the monument.

Because developing an appropriate reference condition for the piñon-juniper habitat was critical for this condition assessment, we closely examined the evidence used to support the widely-held views about the historical condition of piñon-juniper at the monument, and the mechanisms of change of piñon-juniper by addressing the following questions:

1. Does the evidence support the conclusion that Capulin Volcano NM was historically a grassland or savanna, making that an appropriate reference condition for piñon-juniper habitat?
2. Does the evidence support the conclusion that expansion and infilling of piñon-juniper has occurred at Capulin Volcano NM? If yes, is such expansion or infilling outside of the natural range of variability?
3. If yes to "1" or "2", can this conclusion be universally applied to the entire monument?

We were also interested in one additional question that relates to determining an appropriate reference for fire regimes:

4. If yes to "1" or "2", does the evidence support that the piñon-juniper infill has

SALLY KING

REBECCA RICHMAN

Left:
Figure 4.7.1-2.
Some wildlife species, such as Piñon Jays specialize on piñon nuts as a food source.

Right:
Figure 4.7.1-3.
Many trees along the east rim of the crater are covered with distinctive foliose lichens.

occurred over the past century as a result of fire suppression?

Answering these questions was a critical first step in determining the importance of piñon-juniper habitat throughout the monument.

4.7.2 Data and Methods

We adapted criteria developed by Edmonds et al., (2011) in consultation with piñon-juniper experts, W. Romme, C. Allen, and B. Jacobs, to evaluate the condition of piñon-juniper habitat at Capulin Volcano NM. Eight indicators were presented by Edmonds et al. (2011), including one that does not apply to the monument (aquatic species). Two additional indicators, soil erosion and wildlife, were also eliminated (but addressed elsewhere in this assessment), leaving five original indicators. These remaining five were split apart for clarity, and formed the basis of our piñon-juniper indicators/measures.

Indicators/Measures

- Are the species present and their distribution consistent with supply and demand of light, water, nutrients, and growing space, and within their natural range of variability?
- Are stands densities within their range of natural variability for their growing conditions?
- Are the age class distributions of piñons and junipers consistent with the expected range of variability for this site/ecosystem type?
- Do the trees and understory plants appear vigorous and healthy for this site/ecosystem type?
- Are ecological processes (e.g., fire) operating within the natural range of variation?
- Are the current levels of insects and/or disease within the normal range for this ecosystem type?

4.7.3 Reference Conditions

Based on the belief that effective management of piñon-juniper has been hindered by an inadequate understanding of these ecosystems throughout the western United States, a group of 15 of the leading researchers of these ecosystems, including three researchers with whom we consulted for this assessment, held a workshop and published a synthesis paper that represents a consensus of what is known about disturbance regimes, stand structure, and landscape dynamics in piñon-juniper habitats (Romme et al. 2009).

Determining the proper reference conditions for piñon-juniper stands at Capulin Volcano NM was a critical first step of assessing the condition of this vegetation type. Because of the previous perceptions that the piñon-juniper represented a deteriorated state of what was historically a grassland community, we first had to establish whether a grassland state or a piñon-juniper state was an appropriate reference condition.

We assessed a wide variety of information in consultation with the piñon-juniper experts to determine appropriate reference conditions for the piñon-juniper habitat at the monument. This included comparing historic photographs of the habitat throughout the monument with recent photos (e.g., repeat photography), comparing the habitat within the monument with the habitat surrounding the monument, reviewing monument-specific studies related to the piñon-juniper stand age and fire history, and patterns (i.e., historic and current) of piñon-juniper in other regions of the western United States.

Repeat Photography

What is probably the most commonly cited evidence for piñon-juniper expansion into what is believed to be former grasslands is the reference to historic photographs of monument habitat taken in the early 1900s). One such pair of photographs looking at Capulin Volcano from the west has been prominently displayed at the Capulin Volcano NM visitor center (Figure 4.7.3-1). This set, while interesting, lacks the detail that can be seen in some other photo comparisons. Therefore, we decided to compare the habitat between photos as old as possible to present day photos taken from approximately the same location, otherwise known as repeat photography. Others have effectively used repeat photography to compare changes over time as well (sensu Vale 1987).

The best examples of repeat photography at Capulin Volcano NM come from unpublished reports by Jönsson (1992) and Callaghan (1992), which are slightly different report versions from the same repeat photography effort. The two investigators went to great lengths to duplicate

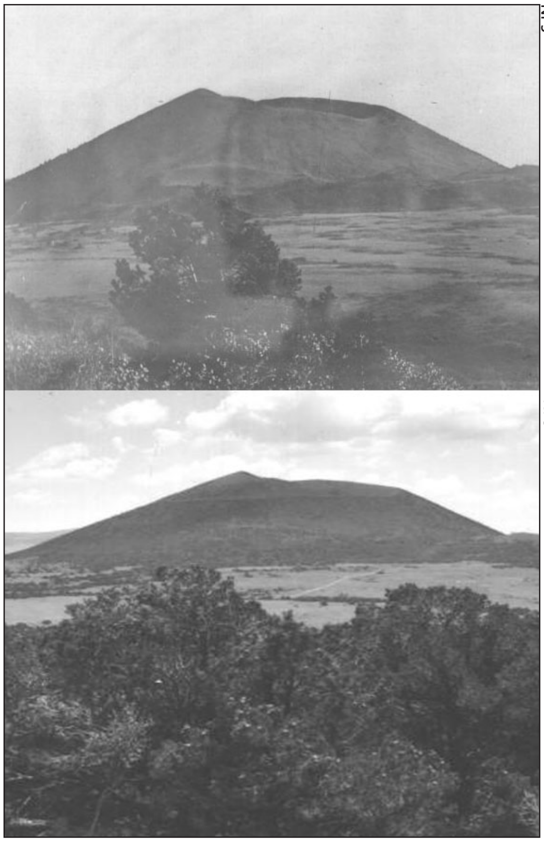


Figure 4.7.3-1.
A set of repeat photographs displayed in the Capulin Volcano NM visitor center, one from the early 1900s (top) and the other from 1976 (bottom).

photographs taken during the early 1900s from the exact position and angle as the originals. Unfortunately, we were unable to locate their original photographs, and the quality of the images in the available report copies were very poor, with much of the detail lost from the copying process. Instead, we researched the U.S. Geological Survey photo archives to find the oldest possible photos of the monument where we could identify the locations from where the photos were taken. We then took new photos from the same location and at the same angle and approximate distance to compare the current habitat to the historic photo habitat. We created five photo pairs of repeat photography and their locations and viewing angles are shown in Figure 4.7.3-2.

Based on the repeat photo comparisons for photo sets one, two, and three, (presented in Figures 4.7.3-3, -4, -5), there is little doubt that piñon-juniper habitats were considerably more sparse during the early 1900s than at present, at least in areas depicted in the photos. Photo set one (Figure 4.7.3-3), taken from the monument's northeastern corner and looking at the cinder cone's north, northeastern side, shows some infill by piñon-juniper along the cinder cone's north, northeastern slope, but as shown in the 1909 photo, piñon-juniper was present on the cinder cone at least since the turn of the 20th century. This is also the case in photo set two (Figure 4.7.3-4) where the 1909 photo shows the presence of piñon-juniper along the western side of the cinder cone, supporting the notion that this area of the cinder cone was a piñon-juniper shrubland as opposed to a shrubland

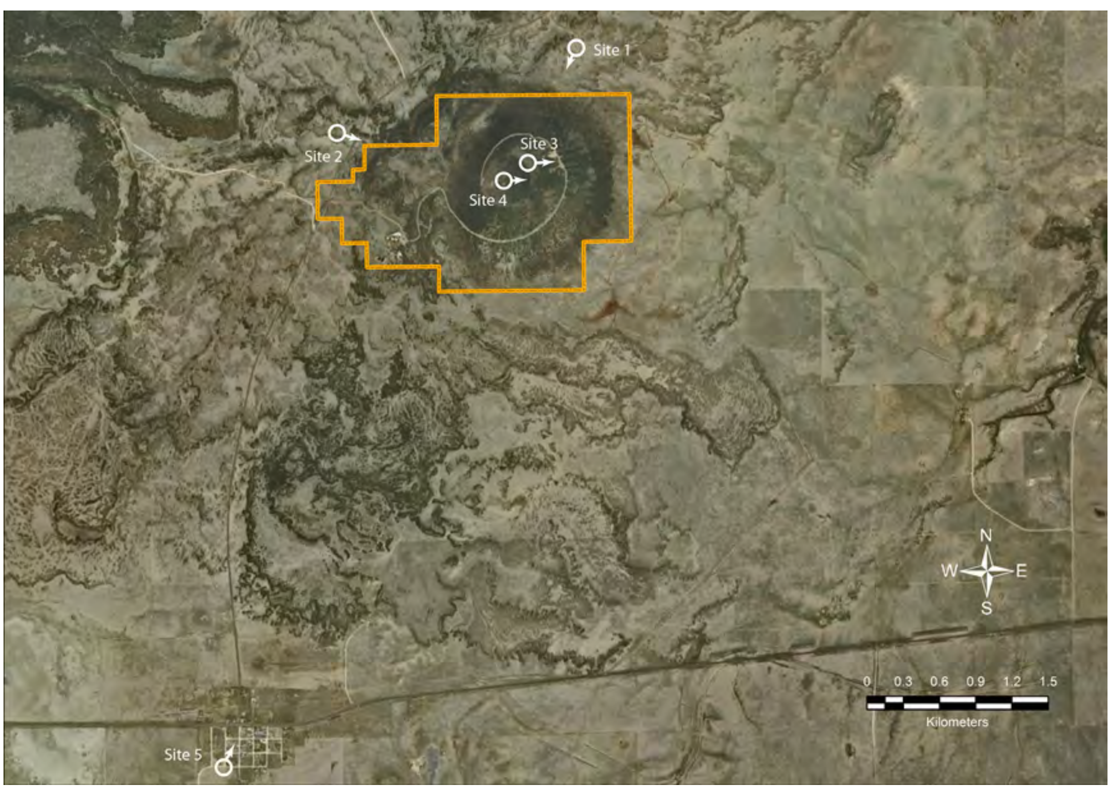
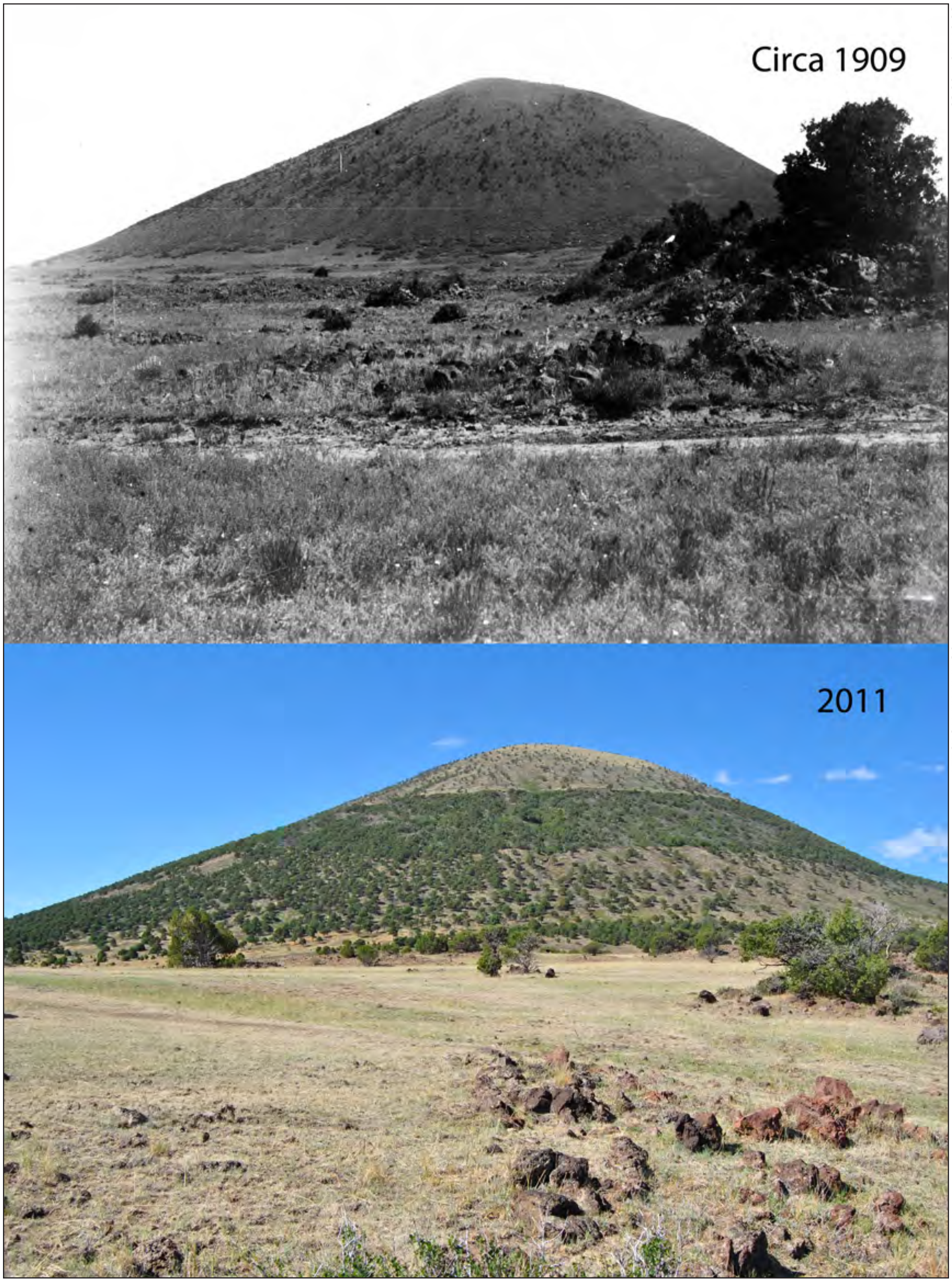


Figure 4.7.3-2.
Photo point locations for the repeat photography, showing the viewing angles with the arrows.



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JONATHIN HORSLEY

Figure 4.7.3-3. Photo set one, viewing the north, northeast slope of Capulin Volcano.

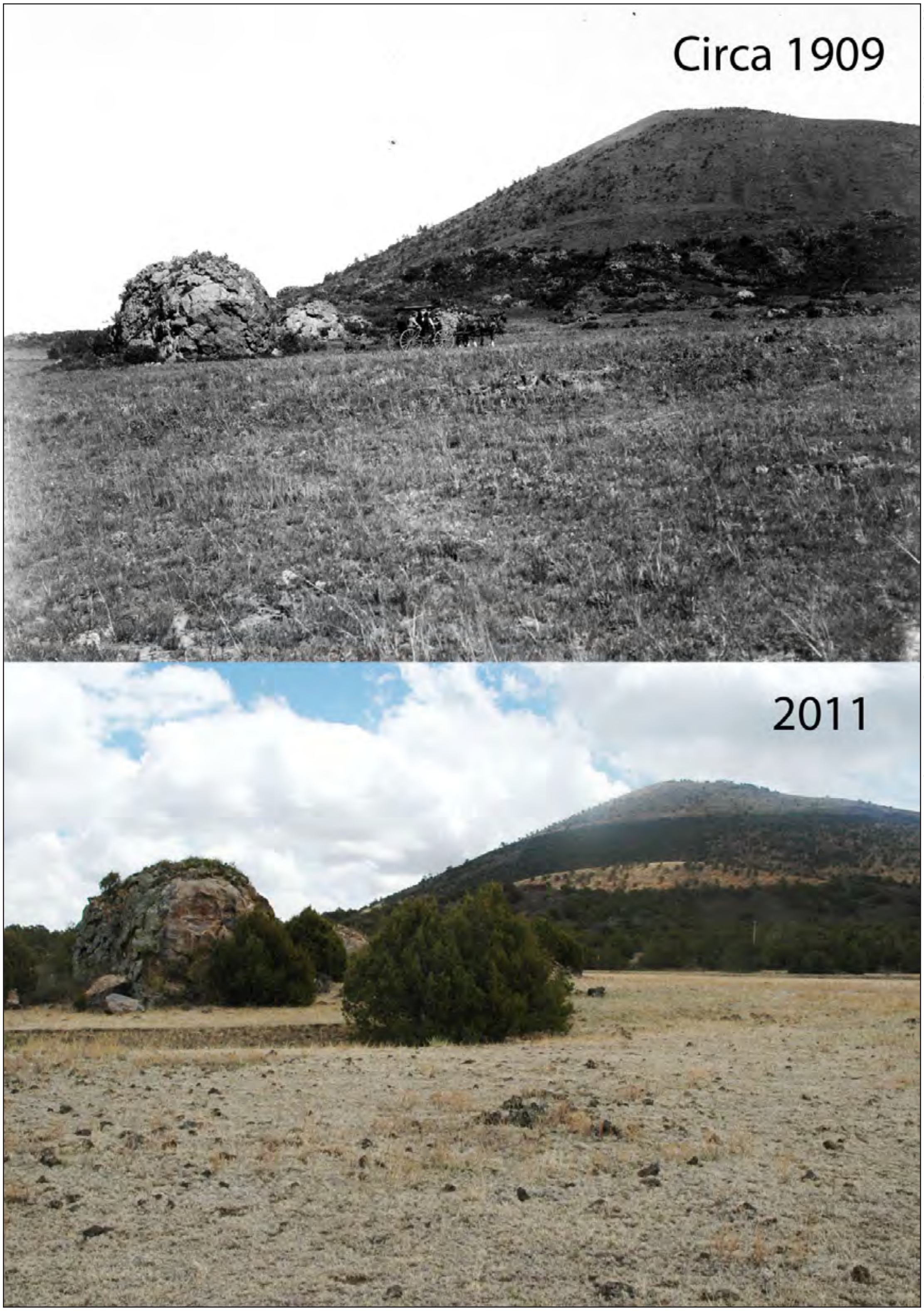


Figure 4.7.3-4. Photo set two, viewing the north, northwest slope of Capulin Volcano.

COURTESY USGS

ROBERT BENNETTS

Figure 4.7.3-5. Photo set three, viewing the north, northeast boundary corner of Capulin Volcano and beyond into the surrounding grassland.

only (without piñon-juniper) or a grassland. It is also important to point out that in photo set two, the grassland area of the Boca is obvious in both the historic and present day photos, indicating that what was a grassland still remains a grassland in present day, although it is true that in some areas piñon-juniper infill has occurred. The historic grassland area is also evident in photo set three (Figure 4.7.3-5), which was taken from the Rim Trail facing northeast and shows what was a grassland at the turn of the century has persisted, and again, has not been degraded by piñon-juniper infill. Photo set four (Figure 4.7.3-6) is taken from within the crater and is very similar to Jönsson (1992) and Callaghan's (1992) photo sites three and eight. Our photo set four shows that some piñon-juniper infill has occurred, however, what is not revealed in this photo set is that piñon-juniper was present in the crater as shown in Jönsson and Callaghan's 1937 photo, which shows a wider angle within the crater than what our photo set captured. The final set of photos (number 5; Figure 4.7.3-7) was taken from outside the monument, overlooking the village of Capulin, NM, facing Capulin Volcano's southern slope. It is very apparent from this photo set that piñon-juniper was the dominant vegetation type on this part of the cinder cone even as early as 1909. In fact, interviews with local residents and historic documentation indicate that residents gathered piñon wood from the cone for firewood and construction materials (S. Cinnamon, pers. comm. 1/24/1980; Hunner and Lael 2003).

The former interpretation that Capulin Volcano NM's historic habitat photos were all of grasslands or savannas is clearly not evident. In fact upon closer examination of these and similar photos, such as those shown in Figure 4.7.3-8, many areas were more likely a shrubland in the early 1900s rather than grassland; the exception being the grasslands pointed out previously in photo sets two and three, as well as the Boca shown on the lower slope, especially in the middle photo in Figure 4.7.3-8. Even the name "Capulin," which means choke cherry in Spanish, is more likely to be given to an area covered by shrubs/trees than of grasslands. In photographs that contain known grasslands, this distinction becomes considerably more obvious. Take for example the photos in Figure 4.7.3-8, which are arranged from most recent at the top to circa 1909 at the bottom. The area in question on the western side of the cinder cone (top photo) as to whether it was formerly a grassland that has been infilled by piñon-juniper is highlighted in yellow. As one zooms in to the area in question (middle photo), the difference is evident between what is clearly a grassland compared to the area in question, which appears to be more of a shrubland (but definitely not the same composition as what is adjacent to it and labeled "grassland"). As one zooms in further (bottom photo), shrubs and/or trees are very visible, documenting their presence on the western side of the cinder cone at least since the turn of the 20th century.

Even if the west slope of the cinder cone was a shrubland in the early 1900s, as we believe evidence from early photographs supports, this still does not necessarily preclude the possibility that it was a grassland at some earlier point in time, as some others believe, so additional information was considered. This additional information included soils, existing ground cover, and general ecological site conditions along the western slope. After site visits by the piñon-juniper researchers, they all agreed that the conditions along the west side of the cone were more consistent with a persistent piñon-juniper woodland or wooded shrubland than a grassland or savanna. They further expressed that tree densities of these piñon-juniper types typically wax and wane in response to climatic fluctuation and disturbance by fire and insects (Romme at al. 2009, Swetnam et al. 1998). They also expressed that the current shrubland conditions with young piñons and junipers is certainly consistent with a piñon-juniper woodland or shrubland possibly recovering from a stand replacing fire in the 18th or 19th century. Additionally, they had no doubt that the remainder of the cinder cone (north, east, and south sides) presented conditions that were consistent with a piñon-juniper woodland versus a degraded grassland or savanna.

Another misinterpretation with using early photography as evidence that Capulin Volcano NM was historically a savanna or grassland is the spatial extrapolation. In many cases, general statements such as "forestation of pinyon-juniper has occurred on the slopes of Capulin Volcano during the past 100 years, as documented by photographic evidence" (NPS 2005) have been applied to Capulin Volcano NM as a whole. However, the photographic evidence that shows piñon-juniper expansion into grasslands applies primarily to a limited subset of the area. The most notable areas that were (and still are) clearly grasslands are (1) patches along the crater rim (2) the grassy areas

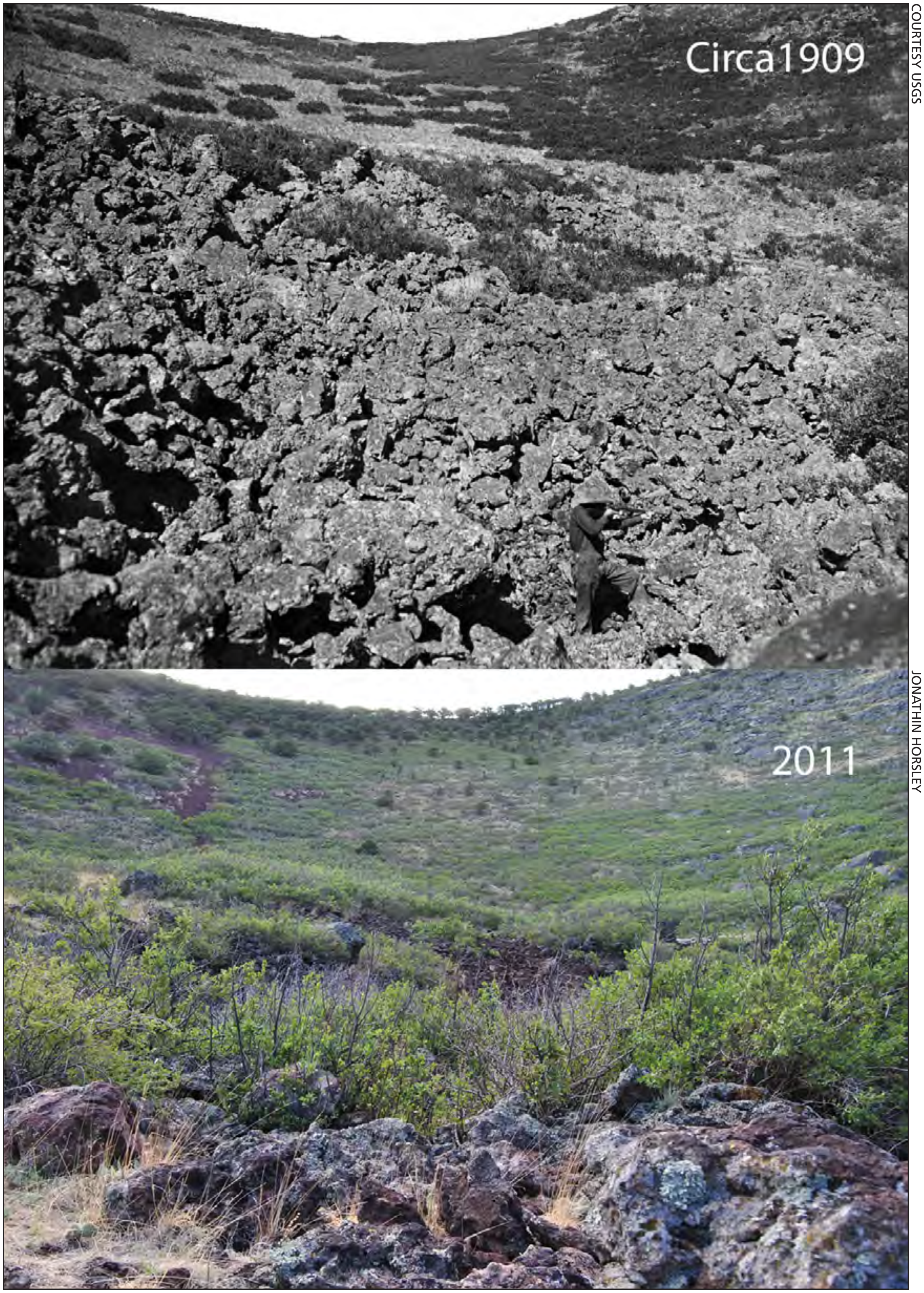
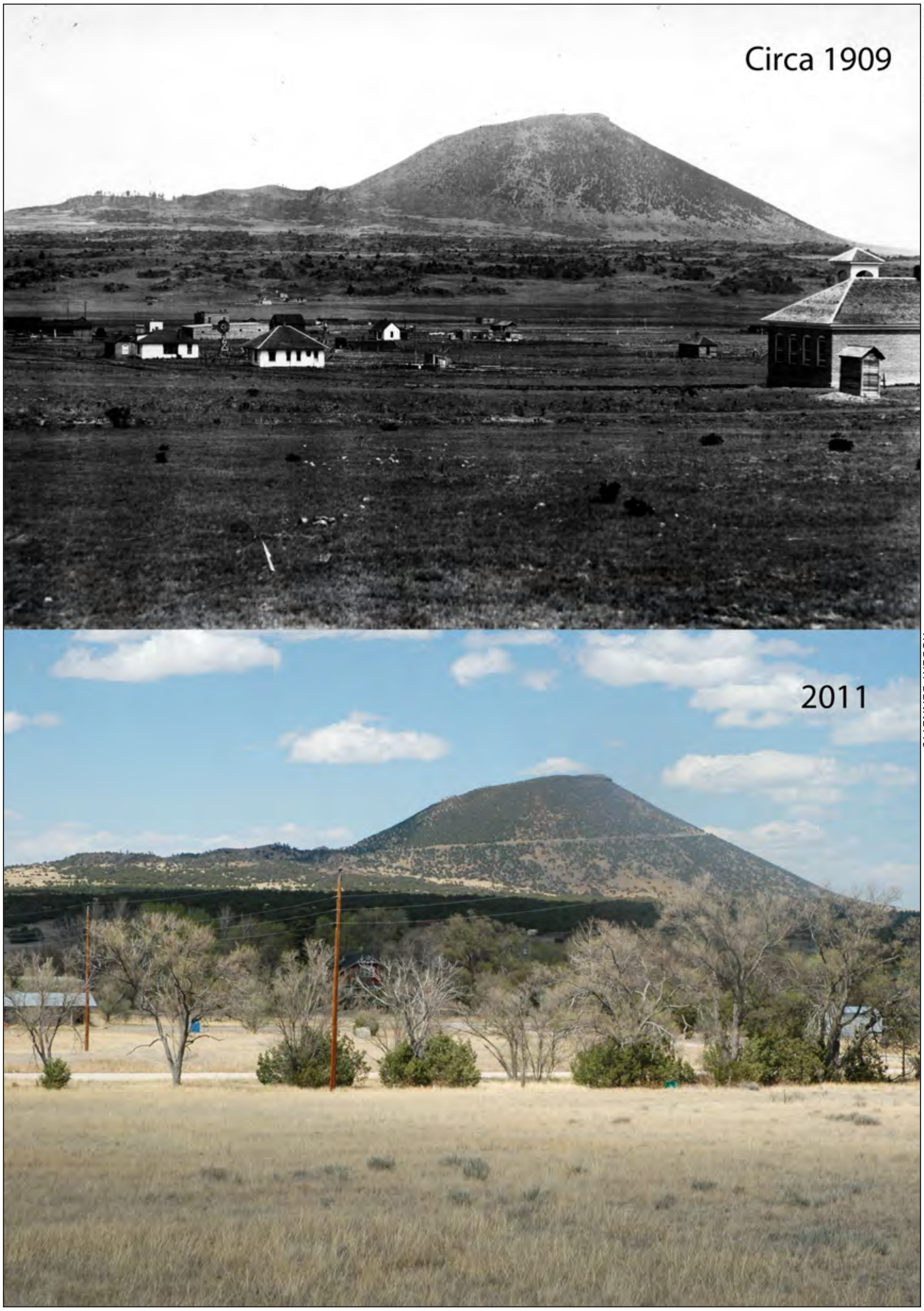


Figure 4.7.3-6. Photo set four, viewing the eastern slope inside Capulin Volcano's crater.



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ROBERT BENNETTS

Figure 4.7.3-7.
Photo set five viewing the southern slope of Capulin Volcano from Capulin, NM village, formerly the town of Dedman.

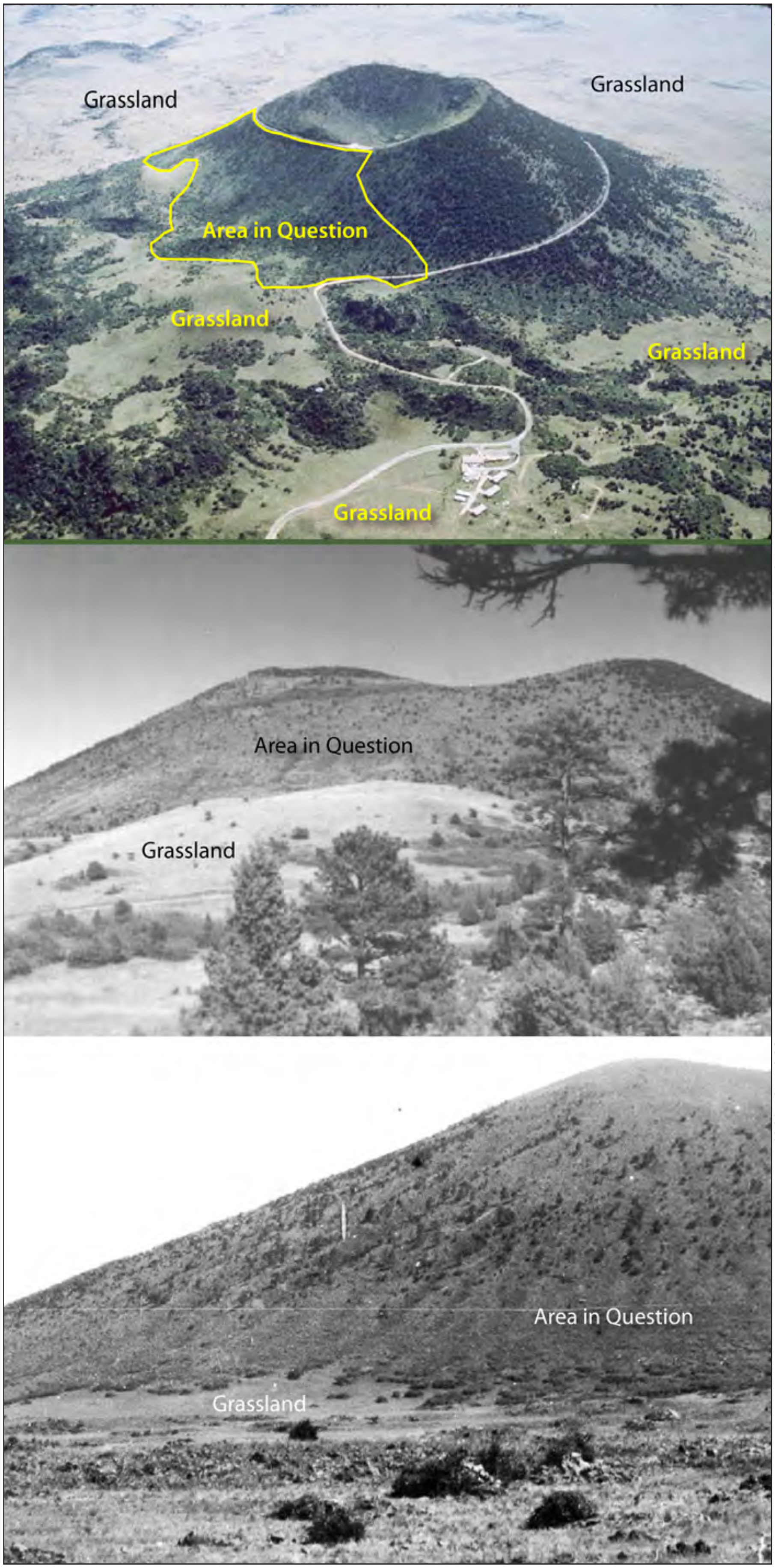

Figure 4.7.3-8.
In photographs that show areas of known grasslands (as labeled on the photos), the distinction between grassland areas and the area in question on the western side of the cinder cone becomes more obvious that the west side is and was something other than grassland at least since the turn of the 20th century.

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NPS

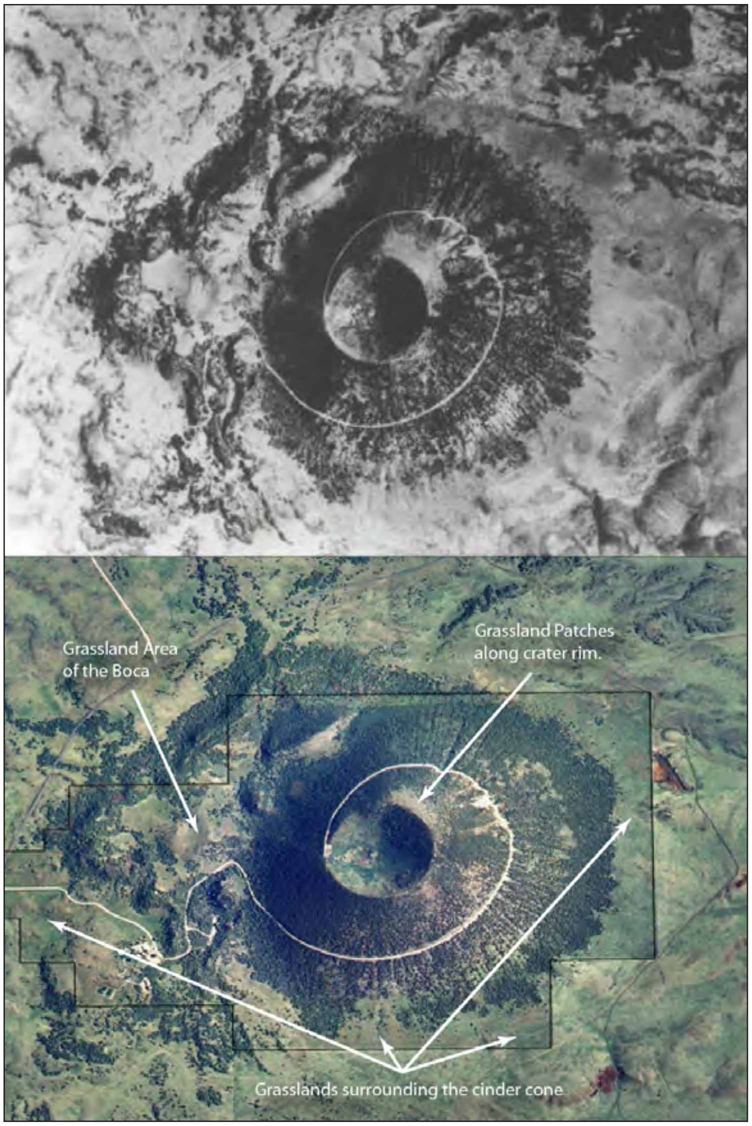

Figure 4.7.3-9. Aerial photo from 1938 (top) showing grassland areas and a 2005 image (below) for comparison.

of the Boca on the lower western slope, and (3) along the southern and eastern boundary and along the entrance road (Figure 4.7.3-9). While the photographic evidence clearly shows some piñon-juniper expansion into these grassland areas, this cannot validly be extrapolated to imply that all of Capulin Volcano NM was a contiguous grassland. This is especially true when other photographs of the monument from directions other than the west clearly show that the cinder cone, even in the early 1900s, was covered with piñon-juniper (Figure 4.7.3-10).

Comparison with Other Cinder Cones in the Raton-Clayton Volcanic Field

The second source of evidence used to support the perspective of the piñon-juniper habitat being a degraded grassland or savannah is that other volcanic features within the Raton-Clayton Volcanic Field are covered by grasslands. Although it is true that some of the other volcanic features are covered with grasslands, there are inconsistencies when using this as evidence that Capulin Volcano NM was historically a grassland or a savanna. First, Capulin Volcano is not the only volcanic feature in the area covered by piñon-juniper (Figure 4.7.3-11).

There also have been two studies we are aware of that specifically examined the question of why piñon-juniper exists on Capulin Volcano, while not on some of the other cinder cones of the Raton-Clayton Volcanic Field. Although both studies were somewhat limited, both concluded that site characteristics, particularly soils, was a primary determinant of piñon-juniper presence. Harfert (1967) examined the vegetation on three volcanos of similar age and physical dimensions. He concluded that one key factor explaining why Capulin Volcano is covered with piñon-juniper is the caliche layer which enhances moisture retention and availability. A later study by Hacker and Grosso (2008), examined characteristics of piñon-juniper stands within the Raton-Clayton Volcanic Field and similarly concluded that site characteristics, particularly soil depth had the greatest influence on piñon-juniper growth. Additionally, Romme et al. (2008) suggest that the strongest evidence that an area was persistently occupied by savanna, grassland, or shrub-grassland in the past is the presence of a mollic epipedon, which typically develops where grasses are dominant over long time. The mollic epipedon depths for the different soils found throughout the monument, as mapped by Weindorf et al. (2008), are shown in Figure 4.7.3-12 and are consistent with what one would expect to find in areas dominated piñon-juniper versus grasslands (e.g., deeper mollic epipedons in grasslands and shallower in woodlands). However, one confounding factor is soil loss, which can occur from erosion and grazing,

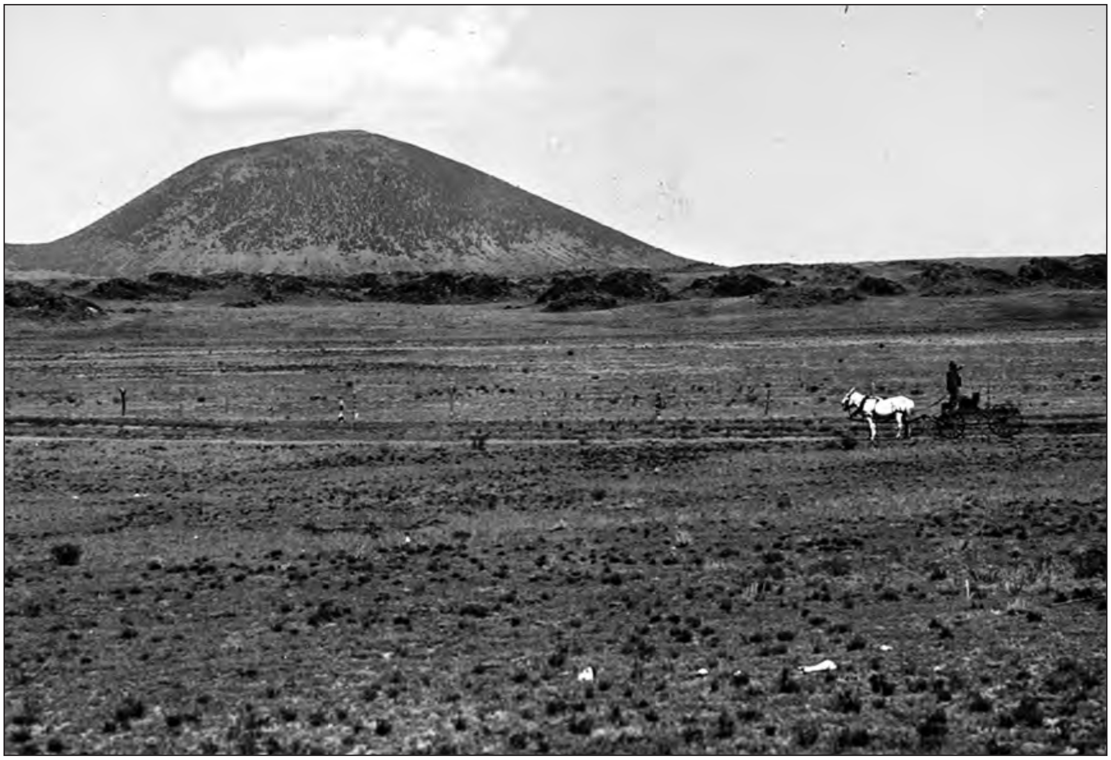

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Figure 4.7.3-10. Photograph of Capulin Volcano (*circa* 1909) viewed from the town of Capulin, NM (formerly Dedman), showing that the south and east side of the cinder cone was covered by piñon-juniper, even during the early 1900s.

making it somewhat difficult to determine total soil development depths.

Stand Age

A source of evidence that is sometimes overlooked is the age of trees on the cinder cone. A recent study by Guyette et al. (2006) found piñon pines ≥485 years on the south and east slopes. This is consistent with the photographic evidence that confirms piñon-junipers having been well-established on the cinder cone at least since the early 20th century. Based on core samples that helped to identify years of establishment, Guyette et al. (2006) also concluded that piñons have exhibited relatively continuous recruitment over the past 300 years. Although this evidence again does not preclude the possibility that these areas were grasslands or savannas at some earlier point in time, it certainly does not support the claim in NPS 2005 that piñon juniper has replaced short-grass prairie over much of the steep slopes of the monument during the past 100 years.

Inference Extrapolated From Other Areas

There is substantial evidence that tree densities of piñon-juniper habitats have increased in many regions of the western United States (Romme et al. 2009). It is also true that in many areas grasslands and/or shrublands have been infilled with piñon-juniper (Romme et al. 2009). However, what is also true, but often overlooked, is that such changes are not occurring across entire regions or in all regions, and that there is substantial variability and uncertainty about historic conditions of piñon-juniper stands and the mechanisms that shape those conditions (Romme et al. 2009). Additionally, expansion of piñon-juniper into former grasslands in New Mexico has occurred most extensively on depositional landforms and within the range of one-seed juniper (*J. monosperma*) (Jacobs et al. 2008), whereas the cinder cone is not a depositional feature and Rocky Mountain juniper is the predominant juniper throughout the monument. Consequently, inferences that are universally extrapolated to provide blanket

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Figure 4.7.3-11. Many, but not all, volcanic features in the Raton-Clayton Volcanic Field are covered by grasslands.

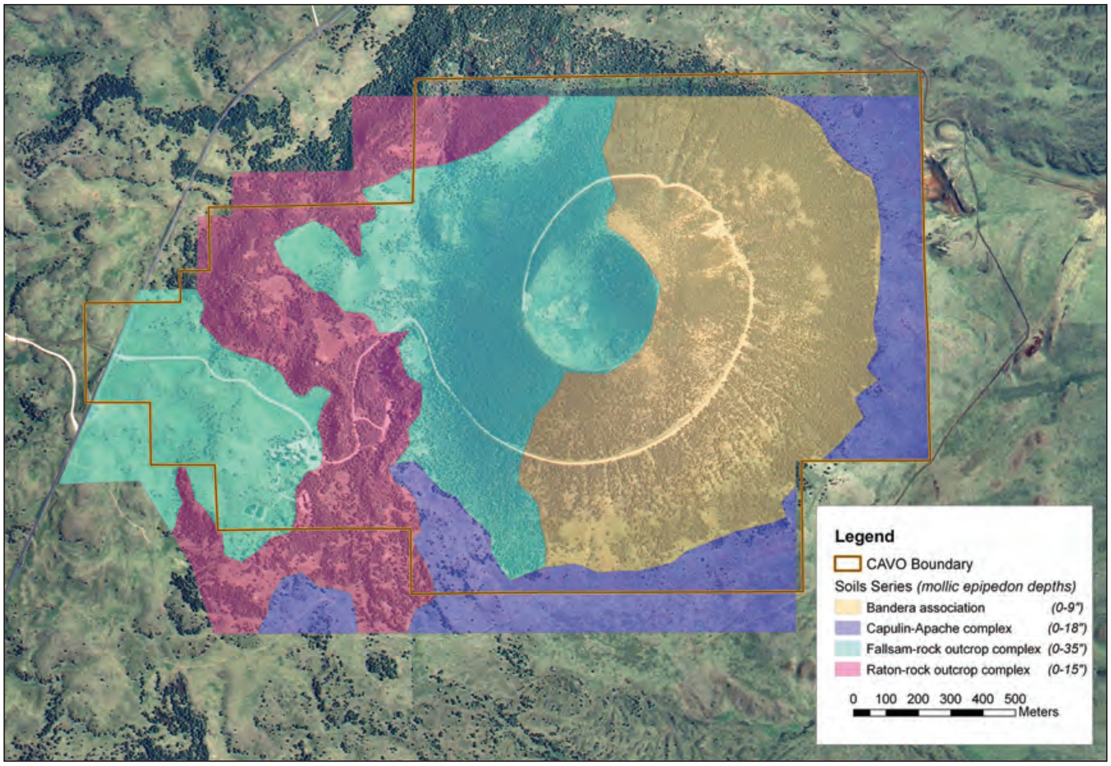

Figure 4.7.3-12. Soils map with mollic epipedons depths for each soil series derived from the USDA-NRCS SSURGO soils data and ancillary physicochemical data (from Weindorf et al. 2008).

solutions or explanations that are applied to all regions without regard to local histories and variability can be misguided. In the vast majority of cases we examined, information from other areas was applied to Capulin Volcano NM with complete disregard for variation in piñon-juniper community types, which is now well known to have a dramatic influence on history of a given site.

Evidence That Changes Are a Result of Fire Suppression Over The Past Century

Most of the evidence cited in support of the claim that changes are a result of fire suppression over the past century is almost always based on inferences extrapolated from other areas without regard to the piñon-juniper types (e.g., woodland, shrubland, or savanna), which dramatically influence fire behavior and history. For example, Gottfried et al. (1995) is cited in NPS (2004) as a general reference applicable to Capulin Volcano NM for fire return intervals ranging from 10–49 years. Although we could not find these specific values in the actual paper, Gottfried et al. reported on a wide variety of sites with substantial variability. Gottfried et al. (1995) also explicitly stated that on low productive soils (e.g., the cinder cone at Capulin Volcano NM), the return interval is often >100 years (page 108 in Gottfried et al. 1995).

The only direct evidence we found relating to changes in fire history at Capulin Volcano NM, was a study by Guyette et al. (2006) who found, based on fire scars (mostly from ponderosa pine) that fires in the Boca area at the foot of the cinder cone did indeed experience a dramatic reduction in fire frequency beginning around 1860, right about the time that widespread grazing began in the area (Guyette and Stambaugh, 2006; Schneider-Hector 2003). It is important to note that the reason ponderosa pines were sampled in the Boca area is that fire scars were lacking in other areas searched throughout the monument. In fact, seven trees were sampled from the cinder cone, which covered a time span of 250 years, from which no fire scars were found. This is consistent with the findings of Romme et al. (2009), who concluded that fire exclusion was not the principle mechanism for infill of persistent woodlands (the primary piñon-juniper type on the cinder cone) because fires were never frequent in this piñon-juniper type. Thus, in our view, the evidence supports that fire frequency was likely substantially reduced in the vicinity of the Boca (and possibly surrounding savannas) where grasses are present to carry a fire. However, the evidence better supports the hypothesis that the introduction of grazing was a more likely mechanism for piñon-juniper infill change than fire suppression. The evidence also does not support, and even contradicts, extrapolating these changes in fire frequency to the cinder cone.

Conclusions About Previous Perceptions of Reference Conditions

After considerable discussion with the piñon-juniper scientists and a careful review of the evidence, we believe that the evidence clearly supports that at least some grassland areas within the monument are experiencing infill by piñons and/or junipers. However, this does not mean that all of Capulin Volcano NM was historically a grassland or savanna. We found virtually no reliable evidence to support this conclusion, and several sources of evidence to the contrary.

Second, and not mutually exclusive of the first conclusion, is that we believe the evidence supports the conclusion that piñon-juniper was well-established on the cinder cone, at least since the early 1900s, but that for many areas, piñon-juniper stands have become increasingly dense. However, the evidence does not support the conclusion that the increased density is a result of fire suppression such as stated in NPS (2004), "pre-settlement woodlands in this region were usually savanna-like or confined to rocky outcrops not typically susceptible to fire.".

An additional conclusion that we must consider when formulating our reference conditions is that piñon-juniper stands are not static. They shift over time in their fundamental characteristics (e.g., stand structure) as a result of a wide variety of factors, including climate change, grazing, fire regimes, insects, and disease. Thus, developing "snapshot" reference conditions that do not reflect the inherent dynamics of these systems cannot be justified based on ecological criteria.

Thus, we asked each of the subject matter experts: does the evidence based on piñon-juniper life forms and ecology, as well as evidence from historic reports and photgraphs, support the conclusion that the piñon-juniper stands at Capulin Volcano NM represent degradation over the past two centuries from what was grassland or savanna? All three experts agreed that a degraded prairie was not an appropriate reference condition for most if not all piñon-juniper habitat at the monument. Based on an exhaustive review of the evidence, Romme et al. (2007, 2008, 2009) found that piñon-juniper savannas are typically found on moderately deep soils in gentle upland and transitional valley settings. The experts we consulted with suggested that the flatter areas at the base of the cinder cone are consistent with a piñon-juniper savanna, but most, if not all, of the cinder cone is characteristic of a persistent piñon-juniper woodland or wooded shrubland, which would not have likely been grasslands or savannas at least within the past few centuries.

Reference Conditions Used for This Assessment

They concluded that there are four fundamentally different kinds of piñon-juniper habitats within the monument, based primarily on canopy structure, understory characteristics, and historical disturbance regimes: (1) persistent piñon-juniper woodlands, (2) piñon-juniper wooded shrublands, (3) piñon-juniper savannas, and (4) persistent piñon-juniper woodland patches interspersed among grassland (Table 4.7.3-1). These four general habitat types form the basis for the reference conditions used to assess the condition of piñon-juniper habitats throughout the monument. We considered the condition to be good for a given indicator within each piñon-juniper habitat type if it was consistent with maintaining:

- a fully functioning community of plants (and animals that each pinon-juniper habitat type supports)
- a resilience to natural or anthropogenic disturbances that vary in intensity, duration, and size, while maintaining or sustaining the pinon-juniper habitat type's inherent complexity
- the natural dynamics of the pinon-juniper habitat type during changes in productivity, nutrient capital, and biodiversity.

We considered the condition to be of moderate concern if there was some departure from the elements listed above for a given indicator, but that the pinon-juniper habitat type was capable of restoring itself to a good condition on its own, or with limited management intervention. And finally, we considered the condition to be of significant concern for a given indicator if there was substantial departure from the elements listed above that were either irreversible or would require substantial management intervention to return the condition to good.

For each of the four piñon-juniper reference condition habitat types, we identified their general spatial pattern of occurrence and

Table 4.7.3-1. Piñon-Juniper habitat types used as references (adapted from Romme et al. 2008, 2009) Fire Regimes (based on Romme et al. 2007, 2008, 2009; Floyd et al. 2000, 2004; Shinneman and Baker 2009).

Persistent Piñon-Juniper Woodland	
	**Canopy**: The canopy of persistent piñon-juniper woodlands ranges from sparse stands of scattered small trees growing on poor substrates to relatively dense stands of large trees on more productive sites. The canopy may be dominated by either piñon or juniper or both.
	Understory: The understory of persistent piñon-juniper woodlands can be dominated by shrubs, forbs, or less commonly grasses. However, the understory is typically sparse with extensive areas of bare soil or rock.
	Site Conditions: Persistent piñon-juniper woodlands may occur on a wide variety of substrates and topographic settings but are most commonly associated with rugged uplands with shallow, coarse-textured, and often rocky soils that support relatively sparse herbaceous cover, such as the cinder cone at Capulin Volcano NM.
	Fire Regime: Stand replacing fires with low frequency and high intensity that most likely vary in size and extent. The fire interval in these stands is typically very long (at least multi-decadal), but more often measured in centuries.
Piñon-Juniper Wooded Shrubland	
	**Canopy**: The canopy of piñon-juniper wooded shrubland typically ranges from low- to moderate-density, which changes over time in response to climatic fluctuation and disturbances.
	Understory: The understory of piñon-juniper wooded shrubland is comprised of a well-developed shrub layer that makes up a major component of the biotic community.
	Site Conditions: Piñon-juniper wooded shrubland occurs on a wide variety of substrates and topographic settings, often in proximity to a more persistent seed source (e.g., the adjacent persistent woodlands at Capulin Volcano NM.
	Fire Regime: In wooded shrublands, fuels are more variable often with a well-developed shrub stratum and, sometimes, a well-developed grass-forb layer. The grass-forb layer has a lesser capacity for spreading fire but more developed than the woodlands, therefore, the fire regime is likely between the savanna and woodland habitats.
Piñon-Juniper Savanna	
	**Canopy**: The canopy of piñon-juniper savanna is typically characterized by low- to moderate-density within a well-developed grassland matrix. In some areas of the western United States, this type may have dense enough canopy to be considered as a woodland, but the key feature remains the relatively continuous grassland.
	Understory: The understory of piñon-juniper savanna is consistently comprised of grasses.
	Site Conditions: Piñon-juniper savanna typically occurs on moderately deep coarse-to-fine textured soils on gentle upland and transitional valley locations. They are most common in areas where the precipitation is dominated by summer monsoon.
	Fire Regime: The pre-1900 fire regimes in piñon-juniper savanna are not well understood, but are believed to be of lower intensity and more frequent than the woodland and shrubland fire frequencies.
Piñon-Juniper Persistent Woodland Patches Interspersed Among Grassland	
	**Canopy:** The canopy of piñon-juniper persistent woodland grassland interspersion is typically characterized by low- to moderate-density within a well-developed grassland matrix. The piñon-juniper occur on small patches of refugia ,such as rock outcroppings, which protects them from fire.
	Understory: The understory of piñon-juniper persistent woodland grassland interspersion is consistently comprised of grasses.
	Site Conditions: The understory is consistently comprised of grasses, except for where the piñon-junipers are located, then the understory is comprised of volcanic rock, with a minimal biotic component.
	Fire Regime: Since the grassland patches of the persistent woodland grassland interspersion are immediately adjacent to the savanna, therefore, strongly interconnected, it is reasonable to assume that the fire regime in the interspersion habitat type includes more frequent but low intensity fires, preserving the piñon-juniper woodland component (e.g., rocky refugia).

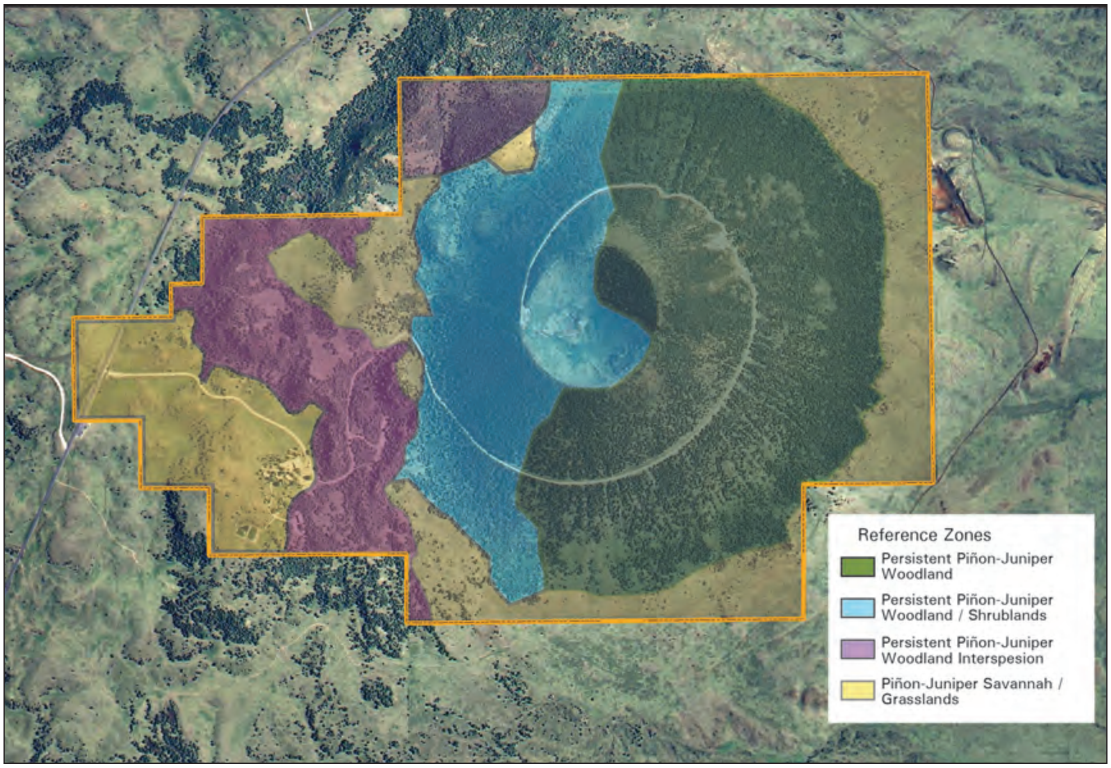

Figure 4.7.3-13. Reference condition zones for piñon-juniper habitats used in this assessment.

designated them as reference condition zones (Figure 4.7.3-13). The condition zones closely resemble the soil series zones as previously shown in Figure 4.7.3-12. All of the subject-matter experts agreed that the cinder cone at Capulin Volcano NM was dominated by persistent piñon-juniper woodland. It is important to note that (Romme et al. 2008) emphasized that piñon-juniper woodlands do not represent a recent conversion of formerly non-woodland vegetation types to woodland. Rather, piñon-juniper woodland consists of areas where trees have been an important stand component for at least the past several hundred years. Guyette et al.'s (2006) finding that recruitment on the Capulin cinder cone has been relatively consistent over at least the past 300 years supports this conclusion.

There was some debate among the experts as to whether the west side of the cinder cone should be considered a persistent piñon-juniper woodland or a piñon-juniper wooded shrubland that is recovering from previous disturbance(s) (most likely fire). Because the west side of the cinder cone continues to have a well-developed shrub layer, and because shrubs have been a dominant component of regrowth following thinning treatments, we consider wooded shrubland as an appropriate reference condition for this area.

All of the subject-matter experts agreed that piñon-juniper savanna occurs at Capulin Volcano NM and that its spatial extent is generally limited to the base of the slopes surrounding the cinder cone.

The persistent woodland/grassland interspersion is an area in the vicinity of the "Boca" (referring to the mouth of the volcano) and comprises persistent piñon-juniper woodlands interspersed among grasslands. This zone differs from a piñon-juniper savanna because the piñon-junipers have all the characteristics of a persistent woodland, but occur on small patches of refugia from fire such as rock outcroppings. In contrast, the piñons and/or junipers that occur in the piñon-juniper savanna are not typically restricted to such refugia; thus, are exposed to all of the associated disturbances that occur in the grasslands in which they occur.

4.7.4 Condition and Trend

Piñon-Juniper Treatments

A substantial portion of the monument, including the piñon-juniper habitat at Capulin Volcano NM has been treated with thinning and/or burning (Figure 4.7.4-1) based upon the belief that these areas were formerly grasslands infilled by piñon-juniper (NPS 2005). These treatments have substantially altered the characteristics of these stands (Figure

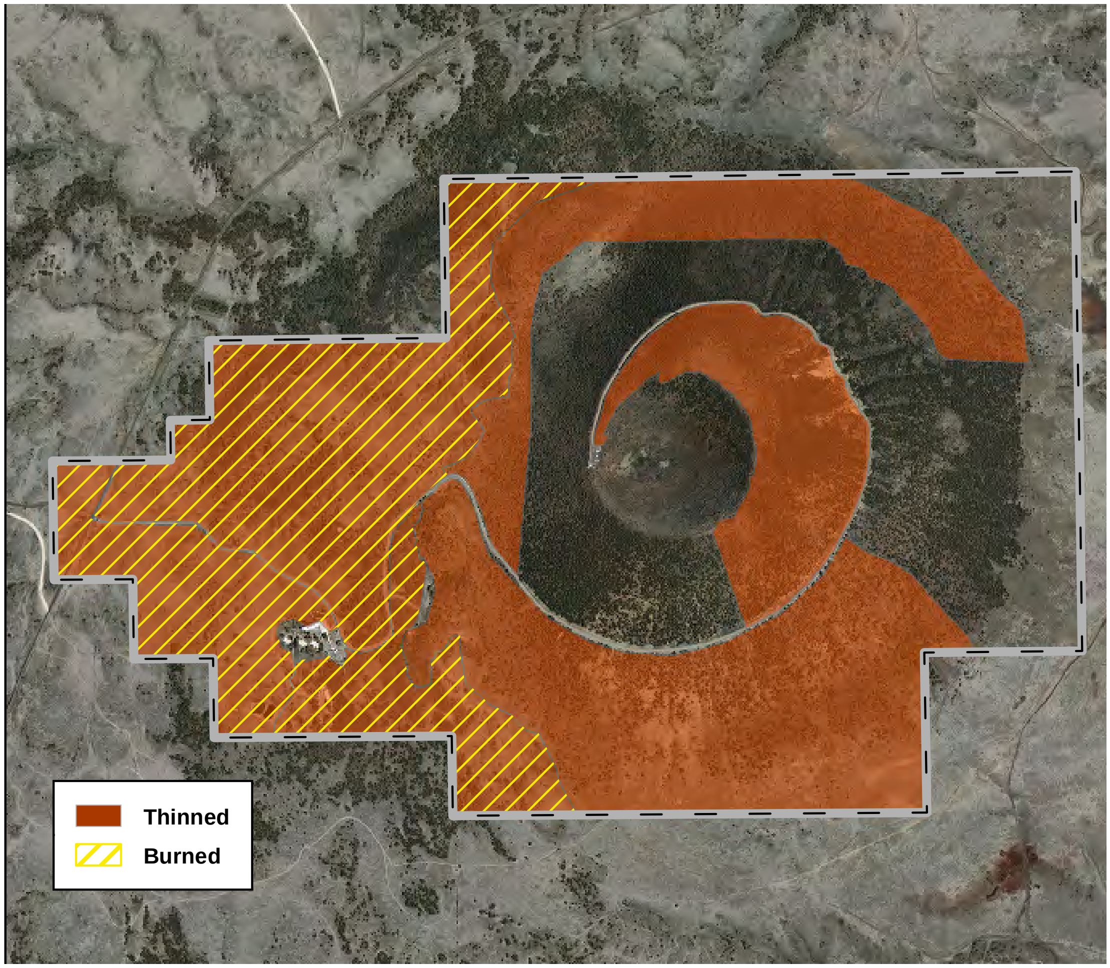

Figure 4.7.4-1. Fire management treatments as of 2009.

4.7.4-2, -3); thus potentially their condition. Consequently, we felt it necessary to consider both treated and untreated stands in order to accurately report on current condition for piñon-juniper habitats.

Are the species present and their distribution consistent with supply and demand of light, water, nutrients, and growing space and, within their natural range of variability?

All three experts agreed that, in general, the species present and their corresponding distributions are probably within their natural range of variability. However, there are two concerns regarding the natural range of variability. First is the widespread occurrence of exotic invasive species, however, this topic is being addressed in the exotic plants chapter and will not be further discussed in detail here. Second, an additional concern expressed by one of the experts (C. Allen, pers. comm.) was the removal of the shrub layer from within the piñon-juniper wooded shrublands on the west slope of the cinder cone through thinning and burning treatments. The shrub component of this habitat type constitutes the foundation of this biotic community (Romme et al. 2007, 2008, 2009) and is an essential component of this habitat type that is (and was) within its natural range of variability.

All three experts also agreed that ongoing treatments of thinning and burning were not needed to "restore" natural ecological conditions, and are potentially detrimental depending on how the resulting slash is treated.

Are Stand Densities Within Their Range of Natural Variability For Their Growing Conditions?

This indicator is particularly relevant to Capulin Volcano NM because of the widely held view that infilling has created a degraded habitat. It is certainly true that untreated stand densities are greater today than during the early part of the 1900s, at least for some parts of the cinder cone. However, persistent piñon-juniper woodlands are characterized by periodic fluctuations in density depending on climatic fluctuation or the time since major disturbance

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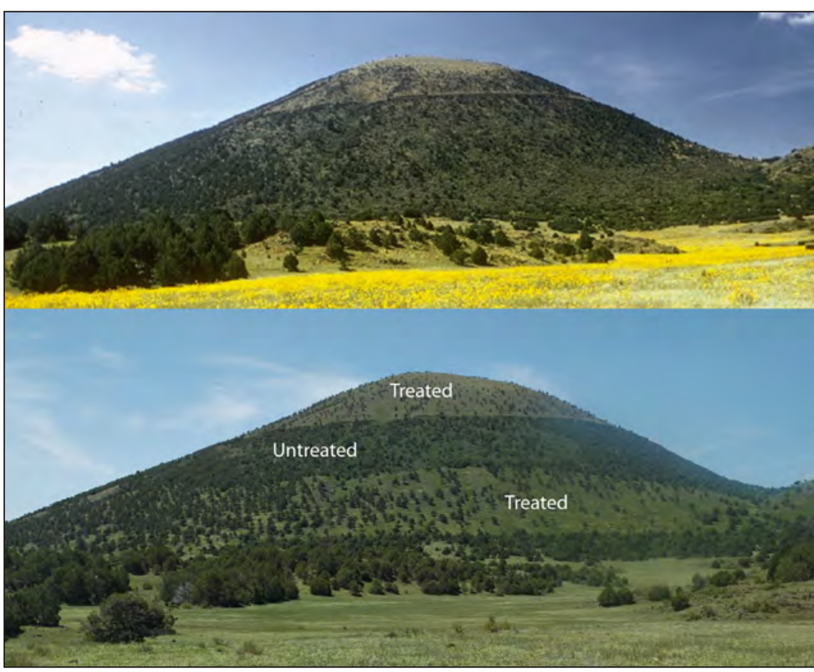
Figure 4.7.4-2. Treated (bottom) and untreated (top) piñon-juniper woodlands on the upper cinder cone.



NPS

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Figure 4.7.4-3. View of Capulin Volcano from the north prior to treatments (top) and since treatments (bottom).

events (Romme et al. 2009; Shinneman and Baker 2009). Furthermore, the current density of piñon-juniper at Capulin Volcano NM is comparable to other mature piñon-juniper stands on the Colorado Plateau (see Romme comments in Appendix D). Thus, it was the belief of all three scientists that tree densities, even prior to treatment, were within their natural range of variability. It should be noted that because of the wide fluctuation of tree densities in response to disturbances, that tree densities of treated stands are also probably within the natural range of variability—the two conditions just represent opposite ends of the spectrum. However, maintaining tree densities at a very low level would not be consistent with natural variation for persistent piñon-juniper woodlands or wooded shrublands. Rather, they would naturally fluctuate in density over long periods (e.g., centuries).

Are the age class distributions of piñons and junipers consistent with the expected range of variability for this site/ecosystem type?

Although we have very limited data that explicitly address the age class distribution of piñon-juniper at Capulin Volcano NM, the subject matter experts did not express any concern about the age class distribution of untreated stands. The untreated persistent piñon-juniper woodlands have trees that range from young to relatively old (>400 years). Although the specific ages are not known, the wooded shrublands on the western slope of the cinder cone have trees that appear relatively young (<100 years), but this is not surprising, and well within the range of variability for a stand possibly recovering from a disturbance during the 18th or 19th century.

In contrast, concern was expressed for the age-class distribution of treated stands (C. Allen, pers. comm.). The prescription for thinning treatments at Capulin Volcano NM called for removal of trees <9" diameter. Piñons and juniper are well known for their slow growth, and based on growth estimates from other areas in the region, this corresponds to trees that may be 200 years or older, especially those growing in harsher soil and wind conditions as found on the monument's volcanic slopes. Further, the removal of these younger trees has, in essence, removed the potential recruitment from these sites that has become established over the past 200 years or older. This recruitment helps to ensure a sustained population and may be negatively affected as a result of the treatments on the cone.

Do the trees and understory plants appear vigorous and healthy for this site/ecosystem type?

None of our subject-matter experts expressed any concern about the healthy appearance of trees or understory plants. Romme explicitly expressed that the trees and understory were healthy in appearance, and that the vegetation was comprised and dominated by native trees, shrubs, and herbs, especially on the cinder cone (Appendix D).

Are ecological processes (e.g., fire) operating within the natural range of variation?

Historically, the role of fire and other disturbances in shaping and maintaining piñon-juniper habitat types has not been well understood, has commonly been over-generalized, and is often misinterpreted (Baker and Shinneman 2004; Romme et al. 2009). The implications of these uncertainties is well expressed in Romme et al. (2009):

> "Uncertainties about historical stand structures and disturbance regimes in piñon–juniper vegetation create a serious conundrum for land managers and policy makers who are charged with overseeing the semiarid landscapes of the West. Vegetation treatments are often justified, in part, by asserting that a particular treatment (e.g., tree thinning or prescribed burning) will contribute to restoration of historical conditions, i.e., those conditions that prevailed before the changes wrought by Euro-American settlers. However, in the absence of site-specific information about historical disturbance regimes and landscape dynamics, "one-size-fits-all" treatments are likely to be ineffective, and some well-meaning "restoration" efforts may actually move piñon–juniper ecosystems further from their historical condition. Some kinds of vegetation treatments may even reorganize ecosystems in such a way that restoration of historical patterns and processes becomes more difficult.

But the general consensus of the piñon-juniper scientists was that the ecological processes were operating within their natural range of variability for untreated stands of persistent piñon-juniper woodland and wooded shrubland.

Based on the mosaic of site and fuel conditions at Capulin Volcano NM, one of our experts (C. Allen) suggested that the spatial pattern of fires was likely variable and opportunistic depending on location and conditions at the time of ignition. When fire weather conditions were mild, fires likely spread through areas with continuous fuels and were extinguished when fuels were sparse. If conditions were more extreme (e.g., dry with high winds), fires were more likely to spread through shrubs or even the piñon-juniper canopy. Such opportunistic fire behaviors would likely result in a variable mosaic pattern over the landscape (Figure 4.7.4-4).

It is possible, but not confirmed, that the wooded shrubland area on the west slope of the cinder cone experienced a stand replacing fire during the 18th or 19th century, which is consistent with the natural range of variability for this piñon-juniper type. There is no evidence of the most recent stand replacing fires for the persistent piñon-juniper woodlands, but the consensus of our experts, as well as the other leading scientists studying piñon-juniper systems is that fire intervals in persistent woodlands are very long and usually measured in centuries (Romme et al. 2009).

Low intensity surface fires played a very limited role in shaping the stand structure and dynamics (Romme et al. 2007, 2008, 2009; see also Baker and Shinneman 2004 and Shinneman and Baker 2009). Rather, stand replacing fires with low frequency and high intensity have dominated these stands from the pre-Euro-American period until today (Romme et al. 2009; Shinneman and Baker 2009). The fire interval in these stands is typically very long, often measured in centuries (Romme et al. 2007, 2008, 2009; Floyd et al. 2000, 2004). Baker and Shinneman (2004), in their review of fire regimes in piñon-juniper woodlands reported two cases where the fire rotation (i.e., time required to burn an area equal to the area of interest) was determined. In one case (Wangler and Minnich (1996), the rotation was 480 years. In another case (Floyd et al. 2000; Romme et al. 2003), the rotation was approximately 400 years. Because of the sparsity of surface fuels that would be needed to carry a fire under most conditions, the fires that do spread to any significant extent are infrequent. There may be patches of very dense live and dead fuels and a heavy fuel load when expressed on a per-acre basis, but fire is unlikely to spread through those heavy fuels except under conditions of very dry, windy weather because of the intervening patches of bare soil or rock (Bill Romme, pers. comm., March 2011). The spatial extent of these high severity fires is less well known; however, they are known to vary from very small (<0.1 ha) to

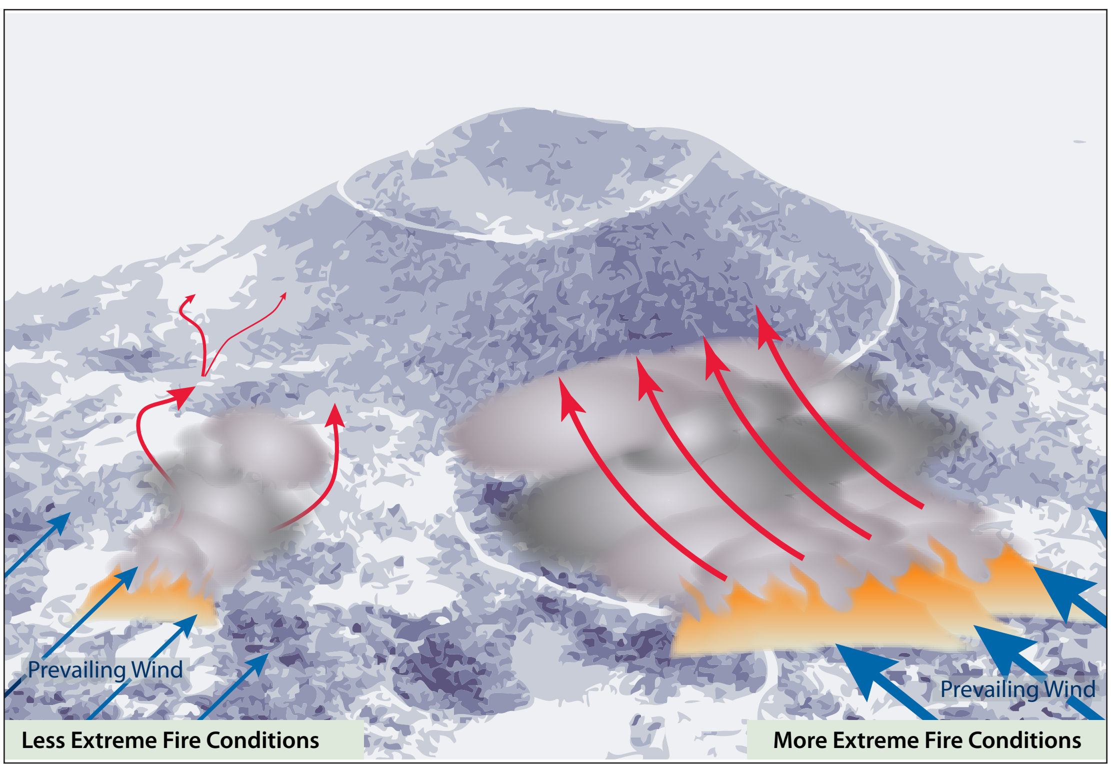

Figure 4.7.4-4. During periods of less extreme conditions, fires likely spread opportunistically through patches with continuous grass/forb fuels. During times of more extreme conditions, fires are likely to spread through shrub layers or even the piñon-juniper canopy.

Figure 4.7.4-5. Indicators of insect activity (e.g., needle browning shown) are occasionally observed at Capulin Volcano NM, but nothing has been observed in recent years that would be considered outside the range of normal variability.

very large (hundreds or thousands of hectares) and were clearly influenced by fuel and weather conditions (Romme et al. 2007, 2008, 2009).

In contrast, the management treatments that have been planned, and in some cases initiated, of thinning and burning on a short interval would be outside of the natural range of variability. The resulting sparse tree densities are likely still within the natural range of variability for a stand that has recently experienced a severe fire, but to maintain this state as a frequently recurring process is not consistent with natural ecological regimes.

In contrast to persistent woodlands or wooded shrublands, evidence suggest that pre-European fire regimes, at least in the Boca area and probably the savanna at the base of the cinder cone, have experienced a dramatic reduction in fire frequency. There is no evidence however that the piñons or junipers in these areas have suffered any deterioration in condition as a result. In the Boca area, the habitat type is persistent piñon-juniper interspersed among grasslands. In this area, the piñon-juniper component occurs on rocky outcrops that are protected from fire; thus, may be little influenced by a change in the fire regime of the surrounding grasslands. However, the grassland portions themselves are likely experiencing infill by piñon-juniper, which may be influenced by the change in fire frequency and/or other environmental changes (e.g., climate).

But overall, there is no evidence that these piñon-juniper habitats at Capulin Volcano NM are outside of their natural range of variability for ecological processes.

Are the current levels of insects and/or disease within the normal range for this ecosystem type?

We found no evidence that the level of insects and/or disease are outside the normal range for this ecosystem type. No unusual insect damage or diseases were observed during site visits by our subject-matter experts, although occasional direct or indirect evidence of typical occurrences have been observed. Terry Rogers, a US Forest Service Entomologist recently diagnosed piñons at Capulin Volcano NM with twig/bark beetles feeding on the tips of branches and mites feeding on the needle juices of junipers, but neither of these were of concern, nor were they likely to kill the affected trees (Figure 4.7.4-5). Similarly, a fungus that was recently found under a juniper was examined by Crystal Tischler (US Forest Service Forest Health Coordinator, New Mexico Zone) and David A. Conklin (US Forest Service Forest Pathologist) who concluded that it was likely feeding on decaying litter under the junipers rather than a pathogen to the trees. It's important to note that both piñons and junipers can serve as host trees for insects, plants, and fungi that are sometimes considered to be detrimental to the trees even though they are native, such as mistletoes. Although none have been detected at Capulin Volcano NM, dwarf mistletoes are often considered a forest pest, particularly when their host has commercial value, but they are also native plants found in the western United States that substantially contribute to native biodiversity (Bennetts et al. 1996).

Overall Condition

For assessing the condition of piñon-juniper, we used a variety of indicators/measures that were adapted from Edmonds et al. (2011) in consultation with piñon-juniper experts. All of the indicators/measures for this resource were intended to capture different aspects of the piñon-juniper communities located within the monument, and a summary of the indicators/measures is in Table 4.7.4-1. The overall condition of piñon-juniper habitats at Capulin Volcano NM is good for both treated and untreated stands, although there are some concerns, particularly for treated stands. Treatments to piñon-juniper stands at Capulin Volcano NM

Table 4.7.4-1. Summary of the piñon-juniper indicators/measures and their contributions to the overall piñon-juniper natural resource condition assessment.

Indicator/Measure	Description of How the Indicator(s) Contributes to the Overall Resource Condition	General Contribution of this Indicator or Measure to the Overall Resource Condition.
Are the species present and their distribution consistent with supply and demand of light, water, nutrients, and growing space and within their range of variability?	This aspect assesses whether the type of plants for a piñon-juniper community and the distribution of those plants are within the natural range expected for piñon-juniper.	In general, the species present and their natural range of variability are most likely in good condition. Some of the previous vegetation thinning treatments may have been adversely affected this particular indicator.
Are stand densities within their range of natural variability for their growing conditions?	This measure assesses the tree densities of the piñon-juniper communities, which can provide insight into the dynamics of a given community to indicate condition.	Periodic fluctuations in densities are expected based upon climatic fluctuations as well as episodic events such as catastrophic fires. It appears as if this indicator is in good condition.
Are the age class distributions of piñons and junipers consistent with the expected range of variability for this site/ecosystem type?	Age classes can provide information pertaining to natural processes such as seedling recruitment, fire, or other disturbances that are characterized by different types of plant communities, such as a shrubland or a woodland.	With limited data, the experts believed the age classes were within their natural range of variability. Once again though, some concern was centered around areas that were thinned, especially where the smaller trees were removed (and believed to be young) but were in fact very old trees.
Do the trees and understory plants appear vigorous and healthy for this site/ecosystem type?	This measure can indicate that nutrient cycling, water supply, light supply, etc., are operating within parameters that support the piñon-juniper plant communities. The plants' physical appearance can offer information pertaining to this measure.	The trees and understory exhibit healthy appearances, and many areas are comprised of native species.
Are ecological processes (e.g., fire) operating within the natural range of variation?	Fire scars, type of vegetation, age of trees, and even historical photographs to a certain extent can provide information that helps assess the range of variation for ecological processes.	The mosaic of the vegetation and the different fuel conditions throughout the piñon-juniper communities result in a wide range of fire variability. Currently, the fire interval is believed to be longer than previously reported.
Are the current levels of insects and/or disease within the normal range for this ecosystem type?	This measures the current condition of infestations from insects or certain diseases that may indicate overall rigor of the system.	Even though insect infestations are present, they do not pose concern for piñon-juniper condition at this time.

(thinning and burning) were based on what we believe was an inappropriate reference condition. The intention of these treatments was to restore the piñon-juniper habitats back to what was believed to have been a historic state of grassland or savanna. As such, treatments were intended to substantially reduce piñon-juniper presence. Treatments were also intended to reduce the potential for erosion of the cinder cone and to reduce the risk of "catastrophic" fires. As stated previously, we now believe that the presumed historic condition of a grassland or savanna was not the previous state for most, if not all, of the piñon-juniper habitats. Further, two additional NPS specialists who visited the monument for purposes of this assessment (Deanna Greco and Pete Biggam) expressed concerns that treatments may actually increase the risk of erosion on the cinder cone, rather than decreasing it (a more detailed discussion of this topic is in the geology section). In addition to the condition, we believe the overall trend is stable at this point.

Level of Confidence/Key Uncertainties

One of the biggest uncertainties regarding our assessment of piñon-juniper habitat condition at Capulin Volcano NM is an appropriate reference for the west slope of the cinder cone. We believe that the evidence most strongly supports a wooded shrubland as being the most appropriate reference condition, but there are clearly some uncertainties associated with this conclusion. At the present time, piñons, and perhaps a few junipers, that appear relatively young (<100 years), are scattered throughout the west slope area. This could be the result of these trees invading a former shrubland or the recovery of a persistent piñon-juniper woodland or wooded shrubland from a stand replacing fire in the 18th or 19th century. At Mesa Verde National Park, piñon-juniper is just beginning to become prominent in shrublands approximately 150 years after some 19th century fires (Romme et al. 2003). Despite the uncertainty described here, we found no evidence to support the conclusion that a grassland or savanna was an appropriate reference condition for this area as has been implied in the monument's fire management documents (NPS 2004, 2005). However, this has been a widely held view, thus, we anticipate that this issue will be debated for some time. Unfortunately, it is extremely difficult to conclude with any certainty the condition of a site in the past. The best we can do is to evaluate the existing evidence and to seek additional evidence if possible.

There are two additional topics that would likely benefit from further evidence. First is the uncertainty and debate of the fire history of the area. The empirical evidence that exists for Capulin Volcano NM is quite limited, and certainly does not represent an unbiased sample over the entire area. Guyette et al. (2006) suggested that the mean fire interval on the Capulin cinder cone was 10–20 years. However, as Guyette et al. (2006) themselves point out, this estimate was inferred from their interpretation of the general characteristics of the area, rather than from any supporting data. In fact, of the seven trees examined on the cinder cone, they found no fire scars for the 250-year period represented in their sample (1790–2004). This lack of evidence for fire scars on the cinder cone is consistent with the consensus of the 15 leading scientists that these piñon-juniper types are characterized by low frequency, high severity fires; a view that was also expressed by our subject matter experts during their site visits.

The pre-1900 fire regimes in piñon-juniper savanna are not well understood (Romme et al. 2009). Guyette et al. (2006) completed one study of fire history at Capulin Volcano NM based on fire scars ,and concluded that the mean fire interval in the Boca area (within what we call the "piñon-juniper interspersion zone") was approximately 12 years for the period of record prior to 1891. After 1891, the estimated mean fire interval was >75 years, coinciding with the onset of extensive grazing in the region, which is widely known to be associated with reduced fire frequencies (Guyette et al. 2006).

Although, the Boca sites sampled by Guyette et al. (2006) are not what would be considered as a piñon-juniper savanna, they are immediately adjacent to areas we consider as savanna and the grassland patches between the two types are strongly interconnected. Thus, we believe that it is reasonable to assume that the fire regimes in the piñon-juniper savanna and the grassland portions of the persistent piñon-juniper interspersion are likely similar (but this does not apply to the persistent piñon-juniper portion of this zone.)

There are however, other concerns about Guyette et al.'s estimate that lead us to conclude the results may be biased. First, the sample of fire scars collected were not a statistically valid sample (e.g., random, systematic) as would be essential for an unbiased estimate of the fire regimes (Baker 2009). Rather, they were collected from sites that after an exhaustive search for fire scars, which would clearly bias their sample toward more fires in that area. Nor were the cross sections in their Boca sample even from piñons or junipers. They were from ponderosa pines (*Pinus ponderosa)*, a species for which fire plays a dramatically different role. Huffman et al. (2008) sampled fire scars at the ecotones between ponderosa pine and piñon-juniper in Arizona and New Mexico and concluded that historically fires in ponderosa pine did not typically spread through adjacent piñon-juniper.

An additional concern about using Guyette et al.'s (2006) conclusions to infer a generalized fire regime is that small localized fires do not typically have sufficient effect on the area (e.g., changes in vegetation) to warrant forming the basis of a reference fire regime for the area as a whole (see Baker 2009 and comments by Romme in Appendix D). Given that many, if not most, fire scars represent very small localized fires, one technique to ensure that such data are more meaningful in the context of a fire regime is to filter data to include only scars for which specified portion of the trees in an area are affected (Baker 2009). Romme re-analyzed the data from Guyette et al. (2006) using only years where at least 20% of the trees sampled in the Boca area were affected and found that the average interval was 40 years for the period from 1702–1860 (Appendix D). A recent study conducted in the Big Bend area of south Texas showed a 150-year fire interval for the persistent pinon-juniper woodlands and 75-year fire interval for the pinon-juniper savannas (Poulos et al. 2009). Even Romme's relatively modest filter and Poulos et al. findings resulted in an estimated interval substantially greater than the 12-year interval suggested by Guyette et al. (2006). Thus, while fire likely played a more significant role in shaping piñon-juniper savannas than persistent piñon-juniper woodlands or piñon-juniper wooded shrublands, there remains considerable uncertainty regarding the historic fire regimes.

A more exhaustive study of fire history that includes searches for live trees in areas other than the Boca with fire scars, scarred tree remains of dead trees or logs, and other charred debris would likely provide additional information.

A second area that would likely benefit from seeking additional evidence would be a thorough examination of the age structure of piñon-junipers at Capulin Volcano NM. Such an investigation would help to reveal the spatial variability of stand replacing fires or other processes or disturbances that have shaped spatial patterns of piñon-junipers across the monument landscape.

4.7.5 Sources of Expertise

Primary Subject-Matter Experts

Craig Allen is a research scientist with the US Geological Survey at the Fort Collins Science Center Jemez Mountain Field Station.

Brain J. Jacobs is a vegetation ecologist with the NPS at Bandelier NM.

William H. Romme is a professor for the Department of Forest, Rangeland, and Watershed Stewardship at Colorado State University.

All three of these subject matter experts have conducted research in the ecology of piñon-juniper ecosystems and are well published in this topic.

Additional Site Visits

Peter Biggam, a soil scientist at the NPS Natural Resources Program Center, visited Capulin Volcano NM as a subject-matter expert for the grassland section of this assessment, but also had an opportunity to look at piñon-juniper habitats and provide input.

Deanna Greco was a geologist with the NPS Natural Resources Program Center's Geologic Resources Division who evaluated erosional processes on the cinder cone and assessed the potential erosion effects of piñon-juniper thinning and prescribed burning applied to the cinder cone.

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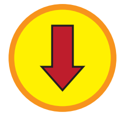
4.8 Grasslands

Indicators/Measures

- Rills
- Water flow patterns
- Pedestals and/or terracettes
- Bare ground
- Gullies
- Wind-scoured, blowout, and/or depositional areas
- Litter movement
- Soil surface resistance to erosion
- Soil surface loss or degradation
- Compaction layer (below soil surface)
- Plant mortality/ decadence
- Invasive plants
- Species composition

Condition - Trend



Moderate Concern - Declining

4.8.1 Background and Importance

The central grassland region of North America is one of the largest contiguous grassland environments on earth (Lauenroth et al. 2008), and depending on which classification is used, there are at least three distinct grassland types: tallgrass prairie, mixed grass prairie, and shortgrass steppe (prairie). Capulin Volcano NM is located within the region generally classified as shortgrass steppe. The shortgrass steppe is located in the warmest and driest area and is the least productive of all grassland types, uniquely adapted to survive drought conditions (Lauenroth et al. 2008). The species that characterize the archetypal shortgrass steppe are blue grama (*Bouteloua gracilis*) and buffalo grass (*Buchloe dactyloides*).

Grassland as a whole is the second largest general habitat type found within the boundaries of Capulin Volcano NM and comprises approximately 26% of the total area within the monument based on recent vegetation mapping efforts by Muldavin et al. (2011). The monument's grassland is located along a transition zone, "where the Rocky Mountains meet the High Plains" (NPS 2010). It is also situated within the Raton-Clayton Volcanic Field, creating an ecotone whose plant assemblages do not necessarily "fit" other Rocky Mountain or shortgrass prairie molds. As a result, there is considerable variation in types of grasslands throughout the monument (Figure 4.8.1-1). The U.S. Geological Survey

ROBERT BENNETTS

Figure 4.8.1-1. An example of grassland at Capulin Volcano NM

Table 4.8.1-1. Alliances and plant associations comprising the grasslands at Capulin Volcano NM

Grassland	Plant Associations	Area (acres/hectares)
Southwest Plains-Mesa Grassland	1. Blue grama shortgrass steppe 2. Blue grama western wheatgrass swale shortgrass steppe	59.7/24.1 59.2/24.0
Southwest Plains-Mesa Mixedgrass Prairie	Big bluestem-little bluestem lava grassland	58.4/23.6
Southern Rocky Mountain Montame-Subalpine Grassland	Arizone fescue-mountain muhly grassland	24.6/9.9
Southwest Ruderal Shrubland and Grassland	Fourwing saltbush shrubland	4.1/1.7

(USGS)-NPS Vegetation Characterization Program is a cooperative effort by the two agencies to classify, describe, and map vegetation communities in more than 280 national parks across the United States. This program uses a hierarchical classification scheme, the National Vegetation Classification Standard (http://biology.usgs.gov/npsveg/nvcs.html), as a basis for classifying vegetation. At the local level, vegetation is classified by alliances (cover types) and associations (communities). Using this system, Muldavin et al. (2011) classified the monument's grasslands into five different associations within four different alliances: Southwest Ruderal Shrubland and Grassland, Southern Rocky Mountain Montane-Subalpine Grassland, Southwest Plains-Mesa Mixedgrass Prairie, and Southwest Plains-Mesa Grassland (Table 4.8.1-1) (Figure 4.8.1-2).

As with most ecological communities, grassland system driver patterns have changed throughout the years. Land use ranged from early Native Americans hunting the open plains for bison to European exploration and subsequent settlement. European occupation in the region began in the mid 1800s with the introduction of sheepherding, which eventually gave way to cattle

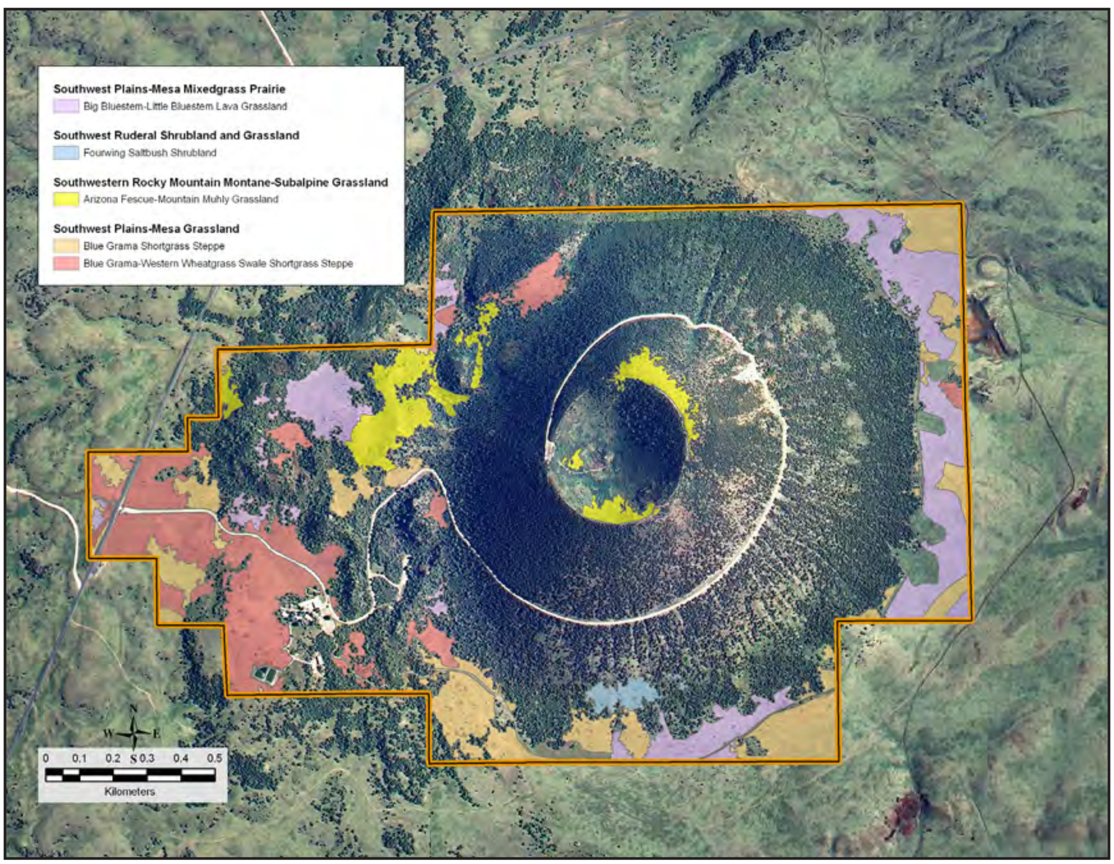


Figure 4.8.1-2. The major grassland alliances and associations within the monument as classified by Muldavin et al. (2011).

KIM STRUTHERS.

Figure 4.8.1-3. Ranching operations present outside the monument boundary.

ranching in the mid to late 1800s (Schneider-Hector 2002). Ranching continues to remain one of the primary land uses throughout the region (Daniel B. Stephens & Associates 2007), including the area surrounding the monument (Figure 4.8.1-3).

As settlement continued, changes in fire patterns and fire frequency followed; although, according to grassland experts Drs. Alan Knapp and William Lauenroth (pers comm.), fire probably played a lesser role in maintaining a healthy prairie in the shortgrass steppe than other drivers such as herbivory and climate variation. Guyette et al. (2006) conducted a study of fire history at Capulin Volcano NM, and suggested that around the time cattle grazing became common throughout the area, the fire frequency began to decrease, creating a "modern fire regime controlled by land use and ignition suppression". However, as previously discussed in section 4.7, Guyette's conclusions were largely based on fire scar samples from ponderosa pine and included scars that may have been from very local ignitions rather than widespread fires. Taking into account some of the biases, the historic fire frequency reported by Guyette et al. (2006) was much greater throughout the monument than other subject matter experts believed who visited the monument and reviewed Guyette et al's. data (Discussed in Appendix D).

In addition to herbivory and fire, climate change is and will continue to increasingly impact the shortgrass prairie region, creating changes in temperature and precipitation patterns and amounts (Morgan et al. 2008), which in turn, will affect the plants and animals native to the shortgrass ecosystem throughout the monument.

4.8.2 Data and Methods

We considered three categories of measures/indicators for the assessment of grassland condition at the monument based on the approach presented by Pellant et al. (2005): soil/site stability, hydrologic functioning, and biological integrity. These categories are defined by Pellant et al. (2005) as follows:

Soil/Site Stability - The capacity of an area to limit redistribution and loss of soil resources (including nutrients and organic matter) by wind and water.

Hydrologic Function - The capacity of an area to capture, store, and safely release water from rainfall, run-on, and snowmelt (where relevant), to resist a reduction in this capacity, and to recover this capacity when a reduction does occur.

Biotic Integrity -The capacity of the biotic community to support ecological processes

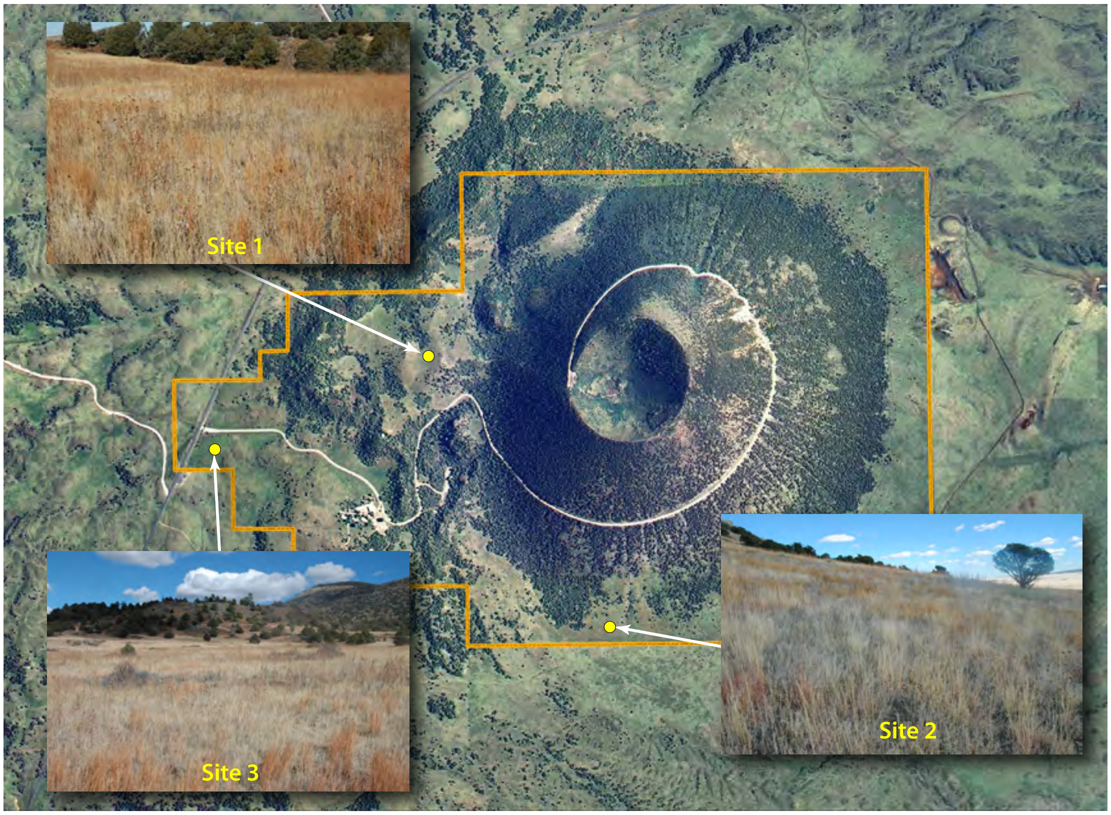


Figure 4.8.2-1
Map of Biggam's 2010 grassland sampling locations.

within the normal range of variability expected for the site, to resist a loss in the capacity to support these processes, and to recover this capacity when losses do occur. The biotic community includes plants, animals, and microorganisms occurring both above and below ground.

In combination, the measures/indicators from each of these categories provide the basis for this assessment, however, there is considerable overlap between soil/site stability and hydrologic function. In fact, Pellant et al. (2005) listed 8 of the 10 indicators we used for these two categories as indicators of both soil/site stability and hydrologic function. Therefore, we chose to combine them into one category instead of addressing each separately.

Indicators/Measures

Table 4.8.2-1

We used a total 13 qualitative indicators (10 for soil/site stability-hydrologic function and 3 for biotic integrity) to assess the condition of grasslands at Capulin Volcano NM (Table 4.8.2-1). Twelve of these indicators are exactly as presented in Pellant et al. (2005), but one indicator for the biotic integrity-species composition-was adapted after discussions with our subject matter experts.

We used a combination of approaches for assessing the grassland indicators. The soil/site stability/hydrologic function was assessed primarily through a site visit and rapid assessment in early November 2010 conducted by Pete Biggam ,(Biggam 2010) who is a soil scientist with NPS' Geoscience and Restoration Branch. During his visit, Biggam conducted qualitative assessments at four sites throughout the monument (Figure 4.8.2-1) (Biggam's full assessment is presented in Appendix E). However, one of the sites was located in piñon-juniper habitat and is omitted from this section but addressed in Chapter 4.7.

The assessment for the biotic integrity of grasslands was made using a similar approach based on visits to Capulin Volcano NM by SOPN's Tomye Folts-Zettner and Robert Bennetts. The assessment for biotic integrity was not made at the three sites used by Biggam (2010) (although Bennetts included those sites as part of a broader evaluation); rather the biotic integrity assessment was based on a more general evaluation of the monument's grasslands from visiting multiple sites. Additionally, two of the biotic integrity indicators (invasive plants and species composition) were also assessed using data collected by the Southern Plains Inventory and Monitoring Network (SOPN) and the Southern Plains Fire Group, following

Table 4.8.2-1. Indicators/measures used to assess the condition of grasslands at Capulin Volcano NM.

Indicator/Measure	Definition
Soil/Site Stability and Hydrologic Function	
Rills	A small, intermittent water course with steep sides, usually only several centimeters deep (SSSA 1997). Rills generally are linear erosion features.
Water Flow Patterns	Characteristics of the way water moves across the soil
Pedestals and/or terracettes	"Plants or rocks that appear elevated as a result of soil loss by wind or water erosion (does not include plant or rock elevation as a result of non-erosional processes such as frost heaving), and "Benches" of soil deposition behind obstacles caused by water erosion."
Bare ground	All land surface not covered by vegetation, rock, or litter (SRM 1999). As used in this document, visible biological crusts and standing dead vegetation are included in cover estimates or measurements and therefore are not bare ground (e.g., mineral soil).
Gullies	A furrow, channel, or miniature valley, usually with steep sides through which water commonly flows during and immediately after rains or snowmelt (SRM 1999). Small channels eroded by concentrated water flow.
Wind-scoured, blowout and/or depositional areas	Areas, generally in interspaces, where the finer soil particles have blown away sometimes leaving residual gravel, rock, or exposed roots on the soil surface
Litter Movement	The uppermost layer of organic debris on the soil surface, essentially the freshly fallen or slightly decomposed vegetal material (SRM 1999). In this document, it includes persistent and non-persistent organic matter that is in contact with the soil surface.
Soil surface resistance to erosion	The top layer underneath vegetation canopy and characteristics of presence/absence/configuration of debris
Soil surface loss or degradation	Intactness of uppermost soil layer
Compaction layer	A near surface layer of dense soil caused by the repeated impact on or disturbance of the soil surface. When soil is compacted, soil grains are rearranged to decrease the void space and bring them into closer contact with one another, thereby increasing the bulk density (SSSA 1997).
Biotic Integrity	
Plant mortality/decadence	In a plant community, decadence refers to an overabundance of dead or dying plants relative to what is expected for a site given the natural range of variability in disease, climate, and management influences
Invasive plants	Plants that are not part of the original plant community or communities that have the potential to become a dominant or co-dominant species on the site if their future establishment and growth is not actively controlled by management interventions.
Species composition *	The proportions of various plant species in relation to the total on a given area; it may be expressed in terms of cover, density, weight, etc. Synonym: Species composition (SRM 1999).

* This indicator was modified from Pellant et al. (2005)

Folts-Zettner et al's. Grassland Monitoring Protocol and Standard Operating Procedures (2011), as part of their ongoing grassland/fire effects monitoring efforts (Folts-Zettner et al., in prep). Grassland monitoring data were collected in 2010 and 2011, along six transects, each with five subplots, as part of this monitoring effort (Figure 4.8.2-2). At each subplot, the percent cover was estimated for each species within a 1x2m^2 quadrat.

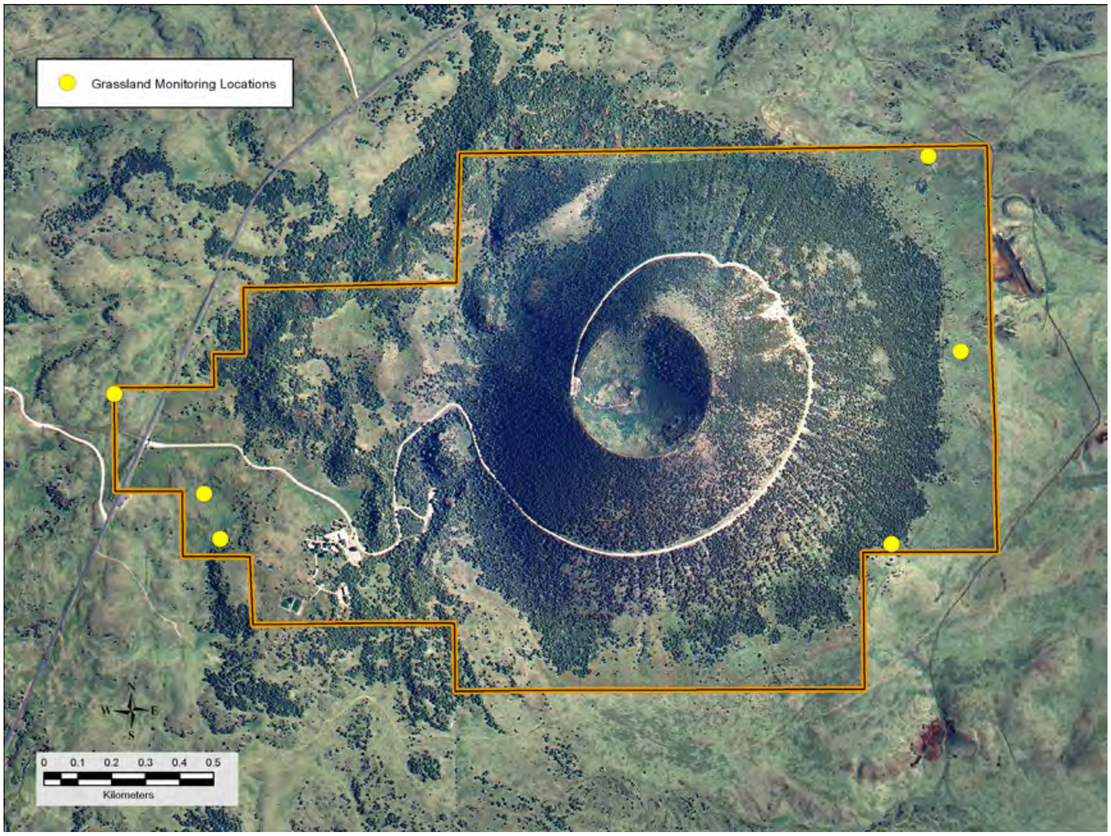


Figure 4.8.2-2 Map of grassland transect locations sampled during 2010 and 2011 as part of the SOPN and Southern Plains Fire Group's grassland/fire effects monitoring.

4.8.3 Reference Conditions

Pellant et al. (2005) described general reference conditions they considered to be an optimal functional state (their none to slight category) under natural disturbance regimes. They then described general descriptions for departures from that optimal state into four other categories of condition. These categories ranged from their optimal state to an extreme or total state of degradation.

We considered the condition of grasslands as "good" if the current condition fell either within Pellant et al.'s (2005) "none to slight", or "slight to moderate" categories. The "moderate" ranking was assigned if the departure from optimal fell within Pellant et al's (2005) "moderate" class. And finally, we considered the condition of grasslands as a "significant concern" if the departure from optimal fell within Pellant et al's (2005) "moderate to extreme" or "extreme to total" classes (Table 4.8.3-1).

One departure from this general conditions scheme was that our reference conditions for the plant species composition indicator was not derived directly from Pellant at al. (2005). Reference conditions for this indicator were more problematic to define, largely due to the fact that the species composition at Capulin Volcano NM would not be expected to conform to that of most surrounding areas of shortgrass steppe due to the volcanic nature of the monument. However, based upon Tomye Folts-Zettner's expertise of southern plains grasslands, Drs. Knapp and Lauenroth's opinions, and referencing Natural Resources Conservation Service's ecological site descriptions plant community species composition lists (NRCS 2007a,b), we developed three (versus five) reference conditions for the species composition "good", "moderate", and "significant concern" categories (Table 4.8.3-1).

4.8.4 Condition and Trend

Soil/Site Stability / Hydrologic Function

The results from Biggam's three grassland sampling sites indicated that the current condition of the soil/site stability/hydrologic function indicator was good at all three sites, falling within Pellant et al.'s (2005) "none to slight" or "slight to moderate" condition categories (Table 4.8.4-1).

In two of the three sites sampled (sites one and three) the Fallsam – Rock outcrop soil complex was present. This soil consists of deep and very deep, well-drained, slowly permeable soils that formed in fine textured materials mixed with

Table 4.8.3-1. Reference conditions for soil/site stability/hydrologic function and biotic integrity indicators.

Indicator	Significant Concern		Moderate Concern	Good	
	Extreme to Total	Moderate to Extreme	Moderate	Slight to Moderate	None to Slight
Soil/site Stability and Hydrologic Function					
Rills	Rill formation is severe and well defined throughout most of the site.	Rill formation is moderately active and well defined throughout most of the site.	Active rill formation is slight at infrequent intervals; mostly in exposed areas	No recent formation of rills; old rills have blunted or muted features.	Current or past formation of rills as expected for the site.
Water Flow Patterns	Water flow patterns extensive and numerous; unstable with active erosion; usually connected	Water flow patterns more numerous and extensive than expected; deposition and cut areas common; occasionally connected.	Number and length of water flow patterns nearly match what is expected for the site; erosion is minor with some instability and deposition.	Number and length of water flow patterns match what is expected for the site; some evidence of minor erosion. Flow patterns are stable and short.	Matches what is expected for the site; minimal evidence of current or past soil deposition and erosion.
Pedestals and/or terracettes	Abundant active pedestalling and numerous terracettes. Many rocks and plants are pedestaled; exposed plant roots are common.	Moderate active pedestalling; terracettes common. Some rocks and plants are pedestaled with occasional exposed plant roots.	Slight active pedestalling; Most pedestals are in flow paths and interspaces and/or on exposed slopes. Occasional terracettes present.	Active pedestalling or terracette formation is rare; some evidence of past pedestal formation, especially in flow patterns on exposed slopes.	Current or past evidence of pedestaled plants or rocks as expected for the site. Terracettes uncommon or absent.
Bare ground	Much higher than expected for the site. Bare areas are large and generally connected.	Moderate to much higher than expected for the site. Bare areas are large and occasionally connected.	Moderately higher than expected for the site. Bare areas are of moderate size and sporadically connected.	Slightly to moderately higher than expected for the site. Bare areas are small and rarely connected.	Amount and size of bare areas match that expected for the site.
Gullies	Common with indications of active erosion and downcutting; vegetation is infrequent on slopes and/or bed. Nickpoints and headcuts are numerous and active.	Moderate in number to common with indications of active erosion; vegetation is intermittent on slopes and/or bed. Headcuts are active; downcutting is not apparent.	Moderate in number with indications of active erosion; vegetation is intermittent on slopes and/or bed. Occasional headcuts may be present.	Uncommon, vegetation is stabilizing the bed and slopes; no signs of active headcuts, nickpoints, or bed erosion.	Match what is expected for the site; drainages are represented as natural stable channels; vegetation common and no signs of erosion.
Wind-scoured, blowout, and/or depositional areas	Extensive	Common	Occasionally present	Infrequent and few.	Match what is expected for the site.
Litter movement	Extreme concentrated around obstructions. Most size classes of litter have been displaced.	Moderate to extreme; loosely concentrated near obstructions. Moderate to small size classes of litter have been displaced.	Moderate movement of smaller size classes in scattered concentrations around obstructions and in depressions.	Slightly to moderately more than expected for the site with only small size classes of litter being displaced.	Matches that expected for the site with a fairly uniform distribution of litter.
Soil surface resistance to erosion	Extremely reduced throughout the site. Biological stabilization agents including organic matter and biological crusts virtually absent.	Significantly reduced in most plant canopy interspaces and moderately reduced beneath plant canopies. Stabilizing agents present only in isolated patches.	Significantly reduced in at least half of the plant canopy interspaces or moderately reduced throughout the site.	Some reduction in soil surface stability in plant interspaces or slight reduction throughout the site. Stabilizing agents reduced below expected	Matches that expected for the site. Surface soil is stabilized by organic matter decomposition products and/or a biological crust.

Table 4.8.3-1. Reference conditions for soil/site stability/hydrologic function and biotic integrity indicators (continued)

Indicator	Significant Concern		Moderate Concern	Good	
	Extreme to Total	Moderate to Extreme	Moderate	Slight to Moderate	None to Slight
Soil surface loss or degradation	Soil surface horizon absent. Soil structure near surface is similar to, or more degraded, than that in subsurface horizons. No distinguishable difference in subsurface organic matter content.	Soil loss or degradation severe throughout site. Minimal differences in soil organic content and structure of surface and subsurface layers.	Moderate soil loss or degradation in plant interspaces with some degradation beneath plant canopies. Soil structure is degraded and soil organic matter is significantly reduced.	Some to no soil loss has occurred and/or soil structure shows signs of degradation, especially in plant interspaces	Soil surface horizon intact. Soil structure and organic matter content match that expected for site.
Compaction layer (below soil surface)	Extensive; severely restricts water movement and root penetration.	Widespread; greatly restricts water movement and root penetration.	Moderately widespread, moderately restricts water movement and root penetration.	Rarely present or is thin and weakly restrictive to water movement and root penetration.	Matches that expected for the site; none to minimal, not restrictive to water movement and root penetration.
Biotic Integrity					
Plant mortality/ decadence	Dead and/or decadent plants are common.	Dead and/or decadent plants are somewhat common.	Some dead and/or decadent plants are present.	Slight plant mortality and/or decadence	Plant mortality and decadence match that expected for the site.
Invasive plants	Dominate the site.	Common throughout the site.	Scattered throughout the site.	Present primarily in disturbed areas within site	If present, composition of invasive species, matches that expected for the site.
Species composition	Species present deviate substantially from those expected for the site, given the soils and supply of water and nutrients.		Species present deviate somewhat from those expected for the site, given the soils and supply of water and nutrients.	Species present are consistent with what is expected for the site, given the soils and supply of water and nutrients.	

basalt fragments on basalt flows around the base of volcanic flows or vents (Weindorf et al. 2008). Evidence of soil movement either by wind and/or water was present at both sites based on the presence of past pedestal formation around the bases of bunchgrasses and litter movement. This resulted in slight to moderate ratings for those indicators. The remaining eight indicators for sites one and three were rated as none to slight departure from what was expected at each location. Overall, the results for sites one and three indicate that the site/soil stability/hydrologic function condition is good.

Site two was located in the Bandara soil association. Bandera soils consist of very deep soils with subsurface horizons dominated by greater than 70% alluvial and colluvial cinders. These soils are somewhat excessively drained, moderately permeable soils on volcanic cone landscapes (Weindorf et al. 2008). All indicators for site two were rated as none to slight departure from what was expected, except for bare ground and litter movement, which were rated as slight to moderate. Overall, the condition for the oil/site stability/hydrologic function at site two was good.

According to Pellant et al. (2005), the amount and pattern of bare ground within a given site is one of the most important contributors to its stability. Data from the 2010 and 2011 SOPN grassland/fire effects monitoring efforts indicate that the average mean cover of bare ground throughout the monument's grasslands is 14.2% (Folts-Zettner et al. in prep). The fire effects/grassland monitoring bare ground result is consistent with Biggam's overall assessment that the monument's grasslands are in good condition relative to their soil/site stability/hydrologic function.

Table 4.8.4-1. Results for the soil/site stability/hydrologic function indicators reported by Biggam 2010 (Appendix E).

Indicator	Site 1	Site 2	Site 3
Rills	None to Slight – Current or past formation of rills as expected for the sitet	None to Slight – None present. Current or past formation of rills as expected for the site	None to Slight – Current or past formation of rills as expected for the site
Water Flow Patterns	None to Slight – Matches what is expected for the site; minimal evidence of past or current soil deposition or erosion	None to Slight – None present. Matches what is expected for the site; minimal evidence of past or current soil deposition or erosion	None to Slight – Matches what is expected for the site; minimal evidence of past or current soil deposition or erosion
Pedestals and/or terracettes	Slight to Moderate – Active pedestalling or terracette formation is rare; some evidence of past pedestal formation around base of bunchgrasses is present on downslope side	None to Slight – Current or past evidence of pedestalled plants or rock fragments as expected for the site. Terracettes absent or uncommon.	Slight to Moderate – Active pedestalling or terracette formation is rare; some evidence of past pedestal formation around base of bunchgrasses is present on downslope side
Bare ground	None to Slight – Soil surface contained approximately 10 - 15 % gravel size cinders, with plant litter present. Very little actual bare ground is present, with what was recognized as an exposed soil surface in small patches, and not connected	Slight to Moderate – Soil surface contained approximately 15-35 % gravel size cinders, with plant litter present. Slightly to moderately higher than expected for the site, with bare ground present in small areas, and rarely connected. Bare ground was more evident in areas with invasive annual grasses and forbs present.	None to Slight – Soil surface contained approximately 10 - 15 % gravel size cinders, with plant litter present. Very little actual bare ground is present, with what was recognized as an exposed soil surface in small patches, and not connected
Gullies	None to Slight – None present	None to Slight – None present	None to Slight – None present
Wind-scoured, blowout, and/or depositional areas	None to Slight – None present	None to Slight – None present	None to Slight – None present
Litter movement	Slight to Moderate – Slightly more than expected for the site, with only small size classes (grass) of litter being displaced	Slight to Moderate – Slightly more than expected for the site, with only small size classes (grass) of litter being displaced	Slight to Moderate – Slightly more than expected for the site, with only small size classes (grass) of litter being displaced
Soil surface resistance to erosion	None to Slight – Soil surface has been stabilized by surface cinders and litter. Biological soil crust is present and intact.	None to Slight – Soil surface has been stabilized by surface cinders and litter. Biological soil crust is present and intact, but is not uniform on the site due to the amount of surface cinders. Biologic crusts found adjacent to bases of bunchgrasses.	None to Slight – Soil surface has been stabilized by surface cinders and litter. Biological soil crust is present and intact.
Soil surface loss or degradation	None to Slight – No apparent loss of surface A horizon, with soil structure and organic matter distribution about what is expected for the site	None to Slight – No apparent loss of surface A horizon, with soil structure and organic matter distribution about what is expected for the site	None to Slight – No apparent loss of surface A horizon, with soil structure and organic matter distribution about what is expected for the site
Compaction layer (below soil surface)	None to Slight – None present	None to Slight – None present	None to Slight

Biotic Integrity

Of the three indicators for biotic integrity, we considered two-plant mortality/decadence and species composition-to be in good condition and consistent with the what was expected for the grasslands at Capulin Volcano NM. However, we believe that the invasive plants indicator warrants a moderate concern rating. (Table 4.8.4-2).

Plant mortality/decadence - Plant mortality and decadence showed only slight to moderate departure from what was expected throughout the monument's grasslands. The assessment of this indicator was also, at least in part, made during a drought period when some mortality/ decadence would be expected. Therefore, the plant mortality/decadence indicator is considered to be in good condition.

Invasive plants - Of all the indicators for grassland condition, invasive plants presented the greatest concern. Our assessment indicated that invasive plants are scattered throughout the grasslands at the monument, with high potential for continued spread. Of particular concern are the non-native bromes. As discussed in section 4.9 (Exotic Plants), non-native bromes are well known to dramatically change the character of an ecosystem, including major shifts in community composition and structure, and in many cases these changes have become, for all practical purposes, irreversible (Knapp 1996). Although we did not detect non-native bromes in our six plots used to assess grassland condition, our more extensive exotic plants monitoring efforts indicated that these species are very widespread throughout the grasslands at Capulin Volcano NM (see figure 4.9.4-2 in section 4.9) and present a substantial threat to the biotic integrity. Consequently, we consider this indicator to be of moderate concern.

Species composition - The native grass species detected during the grassland/fire effects monitoring are consistent with the historic climax plant community species compositions listed in NRCS' ecological site descriptions, which includes little bluestem and blue grama as the dominant warm-season grasses (NRCS 2007a,b). The total number of perennials (n = 56) accounted for 76.7% of the total of species recorded (n = 73) during the grassland/fire effects monitoring (Table 4.8.4-3). This is an important factor because perennials are better able to resist losses in ecological processes (Pellant et al., 2005) due to annual variations in stressors, such as drought or excessive temperatures compared to annuals or even biennials (T. Folts-Zettner pers. comm.). With the exception of the widespread invasive bromes, the species present throughout the monument's grasslands are consistent with what might be expected given the ecological conditions at Capulin Volcano NM; therefore, are considered to be in good condition relative to the speies composition indicator.

Overall Condition

For assessing the condition of grasslands, we used a variety of indicators/measures that were not mutually exclusive but were intended to be different ways of capturing the essence of what we thought represented the condition of the monument's grasslands. Grassland condition can be assessed from many different angles, but we chose two main categories for this resource. A summary of how they contributed to the overall grassland condition is summarized in Table 4.8.4-4. The overall condition of the monument's grasslands would be considered good, if not for the widespread presence of invasive plants, specifically the invasive bromes. The aggressiveness of the non-native bromes and the degree of difficulty to control them,

Table 4.8.4-2. Results for the biotic integrity indicators reported by Folts-Zettner et al. (in prep.) and Robert Bennetts.

Indicator	Departure From Expected
Plant mortality/ decadence	Slight to Moderate - There is some evidence within grasslands throughout the monument of minor plant mortality and decadence, but this was not sufficient to warrant concern.
Invasive plants	Moderate - Invasive exotic plants are scattered throughout the monument's grasslands and are of moderate concern based on their potential to further spread. Of particular concern are the exotic bromes, which are discussed in greater detail in section 4.9.
Species Composition	None to Slight - With the exception of invasive exotic plants (describe above), species composition was consistent with what might be expected for the conditions at Capulin.

Table 4.8.4-3. The average percent cover of species from the grassland/fire effects monitoring plots during 2010 and 2011 (Folts-Zettner et al., in prep.).

Scientific Name	Common Name	Life Cycle[1]	Mean Percent Cover 2010	Mean Percent Cover 2010	Mean Total
GRASSES					
Andropogon gerardii	Big bluestem	P	4.683	2.350	3.517
Aristida purpurea	Purple threeawn	P	1.900	1.183	1.542
Bouteloua curtipendula	Sideoats grama	P	3.233	2.017	2.625
Bouteloua gracilis	Blue grama	P	5.000	2.300	3.650
Bromus porteri	Porter brome	P	0.550	0.000	0.275
Buchloe dactyloides	Buffalograss	P	0.000	0.350	0.175
Carex species	Sedge	P	0.283	0.000	0.142
Elymus elymoides	Bottlebrush squirreltail	P	3.350	1.500	2.425
Festuca arizonica	Arizona fescue	P	0.050	0.000	0.025
Lycurus setosus	Bristly wolfstail	P	3.700	0.000	1.850
Muhlenbergia montana	Mountain muhly	P	1.300	0.800	1.050
Pascopyrum smithii	Western wheatgrass	P	1.617	0.533	1.075
Poa fendleriana	Muttongrass bluegrass	P	0.133	0.067	0.100
Schizachyrium scoparium	Little bluestem	P	3.050	4.767	3.909
Sporobolus cryptandrus	Sand dropseed	P	0.117	0.033	0.075
FORBS					
Achillea millefolium	Yarrow	P	0.000	0.017	0.009
Allium cernuum	Nodding onion	P	0.033	0.033	0.033
Amaranthus hybridus	Slim amaranth pigweed	A	0.100	0.017	0.059
Arabis hirsuta	Hairy rockcress	A/P	0.000	0.017	0.009
Argemone hispida	Rough pricklypoppy	P	0.033	0.033	0.033
Astragalus flexuosus	Pliant milkvetch	P	0.017	0.000	0.009
Castilleja integra	Wholeleaf indian paintbrush	P	0.000	0.033	0.017
Chamaesyce fendleri	Fendler's sandmat	P	0.017	0.000	0.009
Chamaesyce serpyllifolia	Thyme-leaf sandmat	A	0.000	0.033	0.017
Chenopodium leptophyllum	Narrowleaf goosefoot	A	0.067	0.133	0.100
Chenopodium pratericola	Desert goosefoot	A	0.133	0.000	0.067
Cirsium undulatum	Wavyleaf thistle	P	0.083	0.033	0.058
Erigeron flagellaris	Trailing fleabane	B	0.050	0.000	0.025
Eriogonum jamesii Benth.	James buckwheat	P	0.600	0.067	0.334
Euphorbia davidii	David's spurge	A	0.067	0.000	0.034
Gaura coccinea	Scarlet beeblossom	P	0.050	0.133	0.092
Helianthus annuus	Common sunflower	A	3.033	0.033	1.533
Heliomeris multiflora	Showy goldeneye	P	0.150	0.017	0.084
Heterotheca villosa	Hairy false goldenaster	P	1.650	0.883	1.267
Lactuca serriola	Prickly lettuce	A/B	0.383	0.017	0.200
Lappula occidentalis	Western sticktight	A/B	0.017	0.000	0.009
Liatris punctata	Dotted gayfeather	P	0.267	0.000	0.134

[1] *Life Cycle: A = Annual, P = Perennial, B = Biennial*

[2] *Highlight indicates non-native plant*

Table 4.8.4-3. The average percent cover of species from the grassland/fire effects monitoring plots during 2010 and 2011. (continued) (Folts-Zettner et al., in prep.)

Scientific Name	Common Name	Life Cycle[1]	Mean Percent Cover 2010	Mean Percent Cover 2010	Mean Total
Lithospermum multiflorum	Manyflowered stoneseed	P	0.050	0.000	0.025
Lupinus argenteus	Silver lupine	P	0.683	0.133	0.408
Machaeranthera pinnatifida	Lacy tansyaster	P	0.000	0.017	0.009
Marrubium vulgare	Horehound	P	0.033	0.000	0.017
Mentzelia multiflora	Manyflowered blazingstar	P	0.000	0.017	0.009
Mentzelia nuda	Bractless blazingstar	P	0.450	0.017	0.234
Mirabilis linearis	Narrowleaf four o'clock	P	0.050	0.000	0.025
Orthocarpus luteus	Yellow owlclover	A	0.000	0.017	0.009
Packera neomexicana	New Mexico groundsel	P	0.050	0.250	0.150
Pectis angustifolia	Narrowleaf pectis	A	0.500	0.033	0.267
Penstemon angustifolius	Broad-beard penstemon	P	0.133	0.000	0.067
Phacelia heterophylla	Variable leaf scorpionweed	P	0.333	0.000	0.167
Physalis subulata	New Mexico groundcherry	A	0.417	0.000	0.209
Polanisia dodecandra	Western clammyweed	A	0.067	0.000	0.034
Psoralidium tenuiflorum	Slimflower scurfpea	P	0.167	0.017	0.092
Ratibida tagetes	Green mexican hat	P	0.017	0.017	0.017
Salsola tragus	Prickly Russian thistle	A	0.583	0.600	0.592
Senecio flaccidus	Douglas roundsel	P	0.017	0.000	0.009
Solidago canadensis	Canada goldenrod	P	0.050	0.000	0.025
Sphaeralcea coccinea	Scarlet globemallow	P	0.133	0.100	0.117
Stephanomeria minor	Lesser wirelettuce	P	0.100	0.017	0.059
Thelesperma megapotamicum	Hopi tea greenthread	P	0.433	0.133	0.283
Tragopogon dubius	Western salsify	P	0.100	0.000	0.050
Verbascum thapsus	Common mullein	B	0.050	0.000	0.025
Verbesina encelioides	Golden crownbeard	A	0.017	0.000	0.009
Vicia americana	American deer vetch	P	0.183	0.000	0.092
SHRUBS					
Artemisia dracunculus	False tarragon sage brush	P	0.000	0.083	0.042
Artemisia frigida	Fringed sage brush	P	5.917	2.950	4.434
Artemisia ludoviciana	Louisiana sage wort	P	0.100	0.017	0.059
Echinocereus viridiflorus	Nylon hedgehog cactus	P	0.033	0.100	0.067
Gutierrezia sarothrae	Broom snakeweed	P	0.250	0.017	0.134
Rhus trilobata	Skunkbush sumac	P	3.000	0.717	1.859
Yucca glauca	Soapweed yucca	P	2.267	2.117	2.192
TREES					
Juniperus scopulorum	Rocky Mountain juniper	P	2.000	1.000	1.500
Pinus species	Pine	P	0.000	0.033	0.017
Quercus gambelii	Gambel oak	P	4.333	4.500	4.417

[1] Life Cycle: A = Annual, P = Perennial, B = Biennial

[2] Highlight indicates non-native plant

Table 4.8.4-4. Summary of the grasslands indicators/measures and their contributions to the overall grasslands natural resource condition assessment.

Indicator/Measure	Description of How the Indicator(s) Contributes to the Overall Resource Condition	General Contribution of this Indicator or Measure to the Overall Resource Condition.
Soil/site stability and Hydrologic function • 10 indicators	The soil/site stability and hydrologic function indicates an area's ability to limit the loss of soil resources or to recover when a loss occurs. Ten indicators/measures were used for this category to determine how the monument's grasslands have responded to stressors such as wind and water by observing substrate characteristics and patterns.	Little to no soil loss was evident at the study sites. The soil surface horizons were also intact indicating that the monument's grasslands have the capacity to limit the loss of soils and/or to recover from any loss that may have occurred in the past.
Biotic Integrity • Plant mortality/decadence • Invasive plants • Species composition	The biotic integrity category included three indicators/measures tailored towards the vegetation aspects of the monument's grasslands, including mortality of plants that could occur from drought, insect infestations, etc., and whether expected species for shortgrass prairie were present. This category also included the presence of invasive exotics, which have the potential to unfavorably change the grassland plant communities	Through recent SOPN grassland monitoring efforts, some plant mortality has been observed, but not to a degree that warrants concern. Also, the expected species for this region of shortgrass prairie are present, however, one significant invasive plants genus is present-the bromes. Their presence results in a moderate condition rating and declining trend because of the well documented evidence of their ability to rapidly spread and difficulty to control once established.

once established, cause us to assess the overall condition of the grasslands as a moderate concern with a declining trend.

Level of Confidence/Key Uncertainties

There are two key uncertainties for the grassland assessment: 1) annual variability, and 2) a lack of detailed reference conditions for the plant species composition indicator.

First, annual variability in rainfall, temperatures, diseases, etc. can have a dramatic effect on some indicators (e.g., plant species composition), which in turn, affects our interpretation of grassland condition. However, this assessment was conducted, at least in part, during very dry conditions, which may indicate that our assessment is a bit conservative.

Second, the relatively unique ecological conditions of Capulin Volcano NM with its volcanic influence make comparisons with other sites difficult. The absence of any multi-year datasets from a site with similar conditions additionally limits our ability to assess the "normal range of variability" for the plant species composition indicator. Monitoring over a longer period of time is necessary to better understand the monument's grassland ecology and annual variability and to more confidently predict overall condition and trends.

4.8.5 Sources of Expertise

During the course of this assessment, we consulted with the following individuals who provided subject matter expertise.

Dr. Alan K. Knapp is a Professor at Colorado State University, Department of Biology. Dr. Knapp has an extensive background of research and publications related to the ecology of grasslands. Dr. Knapp did not conduct a site visit during this assessment, and his involvement was limited to a visit with him at his office to discuss our approach and ideas.

Dr. William K. Lauenroth is a Professor of Plant Community Ecology and Ecohydrology at University of Wyoming. He also has an extensive background of research and publication in the ecology of grasslands, with an emphasis on shortgrass steppes. Dr. Lauenroth did not conduct a site visit during this assessment, and his involvement was limited to a visit with him at his office to discuss our approach and ideas.

We also consulted with Tomye Folts-Zettner, a biologist/botanist with the SOPN. She is the project lead for monitoring native and exotic plants in SOPN parks.

Dr. Peter Biggam is a soil scientist at the NPS Natural Resources Program Center Geoscience and Restoration Branch., who specializes in, but also has an extensive background in range science and management. Dr. Biggam visited Capulin Volcano NM as a subject-matter expert for the grassland section of this assessment.

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4.9 Exotic Plants

Indicators/Measures

- Significance of impact
- Feasibility of control
- Proportion of high priority blocks infested
- Proportion of interior plots infested
- Distribution of high priority species

Condition – Trend

Significant Concern – Declining

4.9.1 Background and Importance

Globalization of commerce, transportation, human migration, and recreation in recent history has introduced invasive exotic species to new areas at an unprecedented rate. Biogeographical barriers that once restricted the location and expansion of species have been circumvented, culminating in the homogenization of Earth's biota. Although only 10% of introduced species become established and only 1% become problematic (Williamson 1993; Williamson and Fitter 1996) or invasive, nonnative species have profound impacts worldwide on the environment, economies, and human health.

Invasive species have been directly linked to the replacement of dominant native species (Tilman 1999), the loss of rare species (King 1985), changes in ecosystem structure, alteration of nutrient cycles and soil chemistry (Ehrenfeld 2003), shifts in community productivity (Vitousek 1990), reduced agricultural productivity, and changes in water availability (D'Antonio and Mahall 1991). The damage caused by these species to natural resources is often irreparable, and our understanding of the consequences incomplete. Invasive species are second only to habitat destruction as a threat to wildland biodiversity (Wilcove et al. 1998). Consequently, the dynamic relationships among plants, animals, soil, and water established over many thousands of years are at risk of being destroyed in a relatively brief period. For the NPS, the consequences of these invasions present a significant challenge to the management of the agency's natural resources "unimpaired for the enjoyment of future generations." National parks, like land managed by other organizations, are deluged by new exotic species arriving through predictable (e.g., road, trail, and riparian corridors), sudden (e.g., long-distance dispersal through cargo containers and air freight), and unexpected anthropogenic pathways (e.g., weed seeds in restoration planting mixes) (Figure 4.9.1-1). Nonnative plants claim an estimated 4,600 acres of public land each year in the United States

Figure 4.9.1-1. Cheatgrass (*Bromus tectorum*), is an invasive exotic plant found at Capulin Volcano NM.

(Asher and Harmon 1995), significantly altering local flora. For example, exotic plants comprise an estimated 43% and 36% of the flora of the states of Hawaii and New York, respectively (Rejmanek and Randall 1994). Invasive plants infest an estimated 2.6 million acres of the 83 million acres managed by the NPS. Prevention and early detection are the principal strategies for successful invasive exotic plant management. While there is a need for long-term suppression programs to address high-impact species, eradication efforts are most successful for infestations of less than one hectare in size (Rejmanek and Pitcairn 2002).

4.9.2 Data and Methods

In evaluating current condition and trend for exotic plants at Capulin Volcano NM. Five indicators/measures were considered.

Indicators/Measures

- Significance of impact
- Feasibility of control

One of our first indicators for exotic plants was to determine which species pose the greatest risk to the monument. As a foundation for evaluating potential risk, we used the Exotic Species Ranking System presented by Hiebert and Stubbendieck (1993) (Appendix F). This ranking system has been applied in parks throughout the Midwest (Stubbendieck et al. 1992; Stumpf et al. 1994) as well as at Capulin Volcano and Fort Union National Monuments in New Mexico (Willson et al. 2008). Ranking is based on two primary components of the potential risk: *significance of impact* and *feasibility of control/management*. Each component has several subcomponents and is ranked on a scale from 0–100 points.

Significance of impact is subdivided into the current level of impact and the potential for the species to become a pest. The current level of impact takes into account such things as abundance, distribution relative to disturbance, effects on natural processes and community character, potential threat to park resources, and visual impact. The potential for a species to become a pest considers life history traits that might preadapt a given species to become a problem as well as its known impacts in other areas. Important life history characteristics include potential rate of increase, adaptations for long-distance dispersal, and the breadth of habitats in which the species can colonize and thrive.

Feasibility of control/management focuses on such things as its abundance within the monument, the ease to which it is controlled, its reproductive capability, proximity of other populations, potential side effects of control measures, and the potential for biological control.

Indicators/Measures

- Proportion of high priority blocks infested

As part of the Southern Plains Inventory and Monitoring Network (SOPN) exotic plants monitoring program, high priority vectors (e.g., roads and trails) were identified based on their potential risk for invasion by exotic plants. The highest priority vectors were surveyed in 2009 and 2010 (Figure 4.9.2-1), and the data are used for this indicator. This effort is part of a sampling scheme that uses a three-year rotating panel design, whereby a new area is surveyed each year (a panel) for three years, after which the areas surveyed are repeated. It is important to emphasize that this sampling approach does not provide a complete survey of exotic plants throughout the monument; rather, it provides a repeated snapshot for a limited area with high potential (e.g., roads and trails) for new invasions.

Sampling was conducted from June to July. The methodology used in this monitoring is described in detail in Folts-Zettner et al. (2010). The approach is based on a generalized linear model, where 50-meter blocks on both sides of the vector (right [R] and left [L]) are surveyed from a transect running along (e.g., trails) or adjacent to (e.g., along the mow strip of roads) the vector (Figure 4.9.2-2).

The full protocol also includes estimation of four density classes assigned to each block ranging from scattered plants to a dense matrix, as well as four distance classes used to determine the extent to which exotic plants are limited to the zone immediately adjacent to the vector. These measures provide more specific detail for the monument than is warranted for this assessment, therefore, are provided along with other information in the SOPN's annual reports (Folts-Zettner et al. 2010; Folts-Zettner and Sosinski 2010).

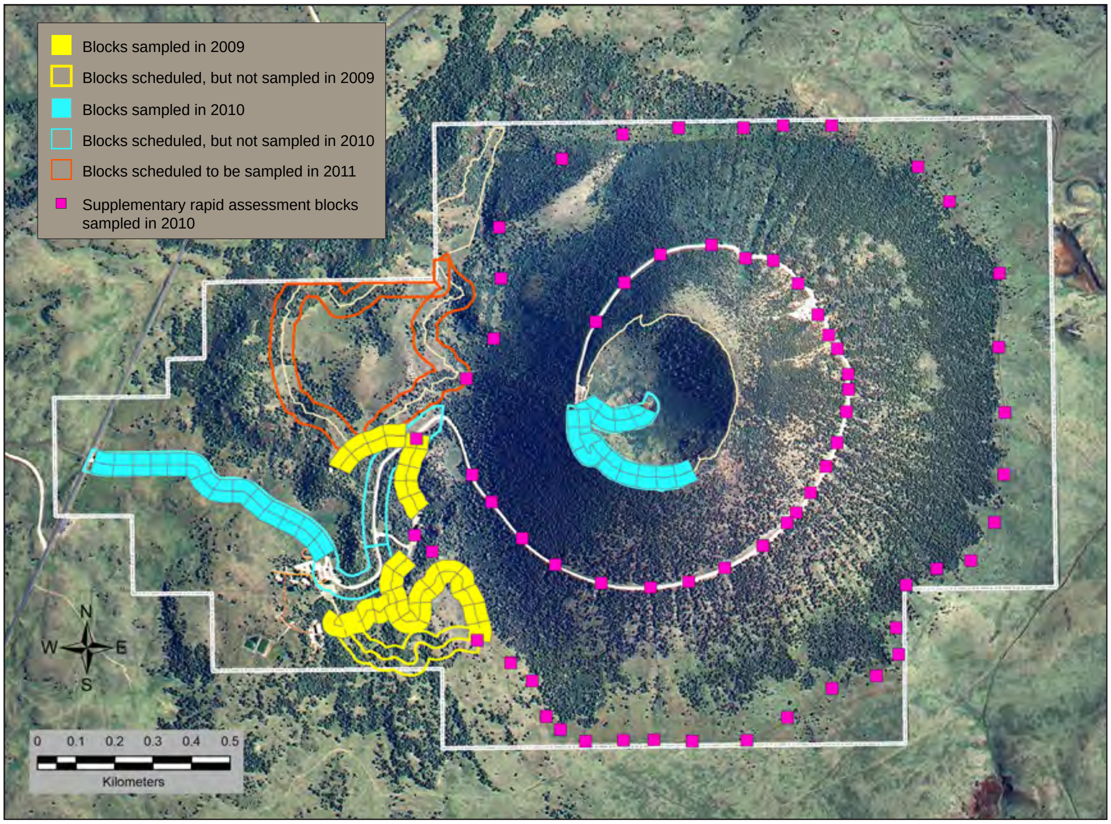

Figure 4.9.2-1. High priority blocks sampled in 2009 and 2010.

As part of this assessment two additional vectors were sampled along Volcano Road and at the base of the cinder cone. These additional blocks were intended as a rapid assessment supplement to our standard monitoring blocks for the purposes of this condition assessment.

Data for these supplemental blocks were recorded in generally the same way as our standard blocks described above, except that these units will not be included in our rotating panel; nor were the blocks carefully measured and laid out as were our standard monitoring blocks. Instead, the blocks at the base of the cinder cone were estimated by pacing the distance, and the blocks on Volcano Road represented sections between culverts, rather than our standard 50 m units.

Indicators/Measures

- Proportion of interior plots infested

We used two data sources for estimating the proportion of interior plots occupied by a given exotic species. First, we used the secondary exotic-plant monitoring that was conducted in 2009 and 2010 in grassland areas within

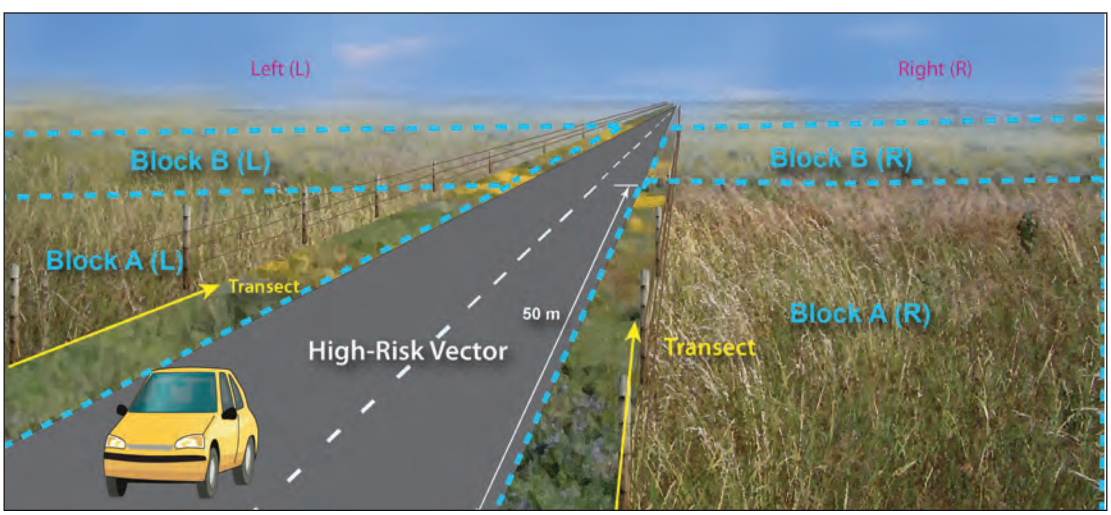

Figure 4.9.2-2. Fifty meter blocks are sampled on each side of a high-risk vector (e.g., roads and trails).

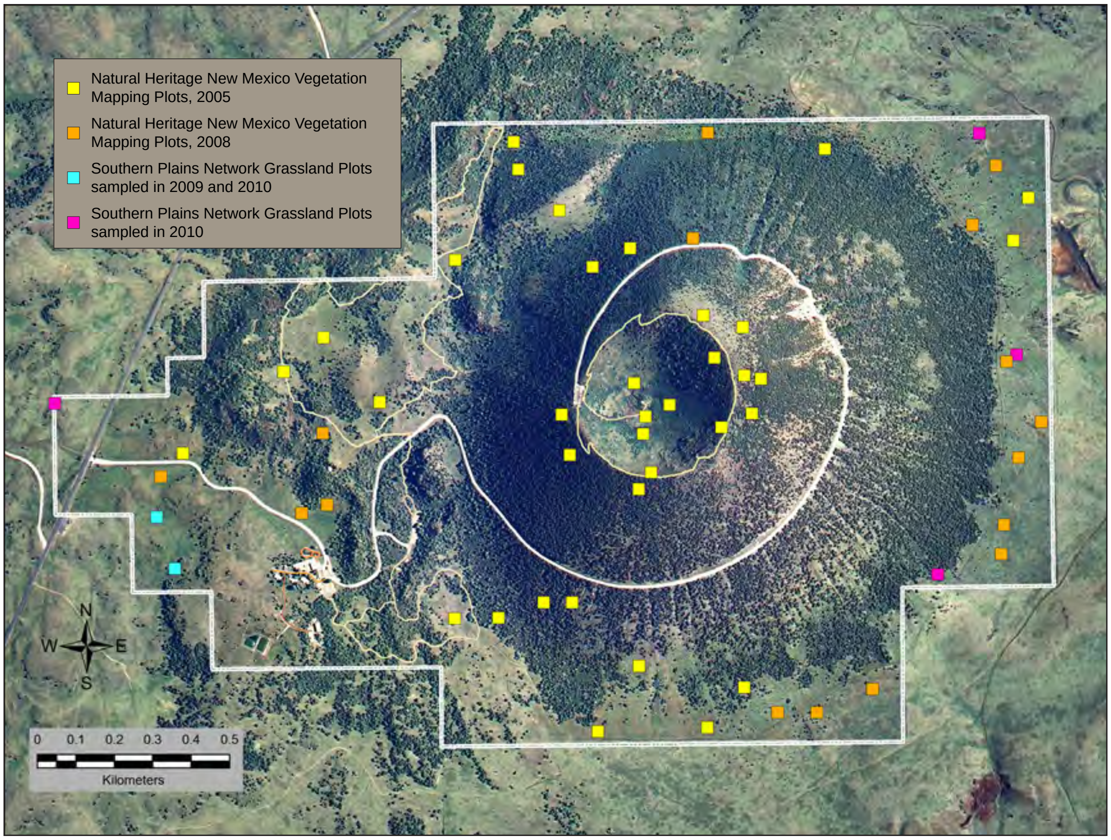

Figure 4.9.2-3. The location of interior plots that were sampled from 2005 to 2010.

the interior landscape in as part of SOPN's grassland/fire effects monitoring efforts (Figure 4.9.2-3). This monitoring consists of collecting plant occurrence and cover data from five 4 x 1-m nested quadrats along a 50 m permanent transect.

The second data source used for assessing interior sites were the standard vegetation plots sampled in 2005 and 2008 as part of the vegetation mapping effort conducted by Natural Heritage New Mexico for the monument (Muldavin et al. 2011). These plots were typically 400 m^2 and square, but occasionally other sizes and shapes were used to fit the structure of a community, especially along drainages where vegetation stands conform to the channel shape (Muldavin et al. 2011). A list of all vascular plant species occurring in these plots was recorded.

Indicators/Measures

- Distribution of high priority species

For this measure, we used all available data sources, including mapping done by Willson et al. (2008), surveys by the SOPN, surveys by park staff and crews, surveys and reports by the Chihuahuan Desert/Southern Shortgrass Prairie Exotic Plant Management Team, inventories by Natural Heritage New Mexico, and standard vegetation mapping points by Natural Heritage New Mexico.

4.9.3 Reference Conditions

The most desirable reference condition for a natural resource park is the complete absence of exotic species. However, such a reference condition is probably not a realistic standard to which exotic plant species should be compared. We consider a more realistic reference condition to be the capability for the integrity of the primary communities (e.g., shortgrass prairie, pinon-juniper, and Gambel's oak shrublands) to be maintained. By this, we mean that the ecological attributes (e.g., species composition, structure, etc.) and natural processes remain within the natural variation for the community type. Therefore, the reference condition of "good" is that species are known to occur regionally or on adjacent lands, but have not yet been confirmed within monument, or if species have been confirmed, distribution is sparse, limited in extent, and may vary from sparse individuals to dense patches. A "moderate" condition is when species have been found in the monument in small, localized patches. Finding and controlling patches might prevent large-scale invasion, and distribution

Table 4.9.4-1. Exotic speices found within Capulin Volcano NM by Willson et al. (2008), Folts-Zettner (2009), and Folts-Zettner and Sosinski (2010)

Scientific Name	Common Name	Life Form[1]	Type[2]	Noxious[3]	Willson et al. 2008[4]	Folts-Zettner et al. 2009	Folts-Zettner and Sosinski 2010
Agropyron cristatum	Crested wheatgrass	G	P		●		●
Bromus inermis	Smooth brome	G	P		●		●
Bromus japonicus	Japanese brome	G	A		●		●
Bromus tectorum	Cheatgrass	G	A		●		●
Chenopodium album	Common lambsquarters	F	A		●	●	●
Cichorium intybus	Chicory	F	B/P	n	●		
Convolvulus arvensis	Field Bindweed	F	P	N	●	●	●
Cynoglossum officinale	Houndstongue	F	B	n	●	●	
Descurainia sophia	Fixweed; Herb sophia	F	A/B		●	●	●
Echinochloa crus-galli	Barnyardgrass	G	A		●		
Euphorbia davidii	David's spurge	F	A		●		●
Kochia scoparia	Kochia	F	A		●	●	●
Lactuca serriola	Prickly lettuce	F	A/B			●	●
Marrubium vulgare	Horehound	F	P		●	●	●
Medicago lupulina	Black medic clover	F	A/P				●
Melilotus alba	White sweetclover	F	A/P				●
Melilotus officinalis	Yellow Sweetclover	F	A/P		●	●	●
Polygonum convolvulus	Climbing Buckwheat	F	A		●	●	
Salsola tragus	Prickly Russian thistle	F	A		●	●	●
Setaria pumila	Yellow bristlegrass	G	A		●		
Setaria viridis	Green Bristlegrass	G	A		●	●	●
Sonchus asper	Spiny sowthistle	F	A			●	
Taraxacum officinale	Dandelion	F	P			●	
Tragopogon dubius[5]	Western salsify	F	P		●	●	●
Tragopogon pratensis (dubius[5])	Western salsify	F	P		●		
Verbascum thapsus	Mullein	F	B	n	●	●	●

[1] Life form: G = Graminoid, F = Forb/Herb

[2] Type: A = Annual, P = Perennial, B = Biennial

[3] Noxious: N = Listed as noxious in New Mexico, n = Listed as noxious in nearby states other than New Mexico

[4] The list in by Willson et al. (2008) was compiled by monument staff and Natural Heritage New Mexico.

[5] Both *Tragopogon pratensis* and *Tragopogon dubius* are reported to occur at the monument, but at the time that surveys are conducted, it is very difficult to differentiate between these very similar species.

is somewhat limited in extent and may vary in intensity from sparse individuals to dense patches. A condition of significant concern is warranted when exotic plants threaten to alter these primary communities to the point where they no longer maintain these attributes or processes. For example, when exotic species dominate a community where key native species are expected for that community type, then the area would be considered as severely degraded. However, significant concern is also warranted when the trend for a community is clearly toward such an degraded outcome rather than it actually having been realized.

4.9.4 Condition and Trend

There are currently 26 exotic species found within Capulin Volcano NM (Table 4.9.4-1).

Significance of Impact

Based on the ranking system of Hiebert and Stubbendiek (1993), the three exotic brome

Table 4.9.4-2. Exotic species ranking for significance of impact at Capulin Volcano NM, based on Hiebert and Stubbendieck (2003) as reported by Willson et al. (2008)

Species	Significance of Impact		
	Level of Impact	Pest Potential	Total
Bromus inermis[1]	23	36	59
Bromus tectorum[1]	26	27	53
Bromus japonicus[1]	26	25	51
Convolvulus arvensis[1]	4	43	47
Marrubium vulgare[1]	13	32	45
Kochia scoparia[1]	10	34	44
Lactuca serriola[2]	10	34	44
Sonchus asper[2]	10	33	43
Medicago lupulina[2]	11	29	40
Taraxacum officinale[2]	5	35	40
Melilotus alba[2]	11	27	38
Melilotus officinalis[1]	11	27	38
Tragopogon dubius[1]	5	32	37
Setaria pumila[1]	10	24	34
Setaria viridis[1]	10	24	34
Verbascum thapsus[1]	17	16	33
Agropyron cristatum[1]	3	27	30
Cynoglossum officinale[1]	7	23	30
Tragopogon pratensis[1]	5	25	30
Descurainia sophia[1]	3	26	29
Salsola tragus[1]	4	23	27
Cichorium intybus[1]	–8	32	24
Euphorbia davidii[1]	–8	30	22
Chenopodium album[1]	–6	26	20
Echinochloa crus-galli[1]	–8	26	18
Polygonum convolvulus[1]	–8	21	13

[1] Species ranking was conducted by, and reported in, Willson et al. (2008).

[2] Species ranking was conducted by Tomye Folts-Zettner of the SOPN.

species have the highest potential impact at Capulin Volcano NM (Table 4.9.4-2). Willson et al. (2008) listed these species as low (*Bromus inermis*) to moderate (*Bromus tectorum)* and (*Bromus japonicus*) urgency based on categories defined by Hiebert and Stubbendiek (1993). We did not use these categories in our assessment because they are based on the amount of increased effort that would result from delays in management action. While this is certainly an important consideration, we believe that in the context of ecological condition, the potential impact to the ecosystem far outweighs changes in the effort required to control the species. Exotic bromes are well known to dramatically change the character of an ecosystem, including such changes as major shifts in community composition and structure (Knapp 1996) as well as substantially altered fire regimes (Whisenant 1990). In many cases these changes have become, for all practical purposes, irreversible (Knapp 1996). Thus, from a standpoint of significance of impact to the monument's ecosystem, we would consider the exotic bromes to be a significant concern.

Additional species that ranked relatively high in their significance of impact were field bindweed (*Convolvulus arvensis*), horehound (*Marrubium vulgare*), and kochia (*Kochia scoparia*). While perhaps not as high of a concern as the exotic bromes, these species also may have a significant impact on the condition of Capulin Volcano NM's natural resources. Both field bindweed and horehound are perennial plants with taproots and highly difficult to control, while the annual kochia rapidly establishes in disturbed areas and spreads seed widely as its dead stems tumble across the grasslands.

<u>*Feasibility of Control*</u>

Based on the ranking by Willson et al. (2008) mullein ranked lowest in feasibility of control. (Table 4.9.4-3). At the time of this ranking, mullein was widespread in the monument, which affected the rank-scoring. Additionally, several traits of the species add to the difficulty of control: difficulty in detecting first-year rosettes, an extensive tap root able to re-sprout from the crown, prodigious seed production, a long-lived seed bank (seeds remain viable in soil for many years), and widespread populations outside the monument boundary. However, in 2009 and 2010, a Student Organization for Youth crew initiated a substantial control effort by severing taproots and seed head cutting of individual plants. Although the long-term extent to which their efforts were effective at the monument remains to be seen, they reported a substantial decrease in the number of plants they observed the following year after initiating control efforts (NPS 2010).

There are additional species, while not ranked as high as those above, that should be watched closely. Mullien (*Verbasum thapsus*) is widely distributed throughout the monument and has a high difficulty of control. Active eradication efforts are hopefully impacting this distribution, but years of follow-up detection/eradication will be necessary to gain control of this plant. The sweetclovers (*Melilotus alba* and *M. officianalis*), the salsifys (*Tragopogon dubius* and *T. pratensis*), and prickly lettuce (*Lactuca serriola*) are spreading in the park due to their efficient wind-born seed distribution and are concerns because of their competitive water use in such an arid environment. Therefore, condition relative to feasibility of control is of moderate concern.

Proportion of High Priority Blocks Infested

Not only did the exotic bromes have the highest ranking for their significance of impact, but they also were among the most widespread within high-risk areas. Collectively, at least one of the three exotic bromes was observed in 92% of the high-risk blocks surveyed in 2009 and 2010. Even individually, the exotic bromes had three of the highest four overall percentages of occurrence (Table 4.9.4-4).

Proportion of interior plots infested

The relative order of proportion of plots infested were similar to the high priority blocks with a few notable exceptions. For example, mullein was found in the highest proportion of any species, regardless of whether they were in high priority or interior sites. In contrast, smooth brome, which was detected on 54% of the high priority blocks was not detected on any of the interior plots; thus, suggesting that its present distribution is largely limited to along roads and trails (Table 4.9.4-5).

Distribution of High Priority Species

The known distribution of the six highest ranked exotic plant species are shown below (Figures 4.9.4-1, -2, -3, -4, -5). The most comprehensively mapped species include the bromes; the other species mapping efforts are limited. Distributions of the remaining species are presented in Appendix G. The exotic brome species are of high concern not only because of their potential ecological impact, but also because their distribution is widespread and they are continuing to spread. It is also worth noting that the distribution of exotic bromes is not known to be widespread on the surrounding landscape (Union County Extension Office, pers. comm.). The exact reason for this is unknown, but some grazing practices are known to help control these species. Thus, grazing practices on private lands surrounding Capulin Volcano NM are likely a contributing factor to their relatively low occurrence on those lands.

Other species, such as field bindweed and kochia, are currently substantially less widespread but have exhibited the potential to become a

Table 4.9.4-3. Ranking of exotic species for feasibility of control, from least to most feasible, at Capulin Volcano NM, based on Hiebert and Stubbendieck (2003) as reported by Willson et al. (2008)

Species	Feasibility of Control
Verbascum thapsus[1]	26
Convolvulus arvensis[1]	31
Bromus inermis[1]	36
Melilotus officinalis[1]	36
Marrubium vulgare[1]	37
Lactuca serriola[2]	38
Tragopogon dubius[1]	40
Euphorbia davidii[1]	40
Agropyron cristatum[1]	41
Descurainia sophia[1]	41
Taraxacum officinale[2]	43
Bromus tectorum[1]	44
Bromus japonicus[1]	44
Setaria pumila[1]	44
Setaria viridis[1]	44
Cynoglossum officinale[1]	50
Polygonum convolvulus[1]	50
Medicago lupulina[2]	50
Melilotus alba[2]	50
Sonchus asper[2]	50
Chenopodium album[1]	56
Echinochloa crus-galli[1]	60
Salsola tragus[1]	61
Tragopogon pratensis[1]	65
Cichorium intybus[1]	65
Kochia scoparia[1, 3]	70

Note: The six species ranked highest for significance of impact are shown by shaded cells for reference.

[1] Species ranking was conducted by, and reported in, Willson et al. (2008).

[2] Species ranking was conducted by Tomye Folts-Zettner of the Southern Plains Network.

[3] Based on its rapid establishment and spread, we would have ranked this species lower in feasibility of control than the rank given by Willson et al. (2008).

Table 4.9.4-4. Number and percentage of exotic plant species detected in high priority blocks sampled in 2009 and 2010 at Capulin Volcano NM

	Standardized Blocks		All Blocks	
Species	No. Blocks	% (N=106)	No. Blocks	% (N=234)
Bromus spp[1]	90	84.9%[2]	216	92.3%[2]
Verbascum thapsus	68	64.2%	158	67.5%
Bromus inermis	15	27.8% [3]	127	54.3%[3]
Bromus tectorum	29	53.7% [3]	126	53.8%[3]
Bromus japonicus	25	46.3% [3]	120	51.3%[3]
Tragopogon spp[4]	37	34.9%	104	44.4%
Salsola tragus	7	6.6%	95	40.6%
Marrubium vulgare	33	31.1%	77	32.9%
Descurainia sophia	32	30.2%	32	13.7%
Agropyron cristatum	10	9.4%	30	12.8%
Chenopodium album	21	19.8%	21	9.0%
Setaria viridis	16	15.1%	16	6.8%
Melilotus officinalis	11	10.4%	13	5.6%
Medicago lupulina	9	8.5%	9	3.8%
Convolvulus arvensis	2	1.9%	8	3.4%
Euphorbia davidii	4	3.8%	5	2.1%
Kochia scoparia	5	4.7%	5	2.1%
Cynoglossum officinale	3	2.8%	3	1.3%
Polygonum convolvulus	2	1.9%	2	0.9%
Taraxacum officinale	2	1.9%	2	0.9%
Lactuca serriola	1	0.9%	1	0.4%
Sonchus asper	1	0.9%	1	0.4%

Notes: Standardized blocks are the monitoring blocks that carefully measured and their size and layout; whereas all blocks includes the rapid assessment supplementary blocks that were based on distances paced (lower slopes) or areas between culverts (Volcano Road). Species are shown in rank order from the highest to lowest percentage for all blocks. The six species ranked highest for significance of impact are shown by shaded cells for reference.

[1]The 2009 sampling occurred after senescence making identification of individual brome species difficult. However, because of the differences in seasonal floristics, these were unlikely to have been native bromes that occur in the monument.

[2]Because exotic brome species are of particular high concern and were identified only to the genus in 2009, we estimated this percentage based on their occurrence in 2009 and the presence of any of the three exotic brome species within a given block in 2010.

[3]Identification to the species level occurred only in 2010; thus this percentage was based only on 2010 (N=54 for standardized blocks and N=182 for all blocks).

[4]Both *Tragopogon pratensis* and *Tragopogon dubius* are reported to occur at the monument, but at the time that surveys are conducted, it is very difficult to differentiate between these very similar species.

Table 4.9.4-5. Number and percentage of exotic plant species detected on interior plots sampled from 2005 to 2010 at Capulin Volcano NM

Species	No. Blocks	% (N=58)
Verbascum thapsus	43	74.1%
Tragopogon spp[1]	18	31.0%
Bromus japonicus	14	24.1%
Salsola tragus	14	24.1%
Lactuca serriola	13	22.4%
Marrubium vulgare	12	20.7%
Bromus tectorum	5	8.6%
Euphorbia davidii	5	8.6%
Melilotus officinalis	4	6.9%
Tragopogon dubius	4	6.9%
Polygonum convolvulus	3	5.2%
Convolvulus arvensis	2	3.4%
Descurainia sophia	2	3.4%
Kochia scoparia	2	3.4%
Chenopodium album	1	1.7%
Melilotus alba	1	1.7%
Setaria viridis	1	1.7%

Notes: The six species ranked highest for significance of impact are shown by shaded cells for reference.

[1] Both *Tragopogon pratensis* and *Tragopogon dubius* are reported to occur at the monument, but at the time that surveys are conducted, it is very difficult to differentiate between these very similar species.

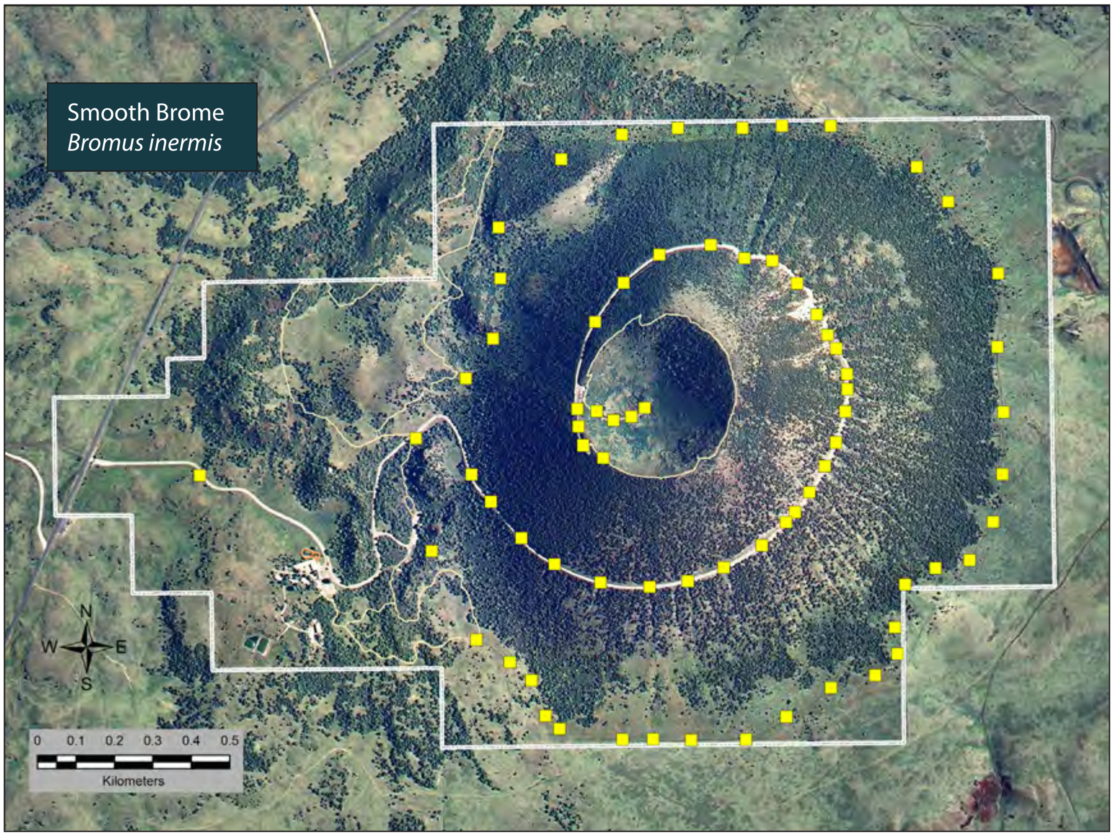

Figure 4.9.4-1. Known distribution of *Bromus inermis* based on surveys conducted by SOPN monitoring efforts, Natural Heritage New Mexico vegetation mapping plots, and monument staff and crew surveys.

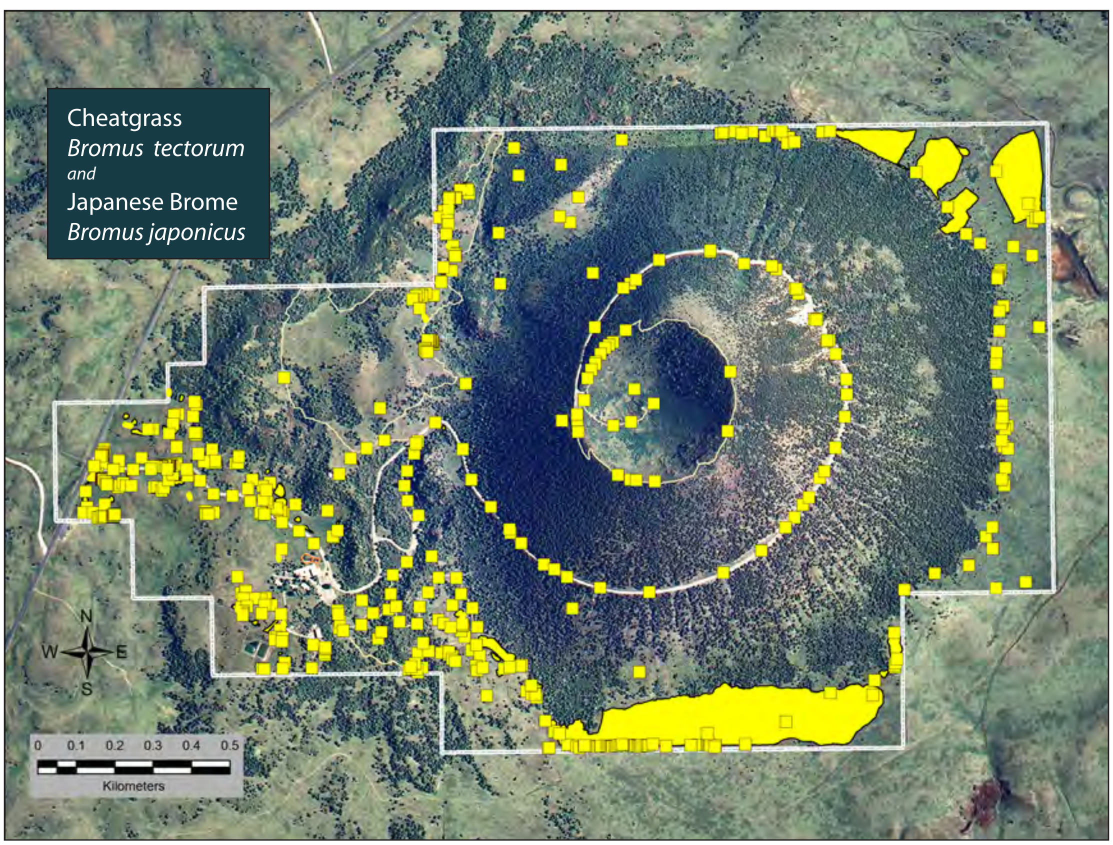

Figure 4.9.4-2. Known distribution of ecologically similar *Bromus tectorum* and/or *Bromus japonicus* based on surveys conducted by SOPN monitoring efforts, Natural Heritage New Mexico vegetation mapping plots, and monument staff and crew surveys.

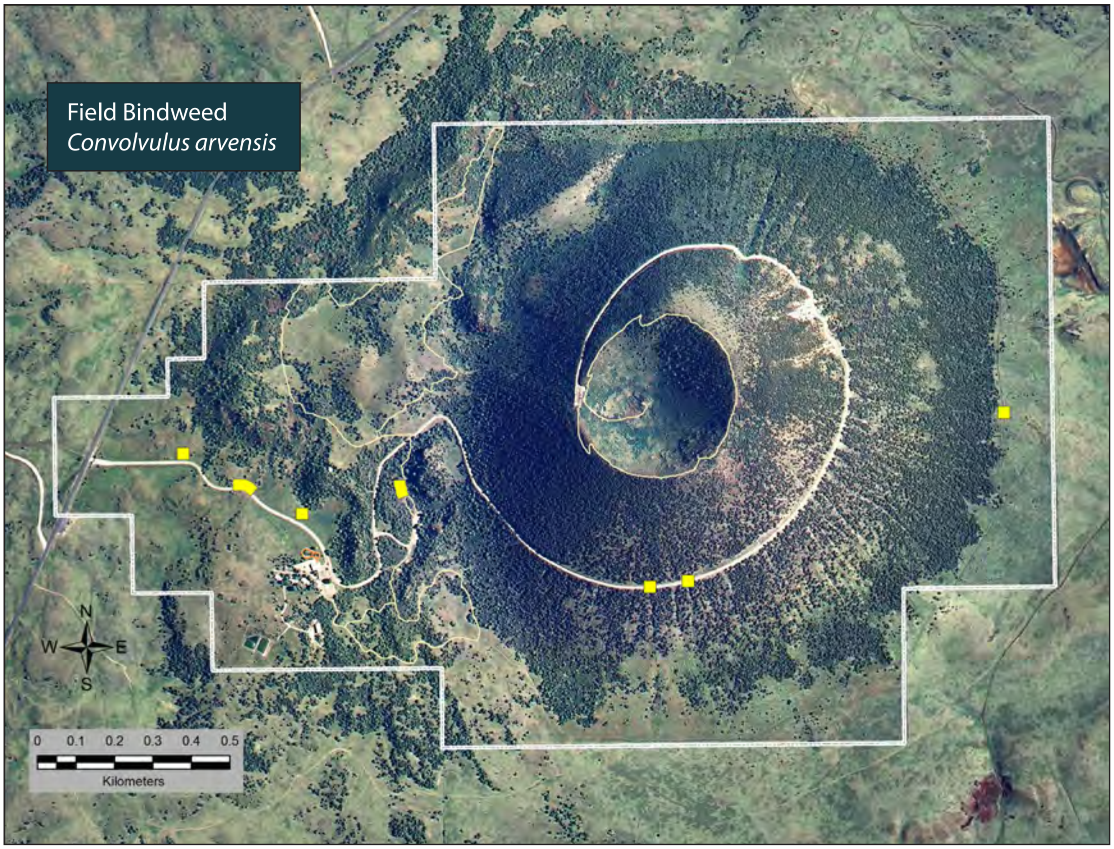

Figure 4.9.4-3. Known distribution of *Convolvulus arvensis* based on surveys conducted by SOPN monitoring efforts, Natural Heritage New Mexico vegetation mapping plots, and monument staff and crew surveys.

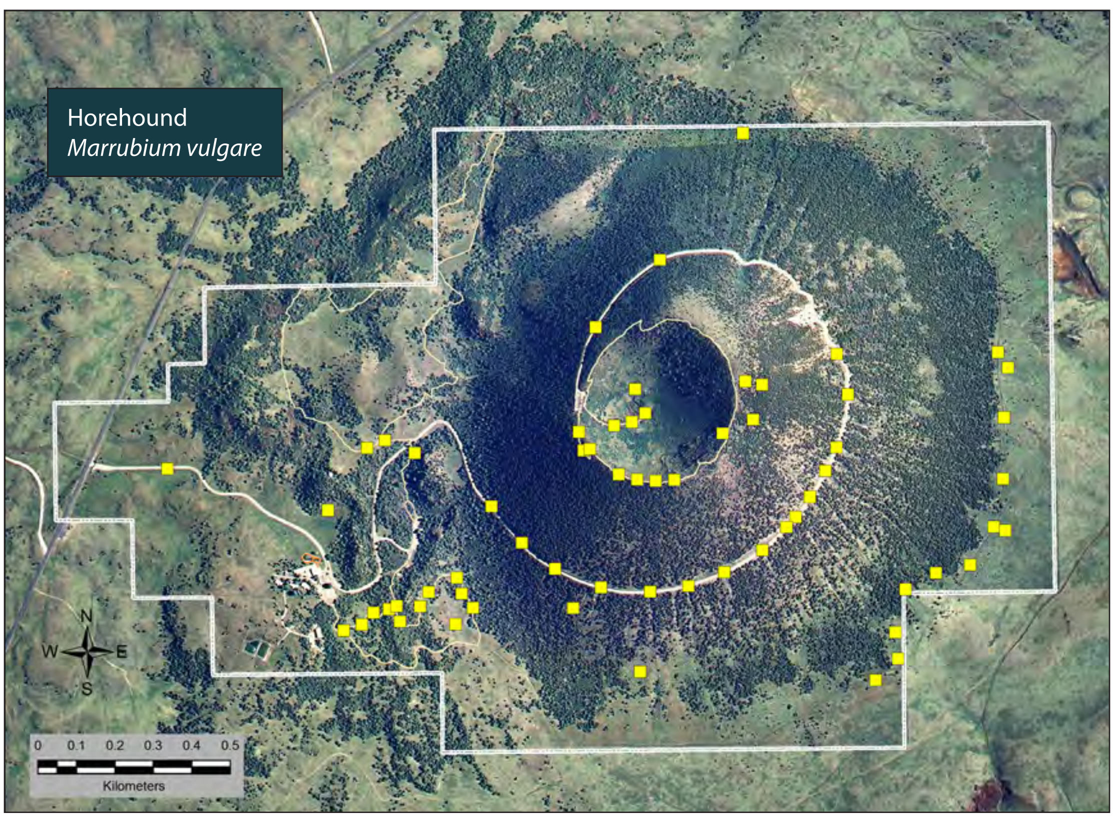

Figure 4.9.4-4. Known distribution of *Marrubium vulgare* based on surveys conducted by SOPN monitoring efforts, Natural Heritage New Mexico vegetation mapping plots, and monument staff and crew surveys.

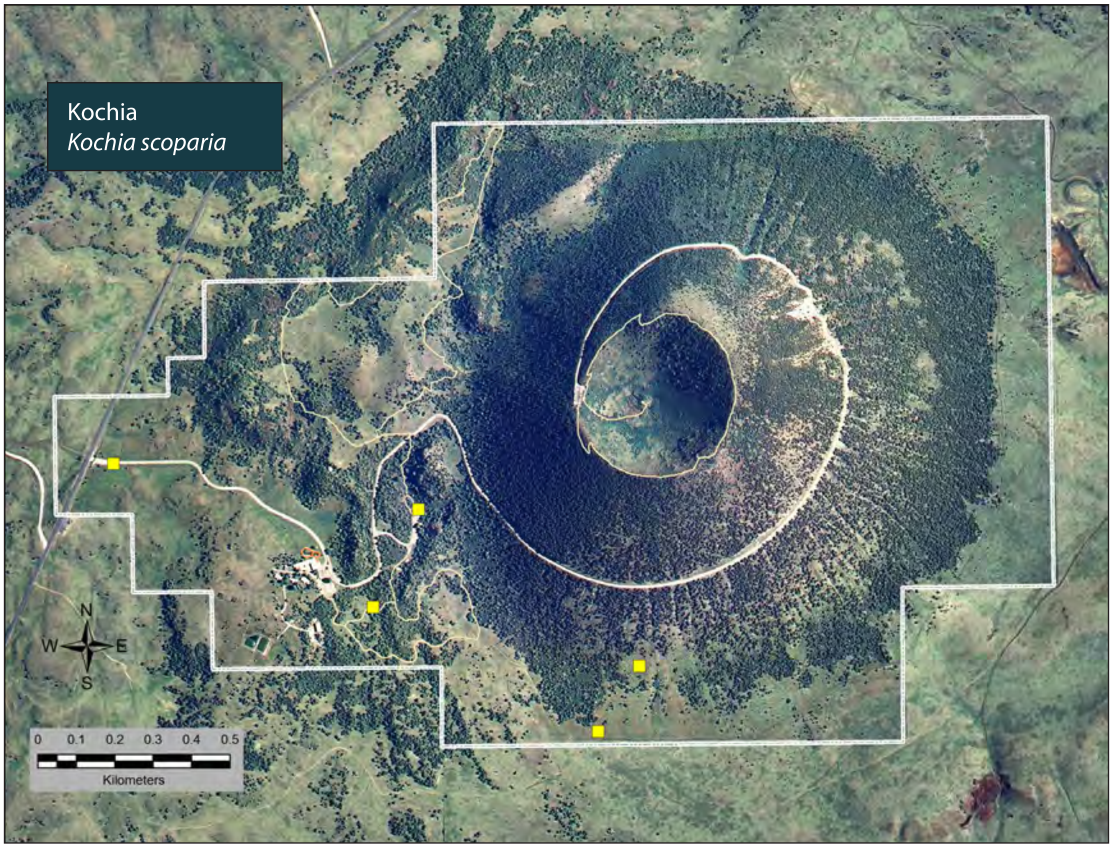

Figure 4.9.4-5. Known distribution of *Kochia scoparia* based on surveys conducted by SOPN monitoring efforts, Natural Heritage New Mexico vegetation mapping plots, and monument staff and crew surveys.

significant pest in other southern plains parks (T. Folts-Zettner, pers. comm.). Both bindweed and kochia are currently not widespread but are becoming well established, particularly along the entrance road and along the southern and eastern monument boundary.

Overall Condition

For assessing the condition of exotic plants, we used five indicators/measures that were not mutually exclusive but were intended to be different ways of capturing the essence of what we thought represented the condition of the monument's exotic plants. Several factors contribute to an exotic's threat to the integrity of a native ecosystem including its current status and potential for invasion based upon its life history. Also, the location where an exotic is found has implications pertaining to its establishment and potential control measures. Thus, our indicators/measures for this resource were intended to capture different aspects of these contributing factors, and a summary of how they contributed to the overall exotic plants condition is summarized in Table 4.9.4-6. Based on a qualitative evaluation of condition findings across the five indicators/measures, we consider the overall conditions for exotic plants at Capulin Volcano NM as a significant concern with a declining trend.

Level of Confidence/Key Uncertainties

One of the biggest uncertainties of this exotic plant assessment is the status of unsurveyed areas. This has several important implications. First, areas where a given species is not reported does not necessarily imply that it is not present; rather, it may imply that the area has not been adequately surveyed. For example, much of the area surrounding the cinder cone has been surveyed from at least one source, at least for the species of highest concern. However, much of the cinder cone itself remains unsurveyed or inadequately surveyed. The cinder cone consists of steep rocky terrain making it difficult to survey, and although the cinder cone may be at a lower risk of invasion from many common sources (e.g., vehicles, foot traffic, mowing equipment), it is also extremely difficult to treat should exotic plants become established.

Another area of uncertainty is the confounding effects of ongoing treatments. For example, areas that were treated within a year or two of surveys may show a lower percentage of occurrence, even if that is a temporary state from having been recently treated. This is especially true for areas that have easy access and are highly visible

Table 4.9.4-6. Summary of the exotic plants indicators/measures and their contributions to the overall exotic plants natural resource condition assessment.

Indicator/Measure	Description of How the Indicator(s) Contributes to the Overall Resource Condition	General Contribution of this Indicator or Measure to the Overall Resource Condition.
Significance of impact	Not all exotics are the same and as such need to be assessed individually from the perspective of which ones pose the greatest risk to a given ecosystem. Significance of impact is divided into two categories, with one assessing the current status of a given exotic relative to abundance and current level of distribution and the other category assessing the potential of impact given the exotic plant's life history characteristics.	Ranking the highest in significance of impact were the three exotic bromes found within the monument. The exotic bromes are well known for their ability to dramatically change an ecosystem sometimes irreversibly.
Feasibility of control	Given the fact that exotic plants vary in their life histories, the feasibility of controlling a particular exotic plant depends upon factors such as its current abundance, ease of control, proximity to other known populations, side effects of control measures, and response(s) to biological control.	A variety of species ranked highly infeasible to control including common mullein, field bindweed, exotic bromes, yellow sweetclover and horehound. This indicator may not reflect the effort needed for control. For example, field bindweed is for the most part isolated to growing along the shoulders of the roads throughout the monument.
Proportion of high priority blocks infested	High priority blocks were established by SOPN as the "well traveled vectors" where the potential for plant introduction and/or dispersal is high, such as along roads and trails. These blocks are divided into four density classes as well as four distance classes to determine the extent of exotic plant infestation.	The exotic bromes were by far the most widespread throughout the high priority blocks, representing a collective 92% detection rate.
Proportion of interior blocks infested	Interior monitoring blocks are scattered throughout the monument as part of additional scientific monitoring efforts. Exotic plants are also recorded when present in these blocks. The interior blocks represent locations other than the high priority blocks listed above and may be a better indicator of plant establishment versus introduction.	The proportion of interior blocks infested was somewhat similar to the high priority blocks. Although, mullein was detected in highest proportion of any species and smooth brome was detected in 54% of the blocks, indicating that it may be more confined to the road and trail corridors.
Distribution of high priority species	Data from all available sources, including the interior and high priority blocks were used to map the distribution of the high priority species from the perspective of their impact, feasibility of control, and current locations.	Known distributions of the highest ranked species were mapped. Overall, the bromes appear to be the most widely distributed throughout the monument resulting in a moderate concern and declining trend as the bromes continue to spread.

to the public (e.g., the entrance road).

The species ranking approach developed by Hiebert and Stubbendieck (1993) does an excellent job of defining the criteria by which individual species are ranked in terms of the significance of impact and feasibility of control. However, as for any ranking system, there is also a certain degree of subjectivity that goes into any such system. Despite this potential for subjectivity, we believe that the overall ranking did reflect at least the top species of concern. There were however, a few species that we would probably have ranked differently than Willson et al. 2008; most notably, we believe that kochia was ranked too high in feasibility of control. However, even with this ranking for control, kochia ranked high in overall concern, which is consistent with our assessment.

4.9.5 Sources of Expertise

Surveys for exotic plants at Capulin Volcano NM were conducted by teams well trained in species identification and methods. These included (1) the exotic plants monitoring team of the SOPN (2) the vegetation monitoring teams of the SOPN, (3) a vegetation mapping team of Natural Heritage New Mexico, the Chihuahuan Desert/Southern Shortgrass Prairie Exotic Plants Management Team, and monument resource management staff and crews. All of these teams work extensively with exotic plants and our confidence is very high regarding the reliability of their surveys.

Tomye Folts-Zettner is a biologist/botanist with the SOPN and is also the project lead for monitoring exotic plants in parks of the SOPN.

Patrick Wharton is the acting liason and Exotic Plant Management Team Leader for the Chihuahuan Desert/Southern Shortgrass Prairie Exotic Plant Management Team.

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4.10 Capulin Goldenrod (*Solidago capulinensis*)

Indicators/Measures

- Presence/absence of Capulin Goldenrod

Condition - Trend

Unknown - Unknown

4.10.1 Background and Importance

Capulin goldenrod (*Solidago capulinensis*) was first described and collected from within Capulin Volcano NM in 1936 by Cockerell and Andrews (1936) but has not been included in any subsequent account of the New Mexico or United States flora (Martin and Hutchins 1981; Keller 1999; Allred 2008; and Semple and Cook 2006 as cited in Nesom and Lowrey 2011). It was rediscovered at the Pueblo Colorado Nature Center, Pueblo, Colorado, which prompted a new survey within the monument in September 2010 by Dr. Tim Lowrey of the Museum of Southwestern Biology at University of New Mexico. Dr. Lowrey found Capulin goldenrod growing in the basalt outcrops at the base of the cinder cone (Figure 4.10.1-1) and re-identified it as a rare endemic plant (Tim Lowrey, University of New Mexico, pers. comm.). It is the only known rare vascular plant species found within the monument.

Capulin goldenrod is a member of the *Solidago* genus, commonly known as goldenrods, in the Asteraceae (aster) family. It is a densely leafy subshrub (short woody plant; perennial) that can reach up to 4 feet (approx. 1.2 m) tall with stems formed at the base covered in dense leaves. The plant produces large, wide flowering heads of yellow flowers (Figure 4.10.1-2). Numerous goldenrod species are found throughout the United States but Capulin goldenrod is an apparently distinct species. The plant is found about 80 miles west of downy ragged golden rod (*S. petiolaris*) populations and near the northern range of the Wright's goldenrod (*S. wrightii*) populations (Figure 4.10.1-3) (Nesom and Lowrey 2011).

Capulin Volcano NM is located within a vegetative transitional zone between the Rocky Mountains and shortgrass prairie, supporting a relatively high diversity of habitats for wildlife and plants not found elsewhere in the surrounding

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Figure 4.10.1-1. Capulin goldenrod (*Solidago capulinensis)* in its native habitat.

Figure 4.10.1-2. The flowering head of Capulin goldenrod (*Solidago capulinensis*).

grassland. Accordingly, the vegetation ranges from ponderosa pine and piñon-juniper woodlands to the montane shrubland and grasslands of the volcano, surrounding a mixture of grassland communities at the base that extend into the prairie (Muldavin et al. 2011).

Floristic surveys within the monument are limited and only include Parmenter et al. (2000) and Johnson et al. (2003). Parmenter at al. (2000) conducted a rare-species inventory and Johnson et al. (2003) completed a comprehensive floristic survey. Results from both surveys reported no rare plant species found within the monument.

Between 2005 and 2009, Natural Heritage New Mexico completed a vegetation classification and mapping project for the monument (Muldavin et al. 2011). Plant species were recorded from within vegetation plots but did not include Capulin goldenrod. The intention of this study was to detect dominant plant species versus a detailed floristic survey, detecting rare species.

4.10.2 Data and Methods

This limited assessment is based on only two informal surveys that have been conducted to specifically document the presence of Capulin goldenrod in the monument: Cockerell and Andrews (1936) and Nesom and Lowrey (2011).

Indicators/Measures

- Presence/absence of Capulin Goldenrod

The only indicator used for this assessment is whether Capulin goldenrod is present or absent

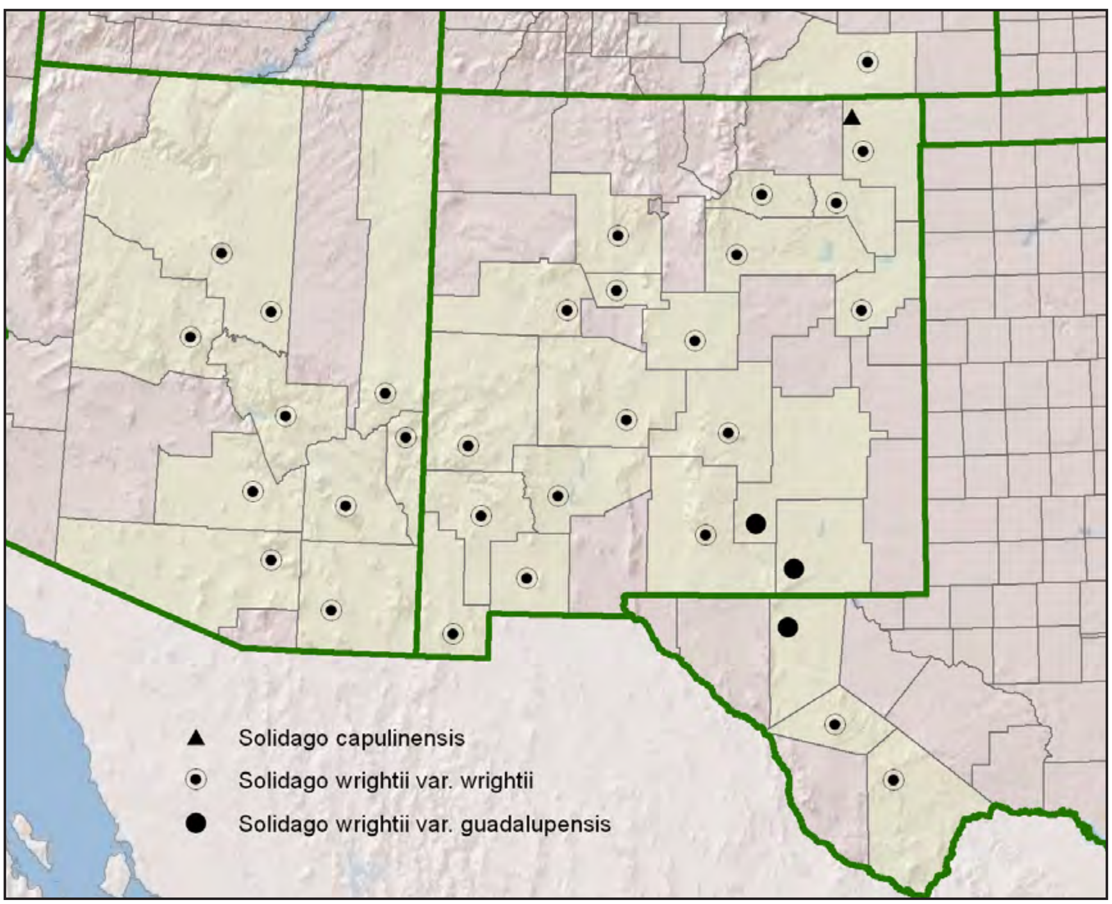

Figure 4.10.1-3. Distribution of Capulin goldenrod (Solidago capulinensis) and Wright's goldenrod (S. wrightii). The distribution of S. wrightii continues southward into Mexico (after Nesome and Lowrey 2011).

Table 4.10.4-1. Summary of the Capulin goldenrod indicators/measures and their contributions to the overall Capulin goldenrod natural resource condition assessment.

Indicator/Measure	Description of How the Indicator(s) Contributes to the Overall Resource Condition	General Contribution of this Indicator or Measure to the Overall Resource Condition.
Presence/absence of Capulin goldenrod	Since the presence of Capulin goldenrod was just recently rediscovered during the fall of 2010, we know that its presence represents a beginning point for future condition assessment. However, at this time, we don't know whether its presence represents one or several plants and do not know anything regarding its distribution. But, it is one of the few rare species found within the monument, therefore, was included as a focal resource for this assessment.	Even though we know that Capulin goldenrod is present at the monument, no additional information about its presence has been gathered. Insufficient information exists at this time to warrant a condition rating other than unknown.

within the monument. Nesom and Lowrey (2011) reconfirmed its presence, stating that it grows in abundance, but a comprehensive survey needs to be conducted to determine distribution and abundance of the population. Pending additional information, abundance and distribution of this species would also be reasonable indicators.

4.10.3 Reference Conditions

A logical reference condition for this species is whether the population is sustaining itself but without ongoing monitoring information this is currently unknown.

4.10.4 Condition and Trend

For assessing the condition of Capulin goldenrod, one indicator/measure was used, which is presented in Table 4.10.4-1. Since the plant was just recently rediscovered at the monument, and is globally rare, very little information about Capulin goldenrod has been discovered, but it was included in the assessment because it represents one of the few rare resources found within the monument's boundary.

Capulin goldenrod was found growing among the basalt boulders below the main cone in the picnic area and next to the visitor center (T. Lowrey, University of New Mexico, pers. comm.), however, condition and trend are unknown at this time. Dr. Lowrey suspects that it also grows among the basalt outcrops of surrounding volcanoes.

4.10.5 Sources of Expertise

Dr. Timothy Lowrey of the Museum of Southwestern Biology at University of New Mexico conducted a survey for Capulin goldenrod at the monument. He is Professor of Biology, Curator for University of New Mexico Herbarium, and Associate Chair for the Department of Biology and Museum of Southwest Biology.

Guy Nesom has been an active researcher, writer, editor, and teacher in biological science since 1980. His research and publishing have encompassed a broad range of topics, including defining and identifying species, developing hypotheses regarding their evolutionary relationships, developing classification systems, and assigning stable nomenclatures and is considered an expert on goldenrods of western North America.

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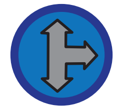
4.11 Landbirds

Indicators/Measures

- Species Occurrence
  - Temporal Context
  - Spatial Context
  - Conservation Context

Condition - Trend



Good/Insufficient Data

4.11.1 Background and Importance

The National Park Service's mission is to manage park resources "unimpaired for future generations." Protecting and managing some of our nation's most significant natural resources requires basic knowledge of the condition of ecosystems and species that occur in national parks. Landbirds are a conspicuous component of many ecosystems (Figure 4.11.1-1) and have high body temperatures, rapid metabolisms, and occupy high trophic levels. As such, changes in landbird populations may be indicators of changes in the biotic or abiotic components of the environment upon which they depend (Canterbury et al. 2000, Bryce et al. 2002). Relative to other vertebrates, landbirds are also highly detectable and can be efficiently surveyed with the use of numerous standardized methods (Bibby et al. 2000, Buckland et al. 2001).

Changes in landbird population and community parameters can be an important element of a comprehensive, long-term monitoring program, such as that being implemented for the SOPN parks. Birds select habitat based on the presence of behavioral cues triggered by the environment (Hutto 1985a; Alcock 2005). In some environments, however, especially those that vary unpredictably, habitat may not be saturated and changes in resources may not always be tracked by changes in animal populations (Wiens 1985). In these situations, relating changes in bird populations to environmental features can be complex, especially when confounded by time lags that are characteristic of site-tenacious bird species. Additional complications occur if birds respond more sensitively to environmental change than we can detect and when cyclical environmental changes result in erratic changes in population size that are ultimately inconsequential. However, the

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Figure 4.11.1-1
Green-tailed Towhee

utility of monitoring landbirds is strengthened by concurrent monitoring of a broad suite of environmental parameters (Dale and Beyeler 2001) that may assist with elucidating changes in the bird community to other environmental factors. Such a broad-based approach is now being undertaken by the SOPN program (NPS 2008) and other monitoring approaches (e.g., Ringold et al. 1996; Stevens and Gold 2003; Barrows et al. 2005).

Perhaps the most compelling reason to monitor landbird communities in SOPN parks is that birds themselves are inherently valuable. The high aesthetic and spiritual values that humans place on native wildlife is acknowledged in the agency's Organic Act: "to conserve . . . the wildlife therein . . . unimpaired for the enjoyment of future generations." Bird watching, in particular, is a popular, longstanding recreational pastime in the United States and forms the basis of a large and sustainable industry (Sekercioglu 2002).

4.11.2 Data and Methods

In 2009, Rocky Mountain Bird Observatory (RMBO) began systematic surveys of birds at Capulin Volcano NM as part of the SOPN program. Although these data will enable quantitative evaluation of trends in birds in the future, it is premature to use them in such a context at the present with only three years of data. Rather, for this assessment, we focus on species occurrence, using the RMBO surveys as our primary source for the occurrence of bird species in recent years, and compare recent occurrence to other data sources (described below) in a temporal context (changes over time), a spatial context (regional comparisons), and a conservation context (the status of species of conservation concern). We describe each of these below, followed by descriptions of the data sources used to support those comparisons.

One obvious indicator for birds would be some quantitative measure(s) of abundance. In particular measures of abundance would be considered relative to references in space and time, such as changes over time at the monument or abundance relative to habitats in the surrounding region. However, for the purposes of this assessment, our treatment was more preliminary and qualitative, setting the stage for more detailed analyses as our monitoring data accumulate. For this assessment we focused on species occurrence.

Indicators/Measures

- Species Occurrence

Species occurrence (presence/absence) focuses on what species are, or are not, observed at Capulin Volcano NM. The most recent data we have for occurrence of birds at the monument are surveys conducted by RMBO. We then evaluated species occurrence in three contexts: (1) a temporal context (e.g., changes over time, (2) a spatial context (e.g., comparison with surrounding region), and (3) a conservation context (i.e., the occurrence and status of species of conservation concern.

Temporal Context – Changes over Time

To evaluate birds in a temporal context, we compared the occurrence of species detected during RMBO Surveys conducted at Capulin Volcano NM (described below) to previous species checklists (described below) of birds at the monument. This is not intended as a rigorous or quantitative comparison given the limitations of such information; rather, it is intended as a crude qualitative indicator of major changes over time. However, to do this in a more meaningful way, we needed the sources to be comparable. For example, the recent RMBO surveys were conducted during the breeding season; thus it is not reasonable to compare these results with species that occur at the monument during other seasons. Consequently, we limited our comparisons to those species in which Capulin Volcano NM is within their primary breeding range. We made this determination based primarily on the Birds of North America (BNA) species accounts (Cornell Lab of Ornithology 2011). Unlike field guides that are often written by persons with general knowledge of birds, the BNA accounts for each species are written by persons that have extensive experience and knowledge working with that particular species. Consequently, these accounts constitute a comprehensive summary of our current knowledge for a given species (including range) written by experts for that species.

Checklists also typically have numerous species resulting from incidental sightings. These can result from individuals that are outside of their range, brief stopovers during migration, individuals exploring during dispersal, etc. The key point being that checklists may contain many species for which there is no reasonable expectation for them to occur at the site for which the checklist applies. An example from the monument is Blue-winged Teal. Since there is generally no surface water at the monument, the occurrence of this species on the monument checklists could have resulted from an individual that stopped at an ephemeral pool after a rainstorm or even a bird that was seen flying over that never really used the monument.

For the purposes of this assessment, we believed that there is little value in assessing whether species that would not typically occur at the monument have been observed in recent surveys. We further refined our comparisons to species for which reasonably suitable breeding habitat (since comparisons are based on the breeding season) exists at the monument. We assigned each species to one of three breeding habitat classes (Table 4.11.2-1) based on the BNA accounts in combination with local knowledge.

Spatial Context – Comparisons with Surrounding Region

We also evaluated species occurrence in a spatial context. This is intended only as a qualitative indicator rather than a rigorous quantitate estimate (which will be possible in the future). For this assessment, we compared the recent RMBO surveys conducted within the monument to other regional surveys (described below), also conducted by RMBO in similar habitats within the surrounding area as a general spatial reference for species occurrence within the region.

Conservation Context – The Occurrence and Status of Species of Conservation Concern

Our intent for this context was to determine which species that occur at Capulin Volcano NM are considered as species of concern at either a national or local scale, to assess the current status (occurrence) of those species at the monument, and to evaluate the potential for the monument to play a role in the conservation of those species. For the latter, we assigned each species that was listed on one or more list of species of conservation concern to a class representing the potential for Capulin Volcano NM to play a role in the conservation of that species, at least during the breeding season (Table 4.11.2-2). This was based primarily on whether or not the monument was within the primary breeding range for that species and the availability of breeding habitat.

To develop a candidate list for species of conservation concern, we used the lists developed by several organizations. There have been a myriad of such organizations that focus on the conservation of bird species. Such organizations may differ however, in the criteria they use to identify and/or prioritize species of concern based on the mission and goals of their organization. They also range in geographic scale from global organizations such as the International Union for Conservation of Nature (IUCN), who maintains a "Red List of Threatened Species" to local organizations or chapters of larger organizations. This has, and continues to be, a source of confusion and perhaps frustration, for managers that need to make sense and apply the applicable information. In recognition of this, the U.S. North American Bird Conservation Initiative (NABCI) was started in 1999 and represents a coalition of government agencies, private organizations, and bird initiatives in the United

Table 4.11.2-1. Breeding habitat classes assigned to each species that has been reported to occur at Capulin Volcano NM and is within or near (within 100 mi) of their reported breeding range.

Breeding Habitat Class	Class Description
Exists	This class was assigned when the habitat at the monument is characteristic of habitats where a given species might be expected to breed.
Possibly Exists	This class was assigned when it was unlikely that the habitat at the monument would support consistent or widespread breeding, but does not preclude some breeding in limited numbers.
Limited to None	This class was assigned when it is unlikely that the habitat at Capulin Volcano NM would support breeding by that species. This does not imply that the species would not occur, but not breed, at the monument in limited numbers or during other seasons.

Table 4.11.2-2. Classes assigned to each species listed on one or more watch list of species of concern for the potential of Capulin Volcano NM to play a role in the conservation of that species.

Potential for Conservation	Conservation Class Description
High	They are species for which the monument is within the primary breeding range or in proximity to the edge of that range. They are also species for which we considered the monument to have good breeding habitat. We assigned species to this class if we believed, based on the evidence, that the potential for breeding was good, regardless of whether they currently occur at the monument in substantial numbers.
Moderate	These are the species for which the monument is within the primary breeding range or in proximity to the edge of that range, and for which there is some habitat at the monument that might support occurrence or even some breeding in limited numbers.
Low to None	These are the species that are either outside of their regular breeding range and/or for which the habitat at the monument is unlikely to support breeding. This does not preclude limited occurrences of the species, but that potential for the monument to play any significant role in the conservation of that species is very limited.

States working to ensure the conservation of North America's native bird populations. Although there remain a number of sources, at multiple geographic and administrative scales for information on species of concern, several of which are presented below, the NABCI has made great progress in developing a common biological framework for conservation planning and design.

One of the developments from the NABCI was the delineation of Bird Conservation Regions (BCRs) (U.S. North American Bird Initiative 2011). Bird Conservation Regions (BCRs) are ecologically distinct regions in North America with similar bird communities, habitats, and resource management issues (Figure 4.11.2-1).

Figure 4.11.2-1. Bird conservation regions in North America.

The purpose of delineating these BCRs was to:

- facilitate communication among the bird conservation initiatives;
- systematically and scientifically apportion the US into conservation units;
- facilitate a regional approach to bird conservation;
- promote new, expanded, or restructured partnerships; and
- identify overlapping or conflicting conservation priorities.

Capulin Volcano NM lies within the Short Grass Prairie Unit (BCR-18), but is also immediately adjacent to the Southern Rockies/Colorado Plateau Unit (BCR-16)(Figure 4.11.2-2). Thus, for this assessment, we present information for both BCRs.

Conservation Organizations Listing Species of Conservation Concern

Below we present a snapshot of some of the organizations that list species of conservation concern and briefly discuss the different purposes or goals of each organization.

U.S. Fish & Wildlife Service

The Endangered Species Act, passed in 1973, is intended to protect and recover imperiled species and the ecosystems upon which they depend. It is administered by the U.S. Fish and Wildlife Service (USFWS) and the Commerce Department's National Marine Fisheries Service

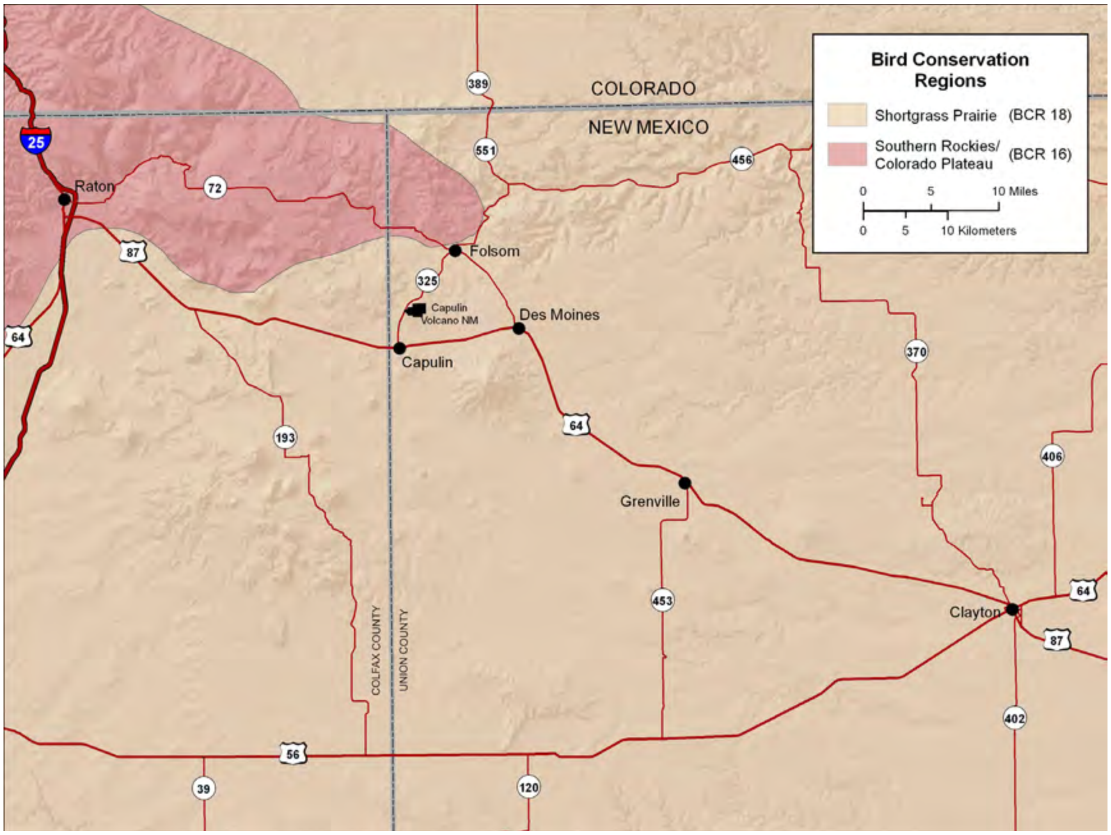

Figure 4.11.2-2. Bird conservation regions in the vicinity of Capulin Volcano NM

(NMFS). USFWS has primary responsibility for terrestrial and freshwater organisms, while the responsibilities of NMFS are mainly marine wildlife such as whales and anadromous fish. In addition to listed species, the Fish and Wildlife Conservation Act of 1988 further mandates that the USFWS) "identify species, subspecies, and populations of all migratory nongame birds (i.e., Birds of Conservation Concern) that, without additional conservation actions, are likely to become candidates for listing under the Endangered Species Act.

State of New Mexico

Under the authority of the Wildlife Conservation Act (17-2-37 through 17-2-46 NMSA 1978), the State of New Mexico, through the New Mexico Department of Game and Fish (NMDGF) also maintains listings of species considered as threatened or endangered (NMDGF 2008). In addition to listing of threatened and endangered species, the State Of New Mexico developed a Comprehensive Wildlife Conservation Strategy (NMDGF 2006) that identifies species and conservation needs for what they consider the Species of Greatest Conservation Need (SGCN). The intended outcome of this strategy is that the key habitats for these species persist in the condition, connectivity, and quantity necessary to sustain viable and resilient populations of resident SGCN and host a variety of land uses with reduced resource use conflicts.

National Audubon Society/American Bird Conservancy

The National Audubon Society and American Bird Conservancy each formerly published its own list of bird species of concern, but have recently combined efforts into a single "Watch List". This collaborative effort was based on a concern by these organizations that there were too many lists with similar purposes, and consequently combined their efforts (Butcher et al. 2007). Their 2007 WatchList is based on, but not identical to, the Partners in Flight (PIF) approach to species assessment (see below).

The 2007 WatchList has two primary levels of concern: a "Red Watchlist" and a "Yellow WatchList", although the latter is subdivided into two categories. The Red WatchList, identifies what these organizations consider as species of highest national concern. This list overlaps considerably with the Union for Conservation of Nature's "Red List" (not presented here); thus, can essentially be considered as a list of globally threatened birds that occur in the United States (Butcher et al. 2007). Species on the Yellow Watch is made up of species that are somewhat less critical but serves as an early warning list of birds that have the potential of being elevated to the Red WatchList. Species on this list can be there either because their populations are considered as declining, or because they are considered rare.

Partners in Flight

Partners in Flight is a cooperative effort among federal, state and local government agencies, as well as private organizations. One of their primary goals, relative to listing species of conservation concern, is to develop a scientifically based process for identifying and finding solutions to risks and threats to landbird populations. Their approach to identifying and assessing species of conservation concern is based on biological criteria to evaluate different components of vulnerability (Panjabi et al. 2005). Each species is evaluated for six components of vulnerability: population size, breeding distribution, non-breeding distribution, threats to breeding, threats to non-breeding, and population trend. The specific process is presented in detail in species assessment handbook (Panjabi et al. 2005). Their assessments are conducted at multiple scales. At the broadest scale, the North American Landbird Conservation Plan (Rich et al. 2004) identifies what PIF considers "Continental Watch List Species" and "Continental Stewardship Species". Continental Watch List Species are those that are most vulnerable at the continental scale, due to a combination of small and declining populations, limited distributions, and high threats throughout their ranges (Panjabi et al. 2005). Continental Stewardship Species are defined as those species that have a disproportionately high percentage of their world population within a single Avifaunal Biome during either the breeding season or the non-migratory portion of the non-breeding season.

More recently, PIF has adopted Bird Conservation Regions (BCRs), the common planning unit under the North American Bird Conservation Initiative, as the geographic scale for updated regional bird conservation assessments. These assessments are available via an online database (http://www.rmbo.org/pif/pifdb.html) maintained by RMBO. At the scale of the individual BCRs, these same principles of concern (sensu Continental Watch List Species) or stewardship (sensu Continental Stewardship Species) are applied at the BCR scale. The intention of this approach is to emphasize conservation of species where it is most relevant as well as the recognition that some species may be experiencing dramatic declines locally, even if that species is not of high concern nationally, etc. There are two categories (concern and stewardship) each for Continental and Regional. The details of the criteria for inclusion in each can be found in Panjabi et al. (2005) and a general summary is as follows:

Criteria for Species of Continental Importance

A. Continental Concern (CC)

- Species is listed on the Continental Watch List (Rich et al. 2004)
- Species occurs in significant numbers in the BCR
- Future conditions are not enhanced by human activities

B. Continental Stewardship (CS)

- Species is listed as Continental Stewardship Species (Rich et al. 2004)
- Relatively high density (compared to highest density regions) and/or a high proportion of the species occurs in the BCR
- Future conditions are not enhanced by human activities

Criteria for Species of Regional Importance

Regional scores are calculated for each species according to which season(s) they are present in the BCR. The formulae include a mix of global and regional scores pertinent to each season (see Panjabi et al. 2005 for details). The criteria for each category are:

A. Regional Concern (RC)

- Regional Combined Score > 13 (see Panjabi et al. 2005 for details)
- High regional threats or moderate regional threat combined with significant population decline
- Occurs regularly in significant numbers in the BCR

B. Regional Stewardship (RS)

- Regional Combined Score > 13 (see Panjabi et al. 2005 for details)
- High importance of the BCR to the species
- Future conditions are not enhanced by human activities

New Mexico Chapter of Partners in Flight

In 1995, a New Mexico state chapter of

Partners in Flight was created and subsequently develop a conservation plan for the State of New Mexico. That initial plan was revised (New Mexico Partners in Flight 2007) and was intended to carry out a new statewide species assessment using updated information from the Breeding Bird Survey and from the new PIF North American Landbird Conservation Plan (Rich et al. 2004). This new assessment was also intended to more closely parallel the system of species assessment adopted by PIF nationally for its continental plan.

Paralleling the ideas of distinguishing concerns for conservation and stewardship, the New Mexico Plan used updated lists of priority species for conservation action or monitoring in New Mexico, distinguishing between species of national and state biodiversity concern. The New Mexico plan identifies lists of species of overall conservation concern under Species Conservation (SC) and species of concern in maintaining state biodiversity under Biodiversity Conservation (BC). Within each of these two lists, species are categorized into two levels of vulnerability. Level 1 includes species of high conservation concern in either the SC or BC. For the most part, these are species facing moderate to severe threats and showing unknown or declining local population trends. They are considered to be species in need of immediate conservation action. Level 2 species are considered to be of moderate or potential conservation concern in either the SC or BC category. They show some signs of vulnerability, and may warrant careful monitoring.

<u>*Primary Data Sources*</u>

Data used as part of this assessment include surveys conducted by the Rocky Mountain Bird Observatory (RMBO) at Capulin Volcano NM, surveys conducted by RMBO in the surrounding region, surveys conducted by Natural Heritage New Mexico (NHNM) at Capulin Volcano NM, species checklists complied for the monument, and Breeding Bird Surveys (BBS). Each of these is described below.

RMBO Surveys at Capulin Volcano NM

RMBO used point-transect surveys (Buckland et al. 2001) during the breeding season to estimate and monitor landbird population parameters (Lock et al. 2011). A total of 45 points in piñon-juniper (n=17) and grassland (n=28) habitats were sampled 2-3 times each in 2009-2011 (Figure 4.11.2-3)(Lock et al. 2011). All birds detected at a given point were recorded. After counts were completed, observers used

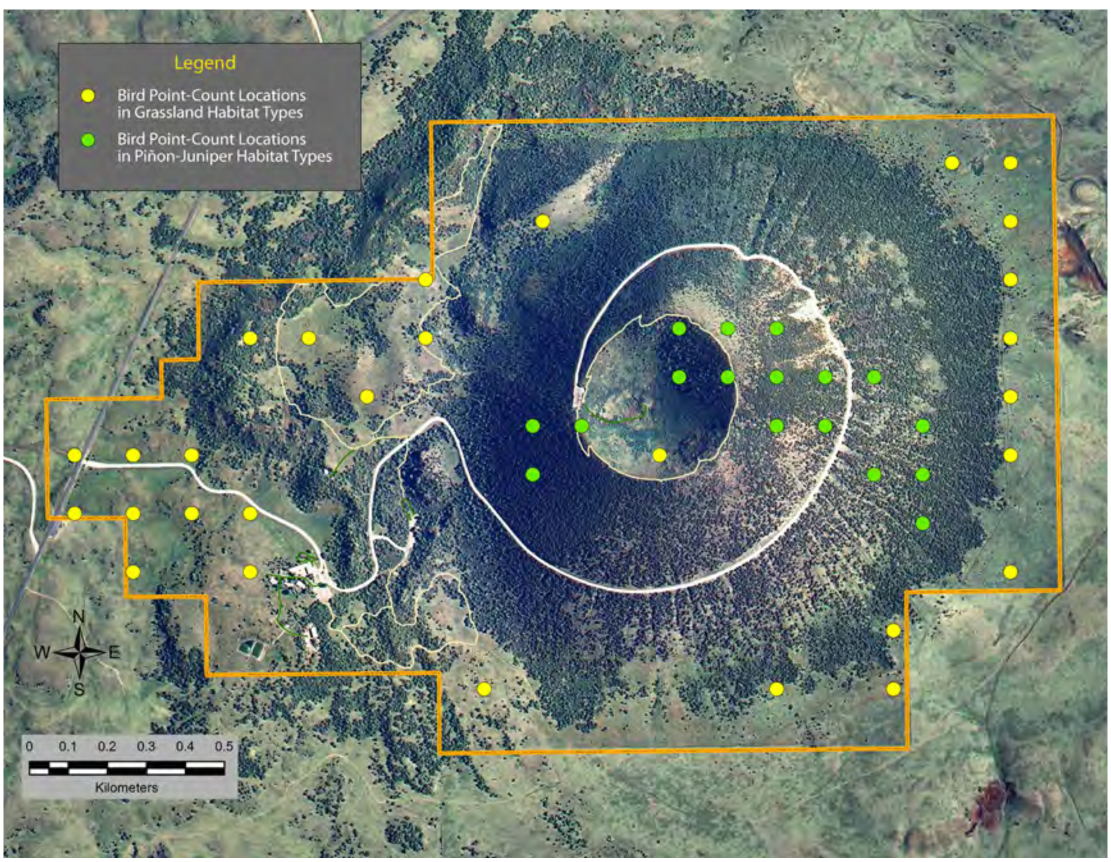

Figure 4.11.2-3. Survey points sampled by the Rocky Mountain Bird Observatory at Capulin Volcano NM in 2009-2011.

a handheld GPS (Global Positioning System) unit to locate successive survey points. While walking between points, observers noted only the species that were not recorded during the count period, which represented species that had never been previously reported for the monument. Surveys were conducted three times for each transect or grid to facilitate occupancy estimates, which rely on an encounter-history matrix derived from repeated visits, rather than a detection function to account for detectability. Observers spent six minutes at each point along the transect or grid and used a rangefinder to estimate the linear distance to each bird or group detected. This protocol of spending six minutes per site is consistent with other efforts being conducted by Rocky Mountain Bird Observatory (RMBO).

Regional RMBO Surveys

Within the surrounding region, the RMBO conducts additional surveys using either point based surveys (Hanni et al. 2009) or section based surveys (Sparks and Hanni 2006). The details for point-based surveys are presented in (Hanni et al. 2009), but surveys consist of 15 points spaced 250 m apart, connected by a transect line. The point-transect sampling effort is stratified by habitat. The details for section-based surveys are presented in (Sparks and Hanni 2006). These surveys are a road-based point count technique with a one square mile "section" as the basic land management unit of the prairie. Capulin Volcano NM is rather unique in that it is situated within the Raton-Clayton Volcanic Field and part of a transition zone between the Rocky Mountains and the Great Plains. Formations within the volcanic field extend eastward from the Sangre de Cristo Range forming an extension into the plains. It is the piñon-juniper and grassland habitats of this area of volcanic origin and transition that we considered as an appropriate reference for regional comparison with the species occurring at Capulin Volcano NM (Figure 4.11.2-4).

NHNM Surveys

Natural Heritage New Mexico conducted limited bird surveys at the monument in May and June of 2002 (Johnson et al. 2003). Birds were counted within a 100 m radius of each point location during a 5-minute survey period. Birds detected outside the 100 m point radius were recorded but not included in summary analyses of species richness and relative abundance. Surveys started at dawn and finished by about 8:30 am. Each transect was surveyed twice, with a two-week period between surveys. Additional sightings were made while walking between survey points or at other times during the day.

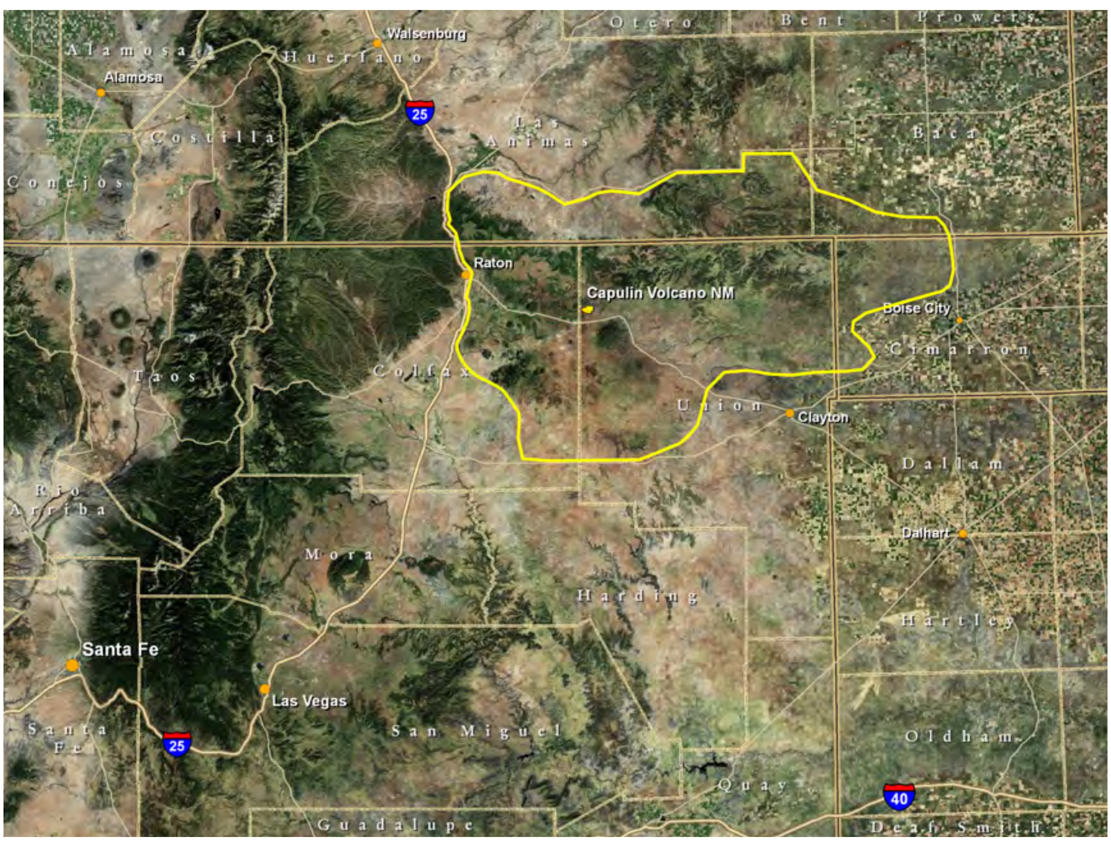

Figure 4.11.2-4. Area in the vicinity of the Raton-Clayton Volcanic Field considered as the reference area for regional comparisons of bird species occurrence at Capulin Volcano NM.

These sightings occurred opportunistically or at locations targeted for their potential to be occupied by species not detected during point counts. We used these surveys, primarily to augment our overall species lists of occurrence at the monument.

Species Check Lists

Bird species checklists have been complied for Capulin Volcano NM at different points in time. These checklists do not represent a census of birds at the moument, nor do they constitute a reliable measure of relative abundance based on systematic surveys. Rather, they represent lists of bird species that have been reported to have been observed at the monument along with a subjective assessment of the season of occurrence of those species and an abundance class. As such, we use these data not as a quantitative basis for assessment of changes over time; rather to derive a qualitative reference for comparison to recent surveys with full recognition of the limitations of those comparisons. For this assessment, we used only checklists that were recognized as a comprehensive checklist of birds by the monument at that time. Thus, we did not include some lists in the monument's files for which there was no specific information regarding its source or secondary lists that were limited to a few casual observations (e.g., lists for a given season by park rangers, etc).

BBS Routes

Breeding bird surveys are conducted on over 4100 survey routes located across the continental U.S. and Canada (http://www.pwrc.usgs.gov/BBS/). Each year during the height of the avian breeding season, participants skilled in avian identification sample birds along roadside survey routes. Each survey route is 24.5 miles long with stops at 0.5-mile intervals. At each stop, a 3-minute point count is conducted. During the count, every bird seen within a 0.25-mile radius or heard is recorded. Surveys start one-half hour before local sunrise and take about 5 hours to complete. We used data from BBS routes primarily as ancillary information to assess whether any apparent departures from reference conditions over time might be reflected in general regional or national trends. Trend estimates were based on a hierarchical model for population change (Link and Sauer 2002) and run on the USGS Breeding Bird Survey Website (Sauer et al, 2011). The analyses use a hierarchical model to produce annual indices of abundance for a given region, then estimate trend as the ratio of the annual indices for the first and last year of the interval.

4.11.3 Reference Conditions

Temporal Reference Condition for Species Occurrence

Although checklists do not typically have any quantitative data (re: abundance), they do typically provide qualitative classes of abundance (common, rare, etc). We compared our refined list of species that have a reasonable expectation to occur at the monument with the results of recent surveys to see if there were any obvious changes over time. Specifically, we looked at species that were not observed during recent RMBO surveys but were documented on previous monument checklists. Although this is a crude measure, it does potentially provide some insights as to major shifts that might have occurred at the monument. For species in which there was some indication of an obvious change in abundance, we then examined data from the Breeding Bird Surveys in the region to determine if those species were experiencing any apparent trends over the past few decades. Such trends might help to explain any disparities between recent and historic occurrence.

Spatial Reference Condition for Species Occurrence

In a spatial context, we compared the species observed during recent RMBO surveys at Capulin Volcano NM to other surveys within the region surrounding the monument conducted by the RMBO (both section-based and point-count based surveys).

Reference Condition for Species of Concern

From the candidate list of species of conservation concern, we compared recent occurrence based on RMBO surveys to the species considered as having the greatest potential for conservation at the monument based on range and habitat.

4.11.4 Condition and Trend

There have been a total of 147 bird species reported at Capulin Volcano NM (Appendix H). Of these, Capulin Volcano NM was determined to be within the primary breeding range of 81 (55%) based on maps from the Birds of North America species accounts (Appendix I). However, of the species that were

Table 4.11.4-1 Sixteen species reported on previous checklists at Capulin Volcano NM that were not observed during the RMBO surveys at the monument, but are within (or close to) their primary breeding range and breeding habitat occurs in the monument.

Common Name	Checklist			
	1966	1968	1981	1993
American Crow	u	u	u	u
American Kestrel	c	c	u	u
Black-throated Gray Warbler	r	r	r	r
Bushtit	u	u	r	r
Clark's Nutcracker	--	--	r	r
Common Nighthawk	a	a	c	u
Common Poorwill	r	c	r	r
European Starling	u	u	u	u
Ferruginous Hawk	r	r	r	r
Greater Roadrunner	r	a	r	r
Killdeer	u	u	r	r
Ladder-backed Woodpecker	r	r	--	--
Lazuli Bunting	--	--	r	r
Lewis' Woodpecker	--	--	u	u
Loggerhead Shrike	u	u	r	r
Long-eared Owl	--	--	r	r

Abundance Class: a = Abundant, c = Common, u = Uncommon, r = Rare

determined to be outside of their breeding range, 25 were determined to be within 100 miles of their primary breeding range. Given the potential for errors in the BNA range maps and/or the potential for us to have made errors in determining whether the monument was within the primary breeding range from hard copy maps (GIS data were not available), we included these additional 25 species for consideration. Thus, 105 bird species were identified for which Capulin Volcano NM was within (n=80), or in proximity to (n=25), their primary breeding range.

Of the 105 species, 54 (51%) had sufficient habitat at the monument such that their occurrence would be expected (Appendix J). It is these 54 species that we used for most comparisons to determine the condition of species occurrence.

Species Comparisons to Monument Bird Checklists (Temporal Context)

Of the full list of 147 species of birds reported to occur or have occurred at Capulin Volcano NM, 86 were not observed on recent RMBO surveys. However, this is not surprising since the monument is not within (or close to) the primary breeding range of 34 of those species and lacks breeding habitat for an additional 36 species. Thus, only 16 species were not observed on recent RMBO surveys that are within (or close to) their primary breeding range with some reasonable breeding habitat found within the monument (Table 4.11.4-1). Of the 16 species not observed by RMBO, there were only two species (Bushtit and Black-throated Gray Warbler) to have existing habitat in the monument. Both of these species are on the edge of their breeding ranges and both have always been considered uncommon or rare at the monument based on previous checklists.

Of the 16 species not observed by RMBO, we considered the most dramatic qualitative changes to be species that were previously listed as abundant or common on previous checklists. There were four such species: the American Kestrel, Common Nighthawk, Common Poorwill, and the Greater Roadrunner. Based on monument habitat availability and their general life history, we considered the potential occurrence for all four of these species to be possible, but certainly not expected.

The American Kestrel was listed as common in two of the four previous checklists (1966 and 1968). However, this species requires cavities, generally in larger trees, which are somewhat lacking at the monument. Thus, it is unclear why this species would have been considered common. It is certainly possible that a nest cavity or foraging perch in the small stand of Ponderosa pines near the visitor center was used for a period of years. This would result in frequent observations, but is purely speculative. It is also possible that its decline that has been observed from the BBS data (Figure 4.11.4-1a) is also the reason why it has changed from common to uncommon.

Common Nighthawks and Common Poorwills are both species that are cryptic and tend to remain perched during the day (except dawn and dusk for the nighthawk); thus can be easily overlooked during surveys. However, the nighthawk can also be readily observed while foraging at dawn and dusk. Their "hawking" behavior, as well as their calls makes them quite conspicuous while on the wing. However, the BBS data for the Common Nighthawk also indicates evidence of a general decline, especially in New Mexico (Figure 4.11.4-1b). In contrast, the Common Poorwill has not shown evidence of a decline (Figure 4.11.4-1c), but is well known to be easily missed during surveys (Woods et al. 2005).

The Greater Roadrunner was listed as abundant on the 1968 checklist and rare on all others. Given that this species is on the edge of its range and tends to be solitary, it is doubtful that it should ever have been considered as abundant at the monument. Further, the BBS data for this species indicate that the population has been increasing (Figure 4.11.4-1d), and that it has been expanding its range northward and eastward (Hughes 2011).

Species Comparisons to Surrounding Region (Spatial Context)

During RMBO surveys of birds in the surrounding region, 34 species were observed in piñon-juniper or grassland habitats but were not recently observed at Capulin Volcano NM during the monument's RMBO surveys. Of these 34 species, 25 are reported to occur, or have occurred, at the monument based on previous bird checklists (Table 4.11.4-2). Given the status of their ranges and habitat

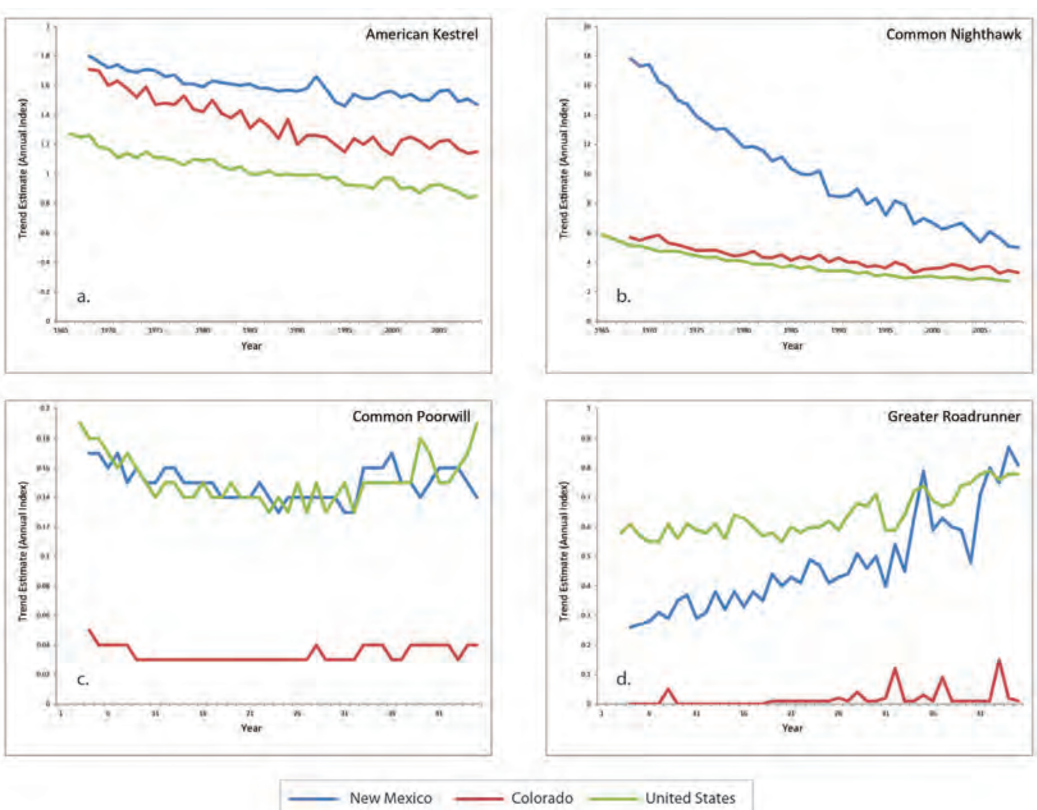

Figure 4.11.4-1. Trends derived from BBS data for American Kestrel (a), Common Nighthawk (b), Common Poorwill (c), and Greater Roadrunner (d)

Table 4.11.4-2 Birds species that are known to occur or have occurred at Capulin Volcano NM that were observed in piñon-juniper or grassland habitats in the surrounding region during RMBO surveys, but not at the monument during RMBO's 2009-2011 surveys. Also shown is the abundance class based on previous bird checklists.

Common Name	Checklist			
	1966	1968	1981	1993
American Crow	u	u	u	u
Black-billed Magpie	u	u	u	u
Black-throated Gray Warbler	r	r	r	r
Blue Grosbeak		r	r	r
Brewer's Blackbird	u	u		r
Brown Creeper			r	r
Burrowing Owl	r	r		
Bushtit	u	u	r	r
Downy Woodpecker			u	u
European Starling	u	u	u	u
Ferruginous Hawk	r	r	r	r
Golden Eagle	r	r	r	r
Gray Vireo	t	t		
Greater Roadrunner	r	a	r	r
Lark Bunting	u	u	r	r
Lazuli Bunting			r	r
Loggerhead Shrike	u	u	r	r
Northern Harrier	u	u	r	r
Pygmy Nuthatch			u	u
Red-breasted Nuthatch	u	u	r	r
Rufous-crowned Sparrow			r	r
Savannah Sparrow	r	r	r	r
Scaled Quail			r	r
Swainson's Hawk	r	r		
White-throated Swift			r	r

* Within 100 mi of range edge.

preferences, we do not find this list particularly alarming. Of the 25 species, 11 are considered outside of their breeding range based on the BNA species accounts, although six of those are on the edge of their range, and an additional three species that are within their breeding range, are also on the edge of their range. Further, only 8 of the 25 species have sufficient habitat at the monument that breeding would be considered at all likely, and only two of those (Bushtit and Black-throated Gray Warbler) have what we considered existing breeding habitat. As discussed above, both of those species are on the edge of their breeding range and both have always been considered uncommon or rare at the monument. Thus, it is not surprising that they might occur only in limited numbers and not be detected during some surveys. Of the 25 species, only one (Greater Roadrunner) has ever been considered more than uncommon at the monument, and as we discussed earlier, we believe that the roadrunner should never have been considered as abundant, as it was on the 1968 checklist.

In addition to the species discussed above, nine species were observed in piñon-juniper or grassland habitats in the surrounding region, but their presence has not been confirmed at the monument on previous checklists:

- Black-chinned Sparrow
- Curved-billed Thrasher
- Dickcissel
- Dusky Flycatcher
- Grasshopper Sparrow
- Gray Flycatcher
- Hammond's Flycatcher
- Long-billed Curlew
- Tree Swallow

We found none of these species to be of particular concern based on the combinations of their distribution and/or range, although some might be observed at the monument in limited numbers some years. In summary, after comparison of species found in the surrounding region to those reported to occur at Capulin Volcano NM a concern for bird species occurrence is not justified.

Species of Concern

There are substantial differences in the species of concern, and/or priority of those species, listed by the various organizations, and trying to make sense of each list can be quite confusing. Thus, we provide a summary of what we believe to be most relevant to the condition of species of concern at Capulin Volcano NM.

Species Listed as Threatened or Endangered by U.S. Fish & Wildlife Service

There are no bird species listed by the U.S. Fish & Wildlife Service as endangered or threatened (in New Mexico) that occur at Capulin Volcano NM (U.S. Fish and Wildlife Service 2011).

U.S. Fish & Wildlife Service - Birds of Conservation Concern

There are 27 species reported to occur, or have occurred, at Capulin Volcano NM that have been identified by the USFWS as having the greatest conservation need at a National, USFWS Regional, or Bird Conservation Region geographic scale (Table 4.11.4-3)(U.S. Fish and Wildlife Service 2008). Of these, only six are probably within their primary breeding range and have at least some possible habitat at the monument for breeding, and two of those (Ferruginous Hawk and Juniper Titmouse) are listed only for BCR 16, which although immediately adjacent, does not actually include the monument. Of the six species within their breeding range and with possible breeding habitat, only two (Juniper Titmouse and Pinyon Jay) have habitat at the monument that we considered available for that species.

Species Listed as Threatened or Endangered by the state of New Mexico

There are no bird species that occur at Capulin Volcano NM, that are listed as endangered by the state of New Mexico; however, there are three species (Bald Eagle, Peregrine Falcon, and Gray Vireo) that are listed as threatened (NMDGF 2008). The Bald Eagle was recorded on the 1981 and 1993 bird checklists for the monument as a rare transient. Although Bald Eagles rarely breed in this area, they do occur during winter in the region. However, their preferred habitat is typically along waterways, where they feed on fish or waterfowl. They do occasionally occur in areas with an abundance of mammalian prey (e.g., rabbits) or carrion, both of which are not sufficient at the monument to support anything but an occasional observation of this species. Thus, the contribution of Capulin Volcano NM to the conservation of this species is likely negligible.

The Peregrine Falcon was observed during the RMBO 2010 survey; however, the monument lacks the Peregrine Falcon's breeding habitat preference for cliffs, typically near water; thus, occurrence of this species is unlikely to be more than an occasional observation. The anatum subspecies of the Peregrine Falcon was federally delisted in 1999 (USFWS 1999), and is now considered by this agency as a species of concern. In contrast, The New Mexico Department of Game and Fish (NMDGF) decided that downlisting this species from endangered to threatened was warranted but that delisting was not (Maracchini 1998). Thus, the species remains listed as threatened by NMDGF (NMDGF 2008).

The Gray Vireo (*Vireo vicinior*), also listed by NMDGF as threatened, might also occur rarely and sporadically at the monument due to its habitat preference for piñon-juniper. Although the monument is not considered within the primary breeding range of this species, it is in proximity to predicted habitat determined by

Table 4.11.4-3. Summary of species that have occurred at the monument of conservation concern listed by primary government agencies and organizations.

Common Name	Listed Species		Species of Conservation Concern Lists																	
	Federal	State	US Fish & Wildlife Service				State of New Mexico	NAS/ ABC	Partners in Flight											
									National Conservation Strategy								NM Bird Conservation Plan	
									BCR 16				BCR 18					
	USFWS	NMDFG	National	Region 2	BCR 18	BCR 16	State Conservation Codes	2007 Watch List	CC	RC	CS	RS	CC	RC	CS	RS	SC	BC
Bald Eagle		T	●	●	●	●	● (orange)											
Black-billed Magpie												●						
Black-throated Gray Warbler							● (orange)			●							●	
Bobolink			●															
Brewer's Sparrow			●			●		● (orange)	●	●			●	●				
Broad-tailed Hummingbird												●					●	
Bullock's Oriole																	●	
Burrowing Owl				●	●	●								●		●		
Calliope Hummingbird			●						●									
Canyon Wren										●								
Cassin's Kingbird																	●	
Cassin's Sparrow														●		●		
Cassin's Finch						●				●								
Chestnut-collared Longspur				●	●	●		● (orange)						●				
Chihuahuan Raven																●		
Clark's Nutcracker											●	●						
Common Nighthawk										●				●				
Cordilleran Flycatcher												●					●	
Ferruginous Hawk						●	● (red)			●				●		●	●	
Golden Eagle				●	●	●	● (orange)			●								●
Grasshopper Sparrow																		
Gray Vireo		T	●	●		●	● (red)	● (orange)	●	●		●					●	

Listed Species Codes
T = Threatened
S = Sensitive

State of NM - State Conservation Codes
● (red) = Imperiled
● (orange) = Vulnerable

NAS/ABC - 2007 Watchlist
● (red) = Red List
● (orange) = Declining or Rare

Table 4.11.4-3. Summary of species of conservation concern that have occurred at the monument listed by primary government agencies and organizations. (cont.)

Common Name	Listed Species		Species of Conservation Concern Lists																		
	Federal	State	US Fish & Wildlife Service				State of New Mexico	NAS/ ABC	Partners in Flight											
									National Conservation Strategy								NM Bird Conservation Plan	
	USFWS	NMDFG	National	Region 2	BCR 18	BCR 16	State Conservation Codes	2007 Watch List	BCR 16				BCR 18				SC	BC
									CC	RC	CS	RS	CC	RC	CS	RS		
Green-tailed Towhee											●	●						
Horned Lark			●															
Juniper Titmouse						●	● (orange)			●		●					●	
Lark Bunting				●	●			●						●	●	●		
Lark Sparrow														●				
Lazuli Bunting																	●	
Lewis's Woodpecker			●	●	●	●		● (red)	●	●	●	●	●	●			●	
Loggerhead Shrike		S	●	●			● (orange)			●				●			●	
Long-billed Curlew																		
McCown's Longspur			●	●	●								●		●	●		
Mountain Bluebird										●	●	●					●	
Mountain Plover		S	●	●	●	●	● (red)	● (red)										
Northern Goshawk		S					● (red)											
Northern Harrier							● (orange)							●				●
Olive-sided Flycatcher			●					● (orange)	●									
Peregrine Falcon		T	●	●		●	● (orange)											●
Pine Siskin										●		●						
Pinyon Jay			●	●		●	● (orange)	● (orange)	●	●	●	●	●				●	
Prairie Falcon					●	●				●				●			●	
Pumbeous Vireo												●					●	
Pygmy Nuthatch										●								
Red-faced Warbler			●	●			● (orange)	● (orange)										

Listed Species Codes
T = Threatened
S = Sensitive

State of NM - State Conservation Codes
● (red) = Imperiled
● (orange) = Vulnerable

NAS/ABC - 2007 Watchlist
● (red) = Red List
● (orange) = Declining or Rare

Table 4.11.4-3. Summary of species of conservation concern that have occurred at the monument listed by primary government agencies and organizations. (cont.)

Common Name	Listed Species		Species of Conservation Concern Lists																
	Federal	State	US Fish & Wildlife Service				State of New Mexico	NAS/ ABC	Partners in Flight									
									National Conservation Strategy								NM Bird Conservation Plan	
	USFWS	NMDFG	National	Region 2	BCR 18	BCR 16	State Conservation Codes	2007 Watch List	BCR 16				BCR 18				SC	BC
									CC	RC	CS	RS	CC	RC	CS	RS		
Red-headed Woodpecker			●	●			● (orange)						●	●				
Rock Wren												●						
Rufous Hummingbird			●															
Sage Sparrow							● (orange)	● (orange)		●								
Sage Thrasher							● (orange)											
Say's Phoebe												●				●		
Scaled Quail							● (orange)	● (orange)	●	●			●	●			●	
Swainson's Hawk			●						●	●			●			●	●	
Vesper Sparrow																		
Violet-green Swallow												●						
Virginia's Warbler			●					● (orange)	●	●		●					●	
Western Bluebird												●					●	
Western Meadowlark																●		
Western Scrub-Jay																	●	
White-throated Swift									●			●	●				●	
Yellow-billed Cuckoo		S	●	●		●	● (orange)											

Listed Species Codes
T = Threatened
S = Sensitive

State of NM - State Conservation Codes
● (red) = Imperiled
● (orange) = Vulnerable

NAS/ABC - 2007 Watchlist
● (red) = Red List
● (orange) = Declining or Rare

NMDGF (Figure 4.11.4-2); thus, may warrant conservation consideration.

In addition to the species listed as threatened, three species (Loggerhead Shrike, Mountain Plover, and Northern Goshawk) that have been reported to occur at Capulin Volcano NM, are listed as sensitive by the state of New Mexico. Of these, only the Loggerhead Shrike has sufficient potential habitat at the monument to warrant consideration in a conservation context, while the other two are unlikely to occur except as rare transients.

State of New Mexico - Birds of Conservation Concern

There are 22 species reported to occur, or have occurred, at Capulin Volcano NM that have been identified by the State of New Mexico as having the greatest conservation need according to the Comprehensive Wildlife Conservation Strategy for New Mexico (2006).

Of the 22 species that have reportedly occurred at Capulin Volcano NM, four (Ferruginous Hawk, Gray Vireo, Mountain Plover, and Northern Goshawk) are considered as imperiled by the State of New Mexico, and of these only one (the Gray Vireo) warrants much consideration regarding the role of the monument in its conservation given their habitat preferences. Although there is some limited habitat for the Ferruginous Hawk around the base of the monument, the area is not nearly enough to have much impact on this species. In contrast, the monument has little if any habitat for Northern Goshawks and this species would unlikely ever be more than an occasional transient.

National Audubon Society/American Bird Conservancy

There are 12 species reported to occur, or have occurred, at Capulin Volcano NM that have been listed on the NAS/ABC 2007 WatchList. Of these, two species (Lewis's Woodpecker and Mountain Plover) are listed on their Red List. Neither of these species has ever been considered more than uncommon at the monument, although both have some limited habitat potential. There are an additional 10 species on the Yellow List, seven because of population declines and three because they are rare.

New Mexico Chapter of Partners in Flight

There are 24 species reported to occur, or have occurred, at Capulin Volcano NM that have been listed on the New Mexico Partners in Flight Conservation Plan (New Mexico Partners in Flight 2007). Of these, six species are listed as Level 1 for species conservation (Ferruginous Hawk, Gray Vireo, Juniper Titmouse, Lewis's Woodpecker, Peregrine Falcon, and Pinyon Jay), and five of these species have at least limited potential for the monument to play a role in their conservation (see summary below).

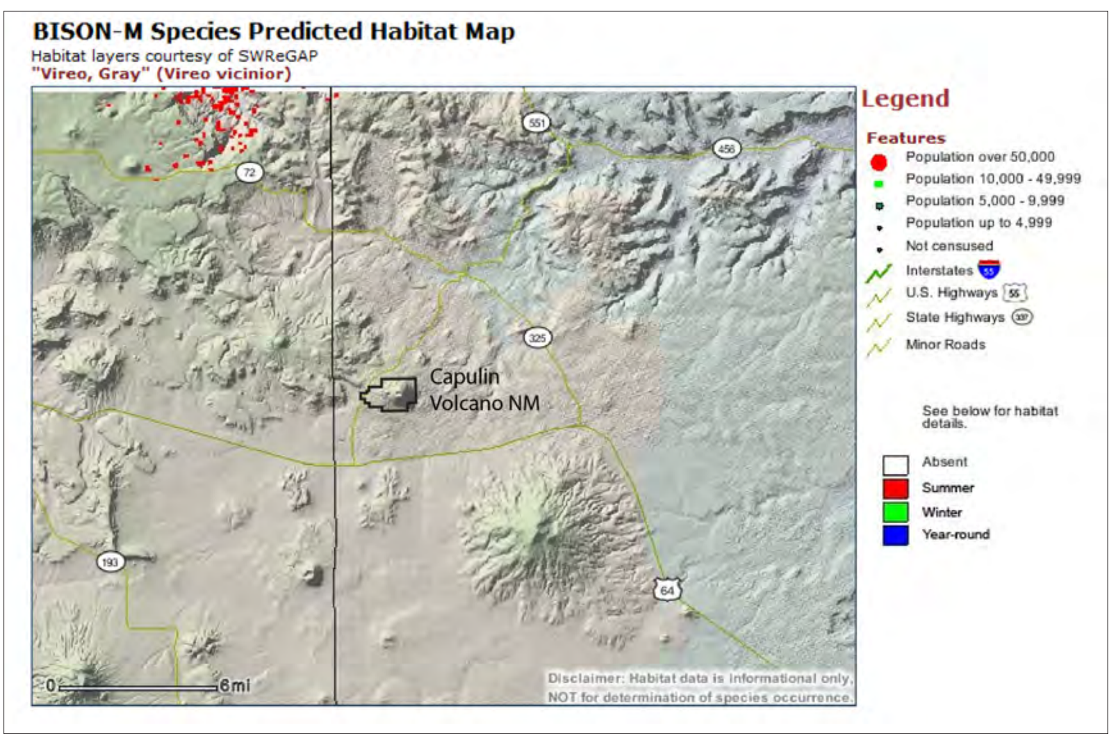

Figure 4.11.4-2. Predicted habitat for Gray Vireos in the vicinity of Capulin Volcano NM from the Biota Information System of New Mexico (Bison-M) (Biota Information System of New Mexico. 2011).

Summary of Species Listed as Birds of Conservation Concern (Conservation Context)

For this summary, we emphasize species for which Capulin Volcano NM has the greatest potential to impact the conservation of species during their breeding season based on their habitat and range. We do not mean to imply that other seasons are not important for the conservation of birds, they are. Rather, we have limited this assessment to the breeding season because that is the only season for which we have current information.

We also recognize that there is considerable uncertainty and subjectivity in our assessment. Thus, we do not mean to imply that the classes we assigned are the only "correct" categories. Rather, this represents our interpretation from the available evidence, but we fully expect that other interpretations might be legitimate or even preferred.

Of the 60 species listed by one or more organizations as being of conservation concern, we believe that 11 have sufficient habitat at the monument to be considered as having high conservation potential (Tables 4.11.4-4 and 4.11.4-5). These are the species that, for the most part, are within or on the edge of their primary breeding range and sufficient habitat exists to support breeding. However, not all of these species regularly occur at the monument.

Table 4.11.4-4. Species reported to occur or have occurred at Capulin Volcano NM that have also been identified as species of concern on one or more watch list. Species are organized by whether they have high, moderate, or low potential for the monument to contribute to their conservation. Also shown are the residency and abundance classes described in previous checklists and whether or not they were detected in recent surveys by the RMBO.

Common Name	Source				
	1966 Checklist (Baily)	1968 Checklist (Jones)	1981 Checklist (Unknown)	1993 Checklist (SWPMA)	Detected on RMBO 2009-2011 Surveys
High Potential					
Black-throated Gray Warbler	Sr	Sr	Sr	Sr	
Cassin's Kingbird	Sa	Sr	Sc	Sc	•
Gray Vireo	St	St			
Green-tailed Towhee	Sc	Sc	Su	Sc	•
Juniper Titmouse				Wc	•
Lark Sparrow	Sa	Sa	Sc	Sc	•
Mountain Bluebird	Pa	Pa	Rca	Rc	•
Pinyon Jay		Tr	Tu	Ru	•
Virginia's Warbler			Tr	Sc	•
Western Meadowlark	Pc	Pc	Sc	Sc	•
Western Scrub-Jay	Pa	Pa	Ru	Rc	•
Moderate Potential					
Broad-tailed Hummingbird			Sc	Sc	•
Cassin's Sparrow	Sr	Sr			•
Common Nighthawk	Sa	Sa	Sc	Su	
Horned Lark	Pa	Pa	Wu	Wu	•
Lazuli Bunting			Tr	Tr	
Lewis' Woodpecker			Su	Su	
Loggerhead Shrike	Su	Su	Tr	Tr	
Plumbeous Vireo	Su	Su	Su	Su	•

Residence Class
S = Summer Resident W = Winter Resident R = Resident P = Permanent Resident T = Transient
Abundance Class
a = abundant c = Common u= Uncommon r = Rrare t = Transient x = Not Provided

Table 4.11.4-4. Species reported to occur or have occurred at Capulin Volcano NM that have also been identified as species of concern on one or more watch list. (cont.)

Common Name	Source				
	1966 Checklist (Baily)	1968 Checklist (Jones)	1981 Checklist (Unknown)	1993 Checklist (SWPMA)	Detected on RMBO 2009-2011 Surveys
Rock Wren	Sc	Sc	Su	Su	•
Vesper Sparrow	Sr	Sr	Su	Su	•
Low to No Potential					
Bald Eagle			Tr	Tr	
Black-billed Magpie	Pu	Pu	Tu	Tu	
Bobolink		Sr	Tr	Tr	
Brewer's Sparrow	Sr	Sr	Tr	Tr	
Bullock's Oriole	Su	Su	Su	Su	•
Burrowing Owl	Sr	Sr			
Calliope Hummingbird			Sr	Sr	
Canyon Wren	Pr	Pr	Sr	Sr	
Cassin's Finch	Wt	Wt			
Chestnut-collared Longspur	Wr	Wr		Tr	
Chihuahuan Raven					•
Clark's Nutcracker			Tr	Tr	
Cordilleran Flycatcher					
Ferruginous Hawk	Pr	Pr	Wr	Wr	
Golden Eagle	Pr	Pr	Tr	Tr	
Lark Bunting	Su	Su	Tr	Tr	
McCown's Longspur	Wr	Wr			
Mountan Plover			Tr	Tr	
Northern Goshawk			Tr		
Northern Harrier	Pu	Pu	Tr	Tr	
Olive-sided Flycatcher			Tr	Tr	
Peregrine Falcon	Pr	Pr		Tr	•
Pine Siskin	Wc	Wc		Tu	•
Prairie Falcon	Pr	Pr	Su	Su	•
Pygmy Nuthatch			Ru	Ru	
Red-faced Warbler			Tr	Tr	
Red-headed Woodpecker			Tr	Tr	
Rufous Hummingbird			Su	Su	
Sage Sparrow	Sa	Sa			
Sage Thrasher	Pr	Pr			
Say's Phoebe	Sa	Wr	Su	Su	•
Scaled Quail			Tr	Tr	
Swainson's Hawk	Sr	Sr			
Violet-green Swallow	Sc	Sc	Tr	Tr	•
Western Bluebird					•
White-throated Swift			Tr	Tr	
Yellow-billed Cuckoo			Sr	Tr	

Residence Class
S = Summer Resident W = Winter Resident R = Resident P = Permanent Resident T = Transient
Abundance Class
a = abundant c = Common u= Uncommon r = Rrare t = Transient x = Not Provided

Table 4.11.4-5. Rationale for inclusion of species as having high potential for conservation at Capulin Volcano NM.

Species	Rationale
Black-throated Gray Warbler	Based on the BNA species accounts, this spcecies is outside, on on the edge of its breeding range at the moument. Although it has never been considered more than rare, its affinity for pinon-juniper habitats warrants consideration at the moument for its conservation.
Cassin's Kingbird	This species is within its primary breeding range, commonly breeds in pinon-juniler habitats in New Mexcio, has been obserded on recent surveys, and has been reported as common or abundant on three of four checklists.
Gray Vireo	Although this species is considered outside of its primary breeding range based on BNA accounts, the combination of its state listing as threatened and affinity for pinon-juniper habitats warrants considering the futire potential for the monument.
Green-tailed Towhee	This species is within, but close to the edge, its primary breeding range. It typically breeds in dry shrubsteppe, including pinon-juniper habitats and has been observed on recent surveys and reported as common on three of four previouls checklists.
Juniper Titmouse	Although on the edge of its primary breeding range, this species typically breeds in pinon-juniper woodlands, has been observed on recent surveys, and warrants considering the futire potential for the monument.
Lark Sparrow	This species is within its primary breeding range, commonly breeds in grassland and shrubsteppe habitats, has been observed on recent surveys, and has been reported as common or abundant on all four previous checklists.
Mountain Bluebird	This species is within its primary breeding range, commonly breeds at prairie/ forest ecotones, has been observed on recent surveys, and has been reported as common or abundant on all four previous checklists.
Pinyon Jay	Although on the edge of its primary breeding range, this species typically breeds in pinon-juniper woodlands, has been observed on recent surveys, and warrants considering the futire potential for the monument.
Virginia's Warbler	Although on the edge of its primary breeding range, this species typically breeds in pinon-juniper and oak woodlands, has been observed on recent surveys, was considered common on at least one previous checklist.
Western Meadowlark	This species is within its primary breeding range, commonly breeds in a wide range of grassland habitats, has been observed on recent surveys, and has been reported as common on all four previous checklists.
Western Scrub-Jay	Although on the edge of its primary breeding range, this species typically breeds in pinon-juniper and oak woodlands, has been observed on recent surveys, was considered common or abundant on three of four previous checklist.

For example, based on the BNA species accounts, the Gray Vireo would be considered outside of its breeding range. However, the state of New Mexico has identified potential habitat on nearby Johnson Mesa (BISON-M; Biota Information System of New Mexico 2011). Given that (1) this species is listed as threatened by the State of New Mexico, (2) the monument is near the edge of its breeding range, and (3) the monument has potential habitat for this species, we decided to list this species as having high conservation potential.

Of these 11, all but two (Black-throated Gray Warbler and Gray Vireo) have been observed on recent RMBO surveys. Similarly, all but three of these 11 species has been listed as common or abundant on at least one previous checklist, and two of those are the same two species that have not been observed on recent RMBO surveys, indicating that their lack of abundance is not a new phenomenon. The third species (Pinyon Jay) not previously listed as common or abundant has been observed 86 times on recent surveys. In fact, all of the nine species with the highest conservation potential that have been observed on recent RMBO surveys have been observed all three years of the survey, and for most of those species, numerous individuals have been observed (Table 4.11.4-6).

Table 4.11.4-6. The number of individuals detected during recent RMBO surveys of the species with highest conservation potential.

Species	2009 Survey	2010 Survey	2011 Survey	Total
Black-throated Gray Warbler	0	0	0	0
Cassin's Kingbird	17	53	17	87
Gray Vireo	0	0	0	0
Green-tailed Towhee	34	47	27	108
Juniper Titmouse	3	5	6	14
Lark Sparrow	8	41	39	88
Mountain Bluebird	2	7	3	12
Pinyon Jay	52	17	17	86
Virginia's Warbler	14	4	2	20
Western Meadowlark	38	14	4	56
Western Scrub-Jay	8	15	5	28

Table 4.11.4-7. Summary of the landbirds indicators/measures and their contributions to the overall landbirds natural resource condition assessment.

Indicator/Measure	Description of How the Indicator(s) Contributes to the Overall Resource Condition	General Contribution of this Indicator or Measure to the Overall Resource Condition.
Species Occurrence • Temporal context • Spatial context • Conservation context	Although other measures that are currently not available (i.e., data for density, occupancy, etc.) maybe more appropriate for this measure, we simply used occurrence for this assessment. We considered three different facets of occurrence to provide a greater perspective to this measure.	A total of 147 bird species have been reported to occur at the monument, with 105 of those species occurring within or in proximity to their primary breeding range. Regionally, 34 species of birds were identified to occur but not recently observed at the monument during RMBO breeding bird surveys. The monument has a high potential to influence 11 species that have been identified as species of concern by various bird conservation organizations.

Overall Condition

For assessing the condition of landbirds, we used one indicator/measure that assessed the occurrence of landbirds. This indicator is summarized in Table 4.11.4-7. Although our assessment is based on limited data, we found no justification to warrant concern for bird occurrence at Capulin Volcano NM. Comparing recent surveys to previous species checklists for the monument, the few species that were reported to have been common or abundant that were not seen during recent surveys are not especially surprising and are more likely to reflect anomalies in the previous checklists rather than a major shift in the occurrence of those species. Similarly, there was nothing particularly surprising or alarming when comparing species observed during recent RMBO surveys to the species observed in piñon-juniper habitats within the surrounding region. We found 11 species that we believe have relatively high conservation potential, and most of these have been observed numerous times at the monument during recent years. The two species that have not been observed in recent years are both considered outside of their primary breeding ranges according to the BNA accounts, although both are on the edge of that range. Both of those species have also never been considered anything more than rare or transient at the monument. Based on the evidence presented here, we consider the condition of birds at the monument to be good. Unfortunately, we do not have sufficient data to justify a trend in that condition, although ongoing monitoring should provide such an estimate for future assessments.

Level of Confidence/Key Uncertainties

The key uncertainties related to this assessment are the overall lack of data and subjectivity with respect to assigning individual species to range, habitat, or conservation classes. Although we are currently collecting data that will provide for a quantitatively rigorous analysis in the future, at the present time we relied primarily on qualitative indicators to assess the condition of landbirds.

We determined the breeding ranges primarily from the BNA species accounts and had to judge from hard copies whether or not the monument was within those ranges. We tried to account for this uncertainty by also including species that were on the edge of their ranges. Similarly, there is considerable subjectivity in our assignment of habitat classes. We based this assessment on a combination of the BNA accounts, as well as our own and local knowledge of the species in question.

4.11.5 Sources of Expertise

Ross Lock and Chris White, both wildlife biologists, with the Rocky Mountain Bird Observatory, assembled regional landbird information, provided consultation, and Ross Lock reviewed the landbirds section.

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4.12 Capulin Alberta Arctic Butterfly (*Oeneis alberta capulinensis*)

Indicators/Measures

- Presence/absence of the butterfly
- Presence/absence (and quality) of butterfly habitat
- Distance from Capulin Volcano NM to the closest known colonies of the subspecies

Condition - Trend

Unknown - Unknown

4.12.1 Background and Importance

The Capulin Alberta arctic butterfly (*Oeneis alberta capulinensis*) was found at Capulin Volcano NM's crater rim in 1969 and determined to be a new subspecies (Brown 1970) (Figure 4.12.1-1). The subspecies is known only in Capulin Volcano NM and some nearby areas on the Raton Mesa complex (Union and Colfax counties, New Mexico), but it is not listed as a state or federally threatened or endangered species. However, the New Mexico Department of Game & Fish includes *O. a. capulinensis* as a Species of Greatest Conservation Need (SGCN) in their Comprehensive Wildlife Conservation Strategy (http://www.wildlife.state.nm.us/conservation/comp_wildlife_cons_strategy/index.htm). Parmenter et al. (2000) recommended that the Capulin Alberta arctic butterfly should be protected as a species of special concern because it is a genetically distinct and isolated population.

Figure 4.12.1-1. Capulin Alberta arctic butterfly (*Oeneis alberta capulinensis*) specimen collected from Capulin Volcano NM.

Figure 4.12.1-2. Capulin Alberta arctic butterfly (*Oeneis alberta capulinensis*)

North American butterflies belonging to the genus *Oeneis* may be referred to as "arctics" in recognition of the windy, often high-elevation, tundra-like habitats they generally inhabit (Johnson et al. 2004). The main population of the Alberta arctic occurs on the prairies of Alberta, Saskatchewan, Manitoba, Montana, and North Dakota (Scott 1986), but "outlier colonies" also occur in Arizona's White Mountains (Figure 4.12.1-2), central Colorado, and northeast New Mexico on the Raton Mesa complex (Johnson et al. 2004) and Opler et al. (2011) lists sighting records for Wyoming (Figure 4.12.1-3).

The Alberta arctic butterfly is described as small and as having variable coloration, from light to darker grayish-brown (Johnson et al. 2004). The butterfly's underside is lighter than the upper side, and the female may appear brighter in color than the male. The Capulin Alberta arctic butterfly looks different than each of the other three accepted subspecies in various ways. It is obviously smaller than *O. a. daura*, about the same size as *O. a. oslari*, and somewhat larger than *O. a. alberta* (Brown 1970). Brown (1970) also described a considerable amount of variation among the individual Capulin Alberta arctic butterflies he observed, suggesting that the subspecies is much more variable than the other populations studied. He further noted that the level and types of variation suggested an isolated population.

The habitat for the Capulin Alberta arctic butterfly at the monument has been mapped as Arizona fescue-mountain muhly grassland (Muldavin et al. 2011; Figure 4.12.1-4) and is located on the volcano's summit (Figure 4.12.1-5). This plant association, at the monument,

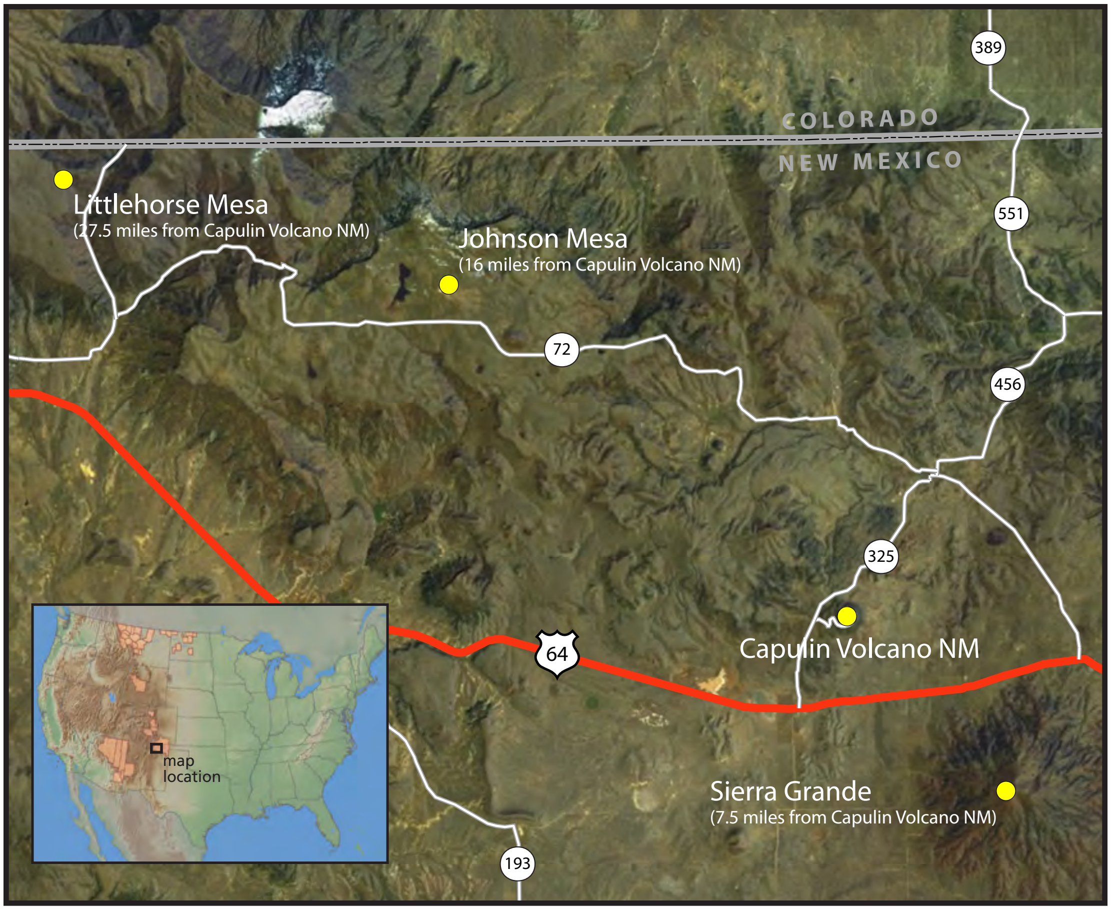

Figure 4.12.1-3. Locations of Capulin Alberta arctic butterfly sightings in northern New Mexico (Johnson et al. 2004).

Inset: The Alberta arctic butterfly is found in Canada and the U.S. in Montana, North Dakota, Wyoming, Arizona, central Colorado, and western and northeast New Mexico.

occurs at elevations of 7,244–8,159 feet (2,208–2,487 m). These grasslands are relatively mesic and dominated by Arizona fescue and mountain muhly (*Mulenbergia montana*), with mountain muhly usually dominant at Capulin Volcano NM. Blue grama (*Bouteloua gracilis*), little bluestem (*Schizachyrium scoparium*), and other prairie species may also be common. Scattered shrubs may be present. Stands of this grassland type also occur between lava outcrops of the monument's Boca, but only the high-elevation stands on the crater rim provide habitat for the butterfly (Brown 1970; Parmenter et al. 2000). Butterflies have been found on the outer slope of the north rim and on the inner slope of the south rim (Brown 1970; Parmenter et al. 2000). Brown (1970) described the habitat on the north rim as several acres in extent and covered with bunch grass (any of various grasses that grow in tufts); that on the south rim was similar, but smaller. Host plants of the butterfly at the monument are unknown, but larvae of the species are known to feed on grasses, especially bunch grasses in the genus fescue (Scott 1986; Parmenter et al. 2000). Similarly, the host plants at Capulin Volcano NM are probably a bunch grass species such as Arizona fescue (*Festuca arizonica*) or Poa (Parmenter et al. 2000).

4.12.2 Data and Methods

Three primary indicators were used to assess the condition of the Capulin Alberta arctic butterfly at the monument.

Indicators/Measures

- Presence/absence of the butterfly

The presence/absence of the butterfly was assessed using previous survey results and personal communication with subject matter experts.

The Capulin Alberta arctic butterfly was first observed at Capulin Volcano NM in 1969 (see Table 4.12.2-1 for a summary of all observations at the monument). Subsequent observations were made in the spring of 1969 and 1970 by Brown (1970). The first butterfly was observed on the outer north rim on May 17, 1969, having been flushed from a patch of grass. A total of 49 butterflies were collected. Although no butterflies were seen on the inside of the south rim in 1969, they were observed there in May 1970 (Brown 1970).

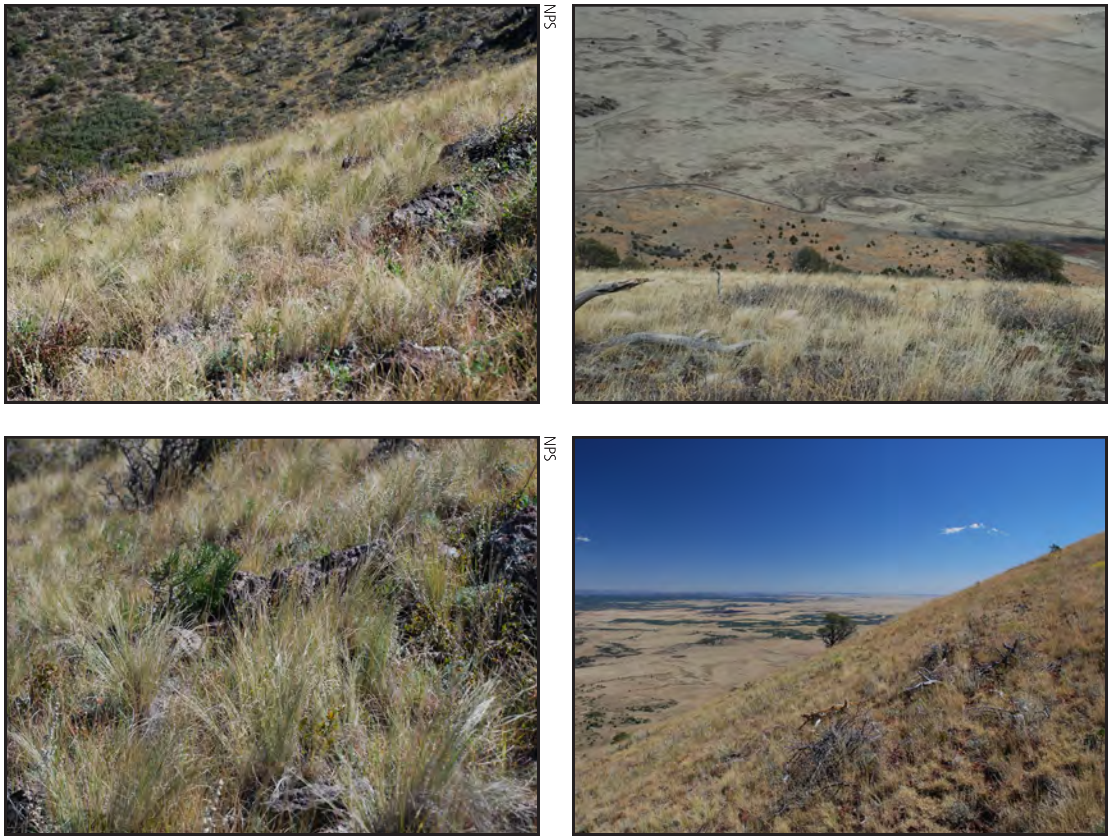

Figure 4.12.1-4. Habitat of the Capulin Alberta arctic butterfly, clockwise from top left: Grassland habitat on the inside of the south rim of the crater; Grassland habitat on the northeast, outside rim of the crater; Close-up of grassland habitat showing Arizona fescue; Grassland habitat on the outside of the north rim.

Several individuals of the subspecies were observed by Parmenter et al. (2000) on the north rim of the crater on May 31, 1996. Because the purpose of their project was to focus on federally-listed threatened and endangered species, they did not attempt to quantify the butterfly's abundance or distribution. However, they reported that the subspecies appeared to be common in the monument (Parmenter et al. 2000; Parmenter 2004). Between the first sightings of the species in 1969 and 1970 and the 1996 sighting, the Capulin Alberta arctic was recorded at the monument during four additional years (Johnson et al. 2004).

In 2003, Johnson et al. conducted surveys at the monument. It is not known whether a hailstorm that occurred at the monument two weeks before the survey may have impacted the butterflies, but if they had been flying at

Table 4.12.2-1. Observations of Capulin Alberta arctic butterfly at Capulin Volcano NM

Study	Study Month/Year	Number of Observation Days	Observations
Brown 1970	May 1969 May 1970	3 unknown	1969: 49 butterflies were collected (42 male, 7 female). 1970: Butterflies observed but not counted
Johnson et al. 2004	May–June 1971 May–June 1972 May–June 1981 May–June 1989	1 1 2 1	Butterflies were observed for each year listed.
Parmenter et al. 2000 and Parmenter 2004	May 1996	1	Butterflies observed as "common" but not counted.
Johnson et al. 2004	May 2003 May 2004	2 7	None observed during survey. None observed during survey.

Notes: No reports were found for the period 1989 to 2003, except for those of Parmenter et al. (2000), who did not attempt to record abundance or distribution. All butterfly observations occurred between the months of May and June. No additional butterfly surveys conducted since 2004.

Figure 4.12.1-5. High elevation Arizona fescue-mountain muhly grassland habitat locations of the Capulin Alberta arctic butterfly (lower elevation habitat omitted).

the time the storm occurred, it is possible that those individuals were killed (Johnson et al. 2004). Alternatively, the butterflies may have flown earlier in the season than usual (Johnson et al. 2004). In May 2004, surveys by Johnson et al. (2004) were conducted at the monument; in addition, the north crater rim was visited twice a week during the two weeks prior to the survey, and three additional times during the week and a half after the survey. No butterflies were observed at Capulin Volcano NM throughout the survey period.

Indicators/Measures

- Presence/absence (and quality) of butterfly habitat

The presence/absence and quality of butterfly habitat was assessed by referencing a recent vegetation survey of the park (Muldavin et al. 2011), along with past reports of known habitat (e.g., Brown 1970). We examined whether the overall condition of the habitat has changed over time (e.g., coverage of the grassland area) by comparing historic aerial photos from 1938 to those from approximately present day (e.g., 2005). Also, results of exotic plant monitoring at the monument were reviewed to determine whether exotic species have affected the butterfly grassland habitat. Finally, the habitat at the monument was compared to other locations on the Raton Mesa complex where the butterfly has been known to occur.

Indicators/Measures

- Distance from Capulin Volcano NM to the closest known colonies of the subspecies

GIS was used to determine the distance from the monument to the other locations known to host the species. This information is of interest because, if the Capulin Alberta arctic presently does not occur at Capulin Volcano NM, it may be possible for the monument's habitat to be recolonized by butterflies from these nearby areas.

The butterfly was found on the nearby Little Horse Mesa at Sugarite Canyon State Park, Dale Mountain on Johnson Mesa, and Sierra Grande (Toliver et al. 1994; Cary 2001), which are similarly windy, grassy mesas in the Raton Mesa complex. There may be other colony sites in the Raton Mesa complex that have not been discovered (Johnson et al. 2004; S. Cary, pers. comm.). Not all sites having suitable habitat for the butterfly have been surveyed, including some sites that are not readily accessible (S. Cary, pers. comm.).

Johnson Mesa: Including the work of Johnson et al. (2004), the butterfly was observed at

Johnson Mesa on five occasions from May 1990 to May 2004 (in 1990, 1996, 2000, 2003, and 2004; Johnson et al. 2004). In the two years that Johnson et al. surveyed, the largest number of butterflies recorded was 27 in 2003; this number was smaller than that reported previously by another researcher (Steven Cary; actual number not reported). Johnson et al. (2004) noted that the butterflies seemed to be more abundant at the lower edges of north-facing slopes, in wetter, greener vegetation; they were found primarily in patches of fescue (*Festuca*). The butterflies appeared to be less abundant in large bunch grasses. Also, one female butterfly was observed on a hairy clematis (*Clematis hirsutissima*) plant, as was one in a clump of warm-season grass. Johnson Mesa is approximately 16 miles (26 km) from Capulin Volcano NM.

Little Horse Mesa, Sugarite Canyon State Park: The 2004 survey conducted by Johnson et al. (2004) at Little Horse Mesa may have detected one Capulin Alberta arctic, but it was unconfirmed. The wind conditions during the survey were not desirable. However, the subspecies was observed in May 2004 by a different researcher. The butterfly has been observed at Little Horse Mesa twice, in 2000 by Steven Cary and in 2004 (Johnson et al. 2004). Little Horse Mesa is approximately 27.5 miles (44 km) from Capulin Volcano NM.

Sierra Grande: Capulin Alberta arctic butterflies were observed at Sierra Grande four times from 1993 to 1998 (Johnson et al. 2004). They were not observed in 2004 by Johnson et al. (2004), but the authors noted that they expected repeated surveys during the month would detect the butterfly. Sierre Grande, the closest known butterfly colony to the monument, is approximately 7.5 miles (12 km) to the southeast.

4.12.3 Reference Conditions

It is somewhat difficult to describe reference conditions for the Capulin Alberta arctic butterfly because of the lack of information on the critical elements of its habitat and lack of consistent and consecutive surveys. The previous surveys are also too limited for us to develop an adequate understanding of the variables affecting the presence/absence of this rare species. Therefore, we are unable to determine whether the lack of sightings is a normal fluctuation in the population, whether it indicates an overall decline, or if it's a result of the survey timing and/or observer training.

The larval plant host for the species is reported as a bunchgrass (Scott 1986), believed to be fescue, but not yet confirmed at Capulin Volcano NM (Johnson et al. 2004). Confirming the host plant(s) was one of the purposes of the project by Johnson et al. (2004), but they found no butterflies at the monument during their survey. Adult butterflies at Johnson Mesa in 2003 were observed primarily in patches of fescue. As previously described, fescue and other bunch grasses occur at Capulin Volcano NM in three grassland patches at the crater's rim. These patches are relatively small (4.74 acres [1.92 hectares], 2.43 acres [0.98 ha], and 0.47 acres [0.19 ha]) compared to the area of habitat at the other known locations of the subspecies (S. Cary, pers. comm.). Furthermore, near the southern extent of the species' range, the subspecies is known to occur only on the archipelago of volcanic uplands in the Raton Mesa complex (Johnson et al. 2004). Among the subspecies' known locations, the habitat for the butterfly at Capulin Volcano NM is at the lowest elevation of the sites (but at the highest elevation possible at the monument). In general, lower elevations may bring warmer and drier habitat not conducive for the butterfly. Additionally, the butterfly colony at Capulin Volcano NM was probably always relatively small (S. Cary, pers. comm.), given the small area of suitable habitat (Johnson et al. 2004). In assessing the habitat condition of the Capulin Alberta arctic butterfly at the monument, comparisons will be made to the other known locations of the butterfly using the relatively small information base that exists.

The Capulin Alberta arctic butterfly is an isolated population that may depend on recolonization from adjacent sites. However, given the limited amount of information for this species, we do not know how close the colony would need to be for recolonization to occur at the monument.

4.12.4 Condition and Trend

Presence/absence of butterfly

The last year that the Capulin Alberta arctic butterfly was sited at the monument was 1996, but at that time no detailed inventory was performed because the study being conducted (Parmenter et al. 2000) focused on state and federally-listed species. However, Parmenter et al. reported that the subspecies appeared to be common in the monument. Prior to that report, the last time the butterfly had been documented was in 1989 by J.A. Scott (Johnson et al. 2004).

Inventories were conducted again in 2003 and 2004, but no butterflies were observed. Johnson et al. (2004) did not believe that the lack of sightings in those years necessarily indicated that the species was extirpated from Capulin Volcano NM, and they recommended that surveys be conducted for several consecutive years from late April to early June to increase the likelihood of sighting the butterflies. However, no surveys for the Capulin Alberta arctic butterfly have been conducted at the monument after 2004.

Based on the available information, it is not possible to state whether the Capulin Alberta arctic butterfly is present or absent at Capulin Volcano NM. Therefore, its condition with regard to presence/absence is unknown.

Presence/absence (and quality) of butterfly habitat

While Johnson et al. (2004) were not able to identify the larval host plant(s) for the species at Capulin Volcano NM, the host plant is thought to be a bunch grass, probably Arizona fescue or a species in the bluegrass genus, *Poa* (Parmenter et al. 2000). Such species do occur in the identified butterfly habitat at the monument, but the area of habitat is small compared to the other known butterfly areas on the Raton Mesa complex (e.g., Johnson Mesa; Johnson et al. 2004 and S. Cary, pers. comm.). Furthermore, Johnson et al. (2004) described the patches at Capulin Volcano NM as "sparse" compared to the habitat at Johnson Mesa. However, based upon historic and near-present day photo comparison, the habitat patches appear to be approximately the same size as when the butterflies were observed at the monument.

Another important aspect of the butterfly habitat is the elevation at which it occurs. The grassland habitat for the butterfly at Capulin Volcano NM is at a lower elevation compared to the other known butterfly colony locations on the Raton Mesa complex (S. Cary, pers. comm.). Because the existing habitat at Capulin Volcano NM is at the top of the cinder cone and elevation range, no additional habitat exists within the monument.

The exotic plants cheatgrass (*Bromus tectorum*), Japanese brome (*Bromus japonicus*), and common mullein (*Verbascum thapsus*) are known to occur at some locations in close proximity to the three Arizona fescue-Mountain muhly habitat patches near the top of the cinder cone. Their known distribution is based on surveys conducted by the Southern Plains Inventory and Monitoring Network monitoring efforts, Natural Heritage New Mexico vegetation mapping plots, and/or Exotic Plant Management Team surveys. Not all of the area within the three Arizona fescue-mountain muhly grassland patches has been surveyed for exotics due to the steep nature of the cinder cone and the possibility of introducing more erosion. However, based on the knowledge of existing exotics at the top of the cone and their invasiveness, these habitats may be vulnerable to invasion.

Based on the information available, suitable habitat for the butterfly continues to exist at the monument even though it may be of somewhat lower quality due to its smaller size, sparser vegetation, and inability to expand uphill (Johnson et al. 2004), compared to other colony locations on the Raton Mesa complex (e.g., Johnson Mesa). The habitat does not appear to have changed much from the historic (1909, 1938) condition nor from the last years that the butterfly was observed at Capulin Volcano NM (1989, 1996).

Distance from Capulin Volcano NM to the closest known colonies of the subspecies

Johnson et al. (2004) reported that "[i]n a metapopulation, simple stochastic events like weather or climate may extirpate tiny colonies (e.g., at Capulin Volcano NM); eventual recolonization of such sites is typical for metapopulations. . . ." Here we discuss the possibility that, if the Capulin Alberta arctic colony at the monument has been extirpated, the habitat may be recolonized by butterflies from nearby sites. The closest location to Capulin Volcano NM is Sierra Grande; although no butterflies have been recorded there since 1998, Johnson et al. (2004) expected that repeated surveys throughout May would detect it. The next closest known colony site of the subspecies is Johnson Mesa, and other undiscovered colonies may also exist (S. Cary, pers. comm.).

No information was found in the literature addressing the distance the species can fly, nor the likelihood that it could recolonize areas with extirpated colonies. Although it remains a possibility, the likelihood of such an occurrence is unknown. Johnson et al. (2004) further reported that modern conditions, such as climate change, make recolonization more difficult. The Capulin Alberta arctic butterfly

Table 4.12.4-1. Summary of the Capulin Alberta arctic butterfly indicators/measures and their contributions to the overall Capulin Alberta arctic butterfly natural resource condition assessment.

Indicator/Measure	Description of How the Indicator(s) Contributes to the Overall Resource Condition	General Contribution of this Indicator or Measure to the Overall Resource Condition.
Presence/absence of butterfly	The presence of the butterfly has been confirmed at the monument; however, we do not know the current status of its presence. It is one of the few rare species that has been detected at the monument in past years therefore was included as a focal resource for this assessment.	The last confirmation of the butterfly at the monument was 15 years ago. Many factors confound the detection of this species and additional formal surveys need to be conducted before condition can be assigned as a result of its presence.
Presence/absence (and quality) of butterfly habitat	It is suspected that the high-elevation Arizona-Fescue grassland is used as the butterfly's habitat. There are two distinct locations at the top of the monument's cinder cone that may provide this habitat necessary for the butterfly's survival.	This habitat exists at the monument, although it may be slightly reduced in area from previous years. The quality of the habitat may also be threatened by invasive species, but no formal surveys of the cinder cone for exotic plants has been conducted.
Distance from Capulin Volcano NM to the closest known colonies of the subspecies	If the butterfly does not inhabit the monument then the possibility of it recolonizing within the monument may be realized if colonies exist nearby.	The closest known colony is located on Johnson Mesa, 16 miles northwest of the monument. No information is available to know how far this species can travel to recolonize an area. In addition, the monument's grassland is located at the highest point in the park, but it is at the lowest elevation this species can occupy. The possibility of recolonization may be limited by elevation.

is a Pleistocene relict, and a warming climate decreases options for a subspecies that is already inhabiting locations at or near the maximum elevations available (Johnson et al. 2004).

Level of Confidence/Key Uncertainties

The Capulin subspecies of the Alberta arctic butterfly faces potential threats in its range (Johnson et al. 2004). Because of the population's small size, natural or human impacts could threaten the existence of the subspecies. Additionally, there are several types of uncertainties involving the natural history/biology of the Capulin Alberta arctic butterfly and its occurrence at Capulin Volcano NM. The lack of professionally conducted, systematic surveys makes it very difficult to determine presence/absence and natural variability that may occur within the population during any given survey year.

Wind and other climatic factors can affect when/whether the butterflies fly (and therefore are observable). In addition to this, aspects of the butterfly itself may make it difficult to survey. The Capulin Alberta arctic butterfly has been described as rarely flying "until it is kicked out of the grass clumps" (Brown 1970). When the butterfly does fly, its flight is erratic, rapid, and low, often less than a foot above the grass (Brown 1970). Additionally, Brown reported only males flying; female butterflies seen on the ground were either crawling among the grass clumps or disappearing into crevices among the cinders. The butterfly also flies in only one generation per year (completes one breeding cycle) and occurs in small populations (Johnson et al. 2004). In addition to these characteristics of the Capulin Alberta arctic butterfly, other butterflies are known to stay in pupal diapause for multiple years during poor climate conditions (until conditions are more favorable; Johnson et al. 2004). The Capulin Alberta arctic butterfly may also be biennial, meaning it requires two years to mature (and flies every other year; Scott 1986; Johnson et al. 2004).

There is also uncertainty regarding the butterfly's habitat; its larval host plant at the monument remains unconfirmed, although it is believed to be a *Festuca* species. Finally, in attempting to assess the ability of the butterfly to recolonize Capulin Volcano NM if it has been extirpated, difficulty arises because there is uncertainty regarding the occurrence of nearby colonies. There remain potential sites on the Raton Mesa complex that may harbor colonies of the species, but the actual occurrence of such colonies is unknown at this time

Overall Condition and Trend

For assessing the condition of Capulin Alberta arctic butterfly, we used three indicators/measures that were not mutually exclusive but were intended to be different ways of capturing the essence of what we thought represented the condition of the monument's Capulin Alberta arctic butterfly. The indicators are summarized in Table 4.12.4-1. With the limited information available and the uncertainties described, the overall condition and trend of the Capulin Alberta arctic butterfly is unknown at this time.

4.12.5 Sources of Expertise

Work on this assessment was conducted in consultation with Steven Cary of New Mexico Audubon Society (formerly with New Mexico State Parks). In particular, he provided information on: whether any surveys had been conducted for the species since 2004, butterfly habitat at Capulin Volcano NM compared to other butterfly colony sites, and the fact that there are other potential sites in the Raton Mesa complex that could harbor the butterfly.

4.12.6 Literature Cited

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NRCA field meeting at Capulin Volcano NM.

Chapter 5: Discussion

National Park Service Director Jonathan B. Jarvis marked the agency's 95th anniversary with the release of A Call to Action: Preparing for a Second Century of Stewardship and Engagement (2011a). A Call to Action identifies 36 action items that NPS employees and partners will do to integrate NPS community programs with 395 national parks and the agency's mission to preserve the country's cultural, historic and natural resources for the enjoyment of this and future generations. Action item 28, Park Pulse, was developed to assess the overall status of park resources and to use this information to improve park priority setting and to communicate complex park condition information to the public in a clear and simple way (NPS 2011a,b). This action item includes condition information pertaining to natural and cultural resources, facilities, and visitor surveys. This resource condition assessment is intended to provide the natural resources information to Capulin Volcano NM staff that can be used by the park in developing such a State of the Park report.

In this chapter, we summarize the information resulting from our assessment in three ways. First, we provide an overall summary of the key findings of this assessment (relative to our hierarchical framework in Chapter 3 Table 3.2.1-1), and the implications of those findings to the park resources. Secondly, using a conceptual framework developed by Parks Canada, we summarize the current state of "Ecological Integrity" based on the available information. Lastly, we provide a summary for each resource topic in the form of a resource brief.

5.1 Overall Condition Summary And broad implications

5.1.1 Landscape Condition Context

The landscape condition at Capulin Volcano NM is comprised of its viewshed, night sky, and soundscape. Overall, the landscape condition at Capulin Volcano NM is very good, however, much of the potential future condition of these resources lies outside of the monument's boundary and is dependent on local and regional planning rather than monument-specific planning to the continued preservation of current conditions.

At present, the greatest viewshed impact results from developments that are located closest to the viewshed's primary vantage points, however, much of the monument's viewshed area is located outside its boundary. Overall, the monument's viewshed currently maintains its rural and natural character.

The monument has one of the darkest night skies out of 90+ dark sky-monitored national parks.

The monument is located on the northwestern edge of a dark hole that extends from southwest of La Junta, CO to northeast of Las Vegas, NM. Once again, this resource is greatly influenced by factors outside the monument's boundary, including light pollution from as far away as Denver, CO and Amarillo, TX.

The soundscape at the monument is largely comprised of natural sounds, including weather-related sound from wind, rain, or falling snow or bird songs and calls. The noisiest periods generated from human activity typically occur during the summer months (June-August) from noon-2 p.m. and usually during Saturdays. However, opportunities for natural quiet can still be found even during these busiest times if one is willing to hike a trail such as the Boca or Lava Flow Trails, which are primarily located adjacent to the natural conservation management zone where natural sounds prevail.

5.1.2 Supporting Environment

The supporting physical environment at Capulin Volcano NM includes its air quality, geology, and groundwater resources. These resources represent the abiotic factors that support the biological integrity of the plants and animals and ecological processes occurring throughout the monument. The overall condition of these resources ranges from good for groundwater, moderate for air quality, and significant concern for geology.

The greatest impact to the geologic resources, specifically the cinder cone, is from Volcano Road, which is built into the cone, and concentrates run-off creating accelerated and sometimes very severe erosion. Although, some naturally occurring erosion would still occur on the cinder cone without the road, due to its steep slopes and loose soils.

The air quality and groundwater resources are impacted primarily by activities occurring outside the monument's boundary; however, their quality is significant to the health of the biotic resources occurring within the monument. Similar to the landscape condition, the condition of the supporting environment's air quality and groundwater resources is largely dependent upon local and regional planning as opposed to monument-specific planning.

5.1.3 Biological Integrity

The biological integrity is comprised of plants (both native and non-native) and animals found throughout the monument. The primary plant communities include piñon pine (*Pinus edulis*) and Rocky Mountain juniper (*Juniperus scopulorum*) habitats and grasslands, which comprise 85% of the monument's habitat types.

The exotic plants found throughout the monument have the potential to negatively impact these native plant communities, which in turn, impacts the wildlife species dependent upon these communities. The exotic bromes probably represent the biggest threat to the condition of native plant communities and are well known to dramatically change the character of an ecosystem, including major shifts in community composition and structure as well as substantially altered fire regimes. In many cases these changes have become, for all practical purposes, irreversible at other locations where they are found. Thus, from a standpoint of potential impact, we consider the exotic bromes to be a concern in species displacement and potentially subsequent species loss.

The primary wildlife taxa included in this assessment is landbirds. Landbirds are surveyed annually, and a total of 147 bird species have been reported to occur, at least at some point in time, at the monument.

The monument is located within an ecotone where the Rocky Mountains meet the High Plains, creating conditions that support potentially unique species. This is true of Capulin goldenrod (*Solidago capulinensis*), which is known to occur in only one additional location (in the world). It was first discovered at the monument in 1936 and rediscovered in 2010. Very little is known about this plant, but it is known to grow in rocky outcrops, and may be more widespread throughout the monument than previously believed.

The Capulin Alberta arctic butterfly (*Oeneis Alberta capulinensis*) is also rare and has not been seen at the monument since 1996, but this may be due to several factors that confound detection of itinerant species. Systematic surveys and methodology would help provide additional information that is currently lacking for this species.

5.2 Ecological Integrity Sensu Parks Canada

In addition, the Leadership Council identified the need to "step up and synthesize our [NPS] monitoring effort" using the Parks Canada natural resource conceptual framework (NPS 2011b). The Parks Canada model approaches ecological integrity as a management endpoint, which is grounded in science, therefore measurable (Woodley 2010). Parks Canada legally defined ecological integrity in its 1998 Canada National Parks Act as follows:

Ecological integrity means, with respect to a park, a condition that is determined to be characteristic of its natural region and likely to persist, including abiotic components and the composition and abundance of native species and biological communities, rates of change and supporting processes (Woodley 2010).

Woodley (2010) offers a simpler definition of ecological integrity stating that it's "an ecosystem that contains its full complement of native species and the processes that ensure the survival of those species."

Using this framework also provides information to park managers who need to clearly communicate the natural resource conditions at their park to a wider audience. To evaluate ecological integrity in this context, Parks Canada developed six questions pertaining to ecosystem condition (Woodley 2010):

1. Is the park losing species?
2. Are selected indicator species doing well?
3. Are the ecosystem trophic levels intact?
4. Do biological communities exhibit a mix of age classes and spatial arrangements that will support native biodiversity?
5. Are productivity and decomposition operating within acceptable limits?
6. Is the system cycling nutrients within acceptable limits?

These ecological integrity questions are intended to help land managers frame the ecological integrity concept into meaningful and measurable ways to aid answering the question of are we achieving our natural resource goals? We will begin our discussion of Capulin Volcano NM's NRCA findings by providing a comprehensive and broader context of the overall resource condition at the monument by answering Parks Canada ecological integrity questions.

5.3 Ecological Integrity at Capulin Volcano NM Sensu Parks Canada Questions

5.3.1 Is the park losing species?

Capulin Volcano NM was established primarily for the nearly perfectly preserved cinder cone, but as a result of the 793 acres (321 ha) set aside to create the monument, other types of natural resources exist as well. However, the relatively small area of the monument precludes it from conserving a wide variety of plants and animals that are typically found in larger areas. The plains bison, (*Bison bison*) historically roamed the area surrounding the monument and shaped the shortgrass prairie plant community, thus serving as a significant shortgrass system driver. Today, the monument's primary herbivore is the mule deer (*Odocoileus hemionus*), which selects plants differently than the bison (Dr. Lauenroth, pers. comm. 2010). Undoubtedly, the monument has lost species over the course of human occupation throughout the surrounding area. But currently, the largest known threat to species loss is due to exotic plant establishment, which is second only to habitat destruction as a threat to wildland biodiversity. However, recent species loss (at least since the early-mid 1900s) cannot be detected given the limited amount of data acquired through recent monitoring efforts.

5.3.2 Are selected indicator species doing well?

Comprehensive inventories and monitoring for taxa are difficult to routinely complete, therefore, species variability and potential loss are also difficult to accurately assess. A more common approach is to use indicator species or a particular taxa group to assess the health and trend of a system. Currently, annual surveys for breeding landbirds, grasslands, and exotic plants occur throughout the monument. Changes in landbird populations may be indicators of changes in the biotic or abiotic components of the environment upon which they depend. They are also highly detectable and can be efficiently surveyed with the use of numerous standardized methods. On the other hand, larger animals typically require larger areas, and given the relatively small size of the monument, it is likely that larger mammals simply pass through periodically, using the habitat for cover and as a food source. The rare species that have been found within the monument, including Capulin goldenrod (*Solidago capulinensis*) and Capulin Alberta arctic butterfly (*Oeneis alberta capulinensis*) have not been systematically surveyed to determine status and trend and may or may not be indicative of overall ecosystem health.

5.3.3 Are the ecosystem trophic levels intact?

A food web is comprised of primary producers, herbivores, and carnivores. Through remote sensing cameras, carnivores such as the mountain lion (*Felis concolor*) and omnivores, such as black bears (*Ursus americanus*) have been photographed within the monument. Furthermore, the photos captured the cougar feeding on a mule deer (*Odocoileus hemionus*) kill, indicating that it located its food source within the monument. Grazers such as mule deer and elk (*Cervus elaphus*) have also been known to use the monument sometimes only during specific seasons (i.e., elk in the winter). The mule deer population throughout the monument appears to be large and may in fact have a detrimental effect on the vegetation, especially since they occupy a different niche, selecting different plants compared to historically endemic species such as the plains bison (*Bison bison*). This may imply an imbalance between predators and prey and cause an imbalance in the grassland vegetation community from historic conditions. However, based upon recent vegetation surveys, the primary trophic levels, which include the photosynthesizers and decomposers appear intact. Additionally, the primary grasses expected for the shortgrass prairie compared to the Natural Resources Conservation Service's ecological site description for this area, include blue grama (*Bouteloua gracilis*) and little bluestem (*Schizachyrium scoparium*), which were the most abundant grasses documented throughout the grassland/fire effects monitoring plots.

5.3.4 Do biological communities exhibit a mix of age classes and spatial arrangements that will support native biodiversity?

The primary vegetation communities comprising 85% of the monument's habitat include piñon pine (*Pinus edulis*) and Rocky Mountain juniper (*Juniperus scopulorum*) (piñon-juniper) habitats and shortgrass prairie grassland communities. Based upon recent monitoring for the grasslands and site visits to the monument by subject matter experts who have studied the ecology of piñon-juniper habitats, nothing observed indicated that the mosaic of the vegetation types and the age class distribution of the piñon-junipers are outside the expected range of variability. Vegetation thinning treatments began in 2004 throughout the monument as a way to reduce the piñon-juniper presence, based upon the belief that those areas thinned were degraded grasslands that had been filled in by piñon-juniper. After careful examination of a variety of information, along with consultation of the piñon-juniper ecologists, we believe the correct reference condition for the piñon-juniper habitats is in fact piñon-juniper (not grassland) and the experts suggested that continued thinning is unnecessary to maintain the ecological integrity of this biological community.

5.3.5 Are productivity and decomposition operating within acceptable limits?

Most systems are driven by primary productivity and when this is disrupted ecosystems can be dramatically affected. Stressed ecosystems can manifest as a disease outbreak or a susceptibility to other environmentally degrading processes, such as plants metabolizing high levels of ozone. Production will decrease as a result of the stressors, weakening the overall health of the ecosystem. So far only small outbreaks of insects and root rot disease have been observed within the monument's plant communities, leading us to believe that productivity and decomposition are operating within acceptable limits.

5.3.6 Is the system cycling nutrients within acceptable limits?

Closely tied to the previous question, when an ecosystem is stressed, nutrient availability becomes a limiting factor in its sustainability. The same types of stressors, such as insect or disease outbreak, as well as reduced groundwater levels, or the impact from air pollutants such as nutrient loading or acidification can have profound impacts upon living systems. To date, none of the monitoring results suggest that the monument's ecosystem appears stressed or outside its natural range of variability for species composition and health within each given vegetation community.

5.4 Resource Briefs

We have compiled the overall condition and trend for each resource topic into a summary table (Table 5.1). In addition, we included the rationale for the condition ratings as well as the data gaps for each resource. These data gaps represent information we believe would help better assess overall conditions and trends. Resource briefs are listed below and include an overall summary of importance, status and trends, and a discussion of each resource topic.

Table 5.1 Overall Resource Condition Summary

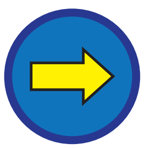
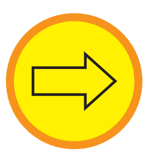
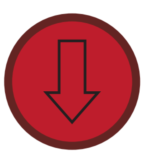
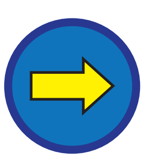
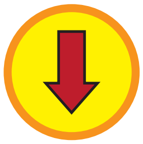
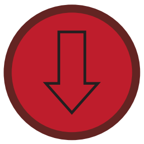
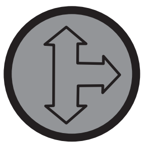
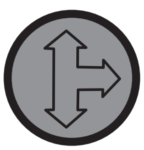
Condition/Trend	Resource	Rationale for Overall Condition/Trend Rating	Data Gaps
		I. Landscape Condition Context	
	Viewshed	The views seen from the top of the cinder cone are sweeping and provide glimpses of the Rocky Mountains on clear days. All indicators for this resource were rated in good condition.	Monument-specific visitor reactions to man-made features within the viewshed, both looking from outside the monument and at the monument while approaching
	Night Sky	The monument has one of the darkest night skies throughout 90+ national parks, with all indicators supporting that claim.	n/a
	Soundscape	The sounds that characterize the monument's soundscape are primarily comprised of its natural ambient sounds that most national park visitors find pleasing.	Monument-specific visitor reactions to human-generated noises throughout the monument's acoustical environments
		II. Supporting Environment Context	
	Air Quality	The majority of indicators were rated as moderate concerns. The most recent level of nitrogen improved from significant concern to moderate, reinforcing the overall moderate condition rating.	Establish ozone and visibility baselines as a basis for future comparisons/references if needed. Determine if ozone damage to the bioindicator species is occurring at the monument
	Geology	The presence and severity of erosion on the cinder cone that is continuing to decline results in a significant concern condition rating.	An understanding of the degree and severity of natural and unnatural erosional processes; comprehensive assessment of remaining geologic features to establish condition baseline
	Groundwater	In a national environment characterized by declining groundwater, the Capulin Basin appears to be in good condition based on monitoring results reported since the 1950s.	Refine and augment information pertaining to existing aquifer basins that influence the area surrounding the monument
		III. Biological Integrity Context	
		Vegetation	
	Piñon-juniper	The overall condition of the piñon-juniper habitats are in good condition and provide some great habitat for nesting landbirds.	Understanding of spatial distribution and age classes to better understand fire regimes and other dynamics; Understanding thresholds for irreversibility of exotic plant invasion into piñon-juniper

Table 5.1 Overall Resource Condition Summary (cont.)

Condition/Trend	Resource	Rationale for Overall Condition/Trend Rating	Data Gaps
		Vegetation (cont.)	
	Grasslands	Even though most of the grassland indicators were good, the risk posed to the biotic integrity from exotic plants degrades the condition to a level of moderate concern.	Understanding thresholds for irreversibility of exotic plant invasion into grasslands
	Exotic Plants	Cumulative effects of exotics, especially the presence of exotic bromes, can ecologically change native plant communities, which results in a significant concern and declining trend.	Comprehensive inventory of exotics on the cinder cone; Understanding thresholds for irreversibility for invasion of exotics
	Capulin Goldenrod	Very little is known about this rare species and it was just recently rediscovered in September 2010 at the monument.	Comprehensive inventory and distribution
		Wildlife	
	Landbirds	A total of 147 bird species have been observed at the monument, and the monument offers high conservation potential for 11 of the species.	Better understanding of reference conditions through space and time
	Capulin Alberta Arctic Butterfly	Very little is known about this species, and it was last observed in the monument in 1996.	Comprehensive inventory and distribution; Long-term monitoring to understand species' dynamic

Capulin Volcano Viewshed Resource Brief

Importance

Capulin Volcano National Monument's viewshed offers spectacular vistas of the surrounding landscape, providing visitors a unique opportunity to take in scenery, not only of New Mexico, but also of neighboring states. The unobstructed view of the Raton-Clayton Volcanic Field, of which Capulin Volcano belongs, has been identified as one of the monument's fundamental resources and values. The viewshed seen by driving the monument's Volcano Road offers 360 degree views as the road spirals to the volcano's top, providing the most comprehensive viewable area the monument has to offer.

Status and Trends

In assessing the quality of the monument's viewshed, housing and road densities were considered, along with the proportion of man-made versus natural features comprising the viewshed area. Additionally, how conspicuous those features are on the landscape when viewed from the monument was also considered to be a significant factor to the quality of the viewshed. At present, greater than 99% of the visible area contains housing densities less than 1.5 units per square mile along with very low road densities. The proportion of the viewshed that is comprised of man-made features is less than 5%, even in the most concentrated developed areas. Characteristics of those man-made features, such as the distance from a viewing point, size, shape, and color or whether the features exhibit movement and/or generate noise, were considered when assessing their impact to the viewshed's quality. Overall, the majority of the man-made features within the monument's viewshed are relatively distant, small, blend with the surrounding landscape, and are located far enough away to minimize noise and/or motion distractions, rendering them by and large inconspicuous throughout the surrounding landscape.

Discussion

The area surrounding the monument is mostly comprised of natural and rural scenes, remaining largely undeveloped. Furthermore, the man-made features that are viewable throughout the monument's viewshed are relatively inconspicuous, resulting in a viewshed that is currently in good condition. Research has shown that people prefer landscapes that are natural versus man-made, especially when visiting a national park. The monument's 2003 visitor study revealed that 94% of the monument's visitors identified sightseeing/scenery as the number one reason they visit Capulin Volcano National Monument. The future condition of the monument's viewshed, primarily comprised of the surrounding scenery, is mainly dependent on local and regional planning since most of the viewshed's viewable area is located outside the monument's boundary.

Capulin Volcano
Night Sky Resource Brief

ROBERT BENNETTS

Importance

Capulin Volcano National Monument's night sky offers spectacular views of starry nights, providing visitors a tremendous recreational opportunity of star-gazing. The night sky has been identified as one of the monument's fundamental resources and values and is among the top 20 darkest night skies measured in 90+ national parks. The monument's night sky is situated along the edge of a "dark hole"-an area largely devoid of light pollution-, which extends from southwest of La Junta, CO to northeast of Las Vegas, NM.

Status and Trends

In assessing the quality of the monument's night sky, three measures were considered-all relating to the darkness of the sky and the lack of artificial light. Two of the measurements, Bortle Dark-Sky and limiting magnitude scales, are commonly used by amateur astronomers, providing a qualitative assessment of night sky darkness. These along with the measurements of sky brightness were collected by NPS Night Skies scientists using charged coupled device cameras that capture night sky images from which sky brightness at the darkest and brightest areas and integrated sky brightness (both whole sky and above 20 degrees)are gathered. At present, the monument has one of the darkest night skies throughout the park service and falls within the Bortle Dark-Sky Class 2, with a limiting magnitude between the range of 7.1. This value corresponds to the low end of Bortle Class 2, though there are many factors that confound an exact translation of one system to another. Regardless, these values represent a truly dark sky and are considered indicators of good condition.

Additionally, he sky brightness values at the monument are consistent with a night sky in good condition, though the data also show the notable impact of light pollution along the horizon.

Discussion

The area surrounding the monument is mostly comprised of natural areas, remaining largely undeveloped. Furthermore, the developments that do exist throughout the surrounding area are relatively small and non-industrialized, resulting in a locally unpolluted night sky that is currently in good condition. Research has shown that 86% of national park visitors surveyed throughout Utah parks considered night sky quality to be somewhat-very important to their visitor experience and stargazing events are the most popular ranger-led program throughout the national parks. The future condition of the monument's night sky, primarily influenced by activities outside its boundary even as far away as 250 km, is mainly dependent on regional planning. Unfortunately night sky degradation, especially in developed countries, is pervasive and has occurred quickly over the past several decades and is expected to continue without conservation efforts.

Capulin Volcano Soundscape Resource Brief

NPS

Importance

The National Park Service considers a park's natural sounds to be comprised of physical resources, including natural (i.e., wind, water sounds, bird songs, leaves rustling, etc.) and/or cultural (i.e., battle reenactments, quiet reverence, living history, etc.). These natural sounds are a park's acoustical resources and are essential to wildlife survival and visitor experiences. The preservation of the monument's acoustical environment is vitally important to overall ecosystem health. The peer reviewed literature widely documents that sound plays a critical role in intra-species communication, courtship and mating, predation and predator avoidance, and effective use of habitat. Additionally, similar studies have shown that wildlife can be adversely affected by sounds and sound characteristics that intrude on their habitats.

While not necessary for survival, national park visitors also prefer sounds of nature and natural quiet while visiting parks. The natural sounds create what is considered to be the natural ambient sound level (baseline condition) within a park, and the locations where these natural sounds occur are referred to as acoustical environments. Noise, on the other hand, is any human-created sound, aside from culturally relevant sounds, that degrades or masks these natural sounds, and is therefore considered undesirable. A person's ability to detect and hear sounds (i.e., audibility) of both natural and human-generated sounds, and how the acoustical environments are perceived by visitors comprise a park's "soundscape".

Status and Trends

At Capulin Volcano NM, a variety of sounds, including wildlife, weather, and anthropogenic noises such as vehicles, conversation, and even aircraft, as well as visitor perceptions of those sounds comprise its soundscape. The levels of noise heard are largely influenced by a given location throughout the monument and by daily and seasonal patterns. Areas where developments are located, providing vehicle access and a concentration of monument visitors (i.e., parking lots) are the most probable locations to experience higher levels of noises due to traffic sounds as well as human conversations. However, due to relatively low visitation, the noises generated, have distinct daily and the seasonal patterns that tend to concentrate the timing of the noise, making noise-free opportunities readily available to any monument visitor.

Discussion

The soundscape condition at the monument is strongly related to its seasonal nature of visitation. Data on monument visitation by month are available from 1979-2010, and in every year during this 32-year period, the number of visitors peaked during the months of

June-August. In 2010, 59% of the total visitation (28,662 visitors) occurred during this time period alone. In addition to the seasonal nature of visitation, there is a daily variation as well. In the monument's 2003 visitor study, 31% percent of visitors surveyed arrived between noon and 2 pm, and 32% of the visitors departed between 1 pm-3 pm. To further refine the monument's visitation pattern, and subsequently identify the noisiest periods within the monument, the 2003 visitor study discovered that 19% of visitors surveyed arrived on Saturday. Given the highly concentrated pattern of visitation at the monument, sounds of nature often prevail, and even during the busiest times, if one is willing to explore areas away from the parking lots, such as hiking the Boca or Lava Flow Trails, natural sounds will abound.

Capulin Volcano Air Quality Resource Brief


MARK DOIRON

Importance

Air quality doesn't just affect the air we breathe, it affects many air quality related values, such as visibility and natural and cultural resources. Air quality in national parks, which includes Capulin Volcano National Monument, is protected by the Clean Air Act and by the National Park Service (NPS) Organic Act. Understanding how directly linked air quality is to the health of the monument's resources can help with interpreting changes that occur in vegetation resulting from elevated levels of ozone or elevated levels of nitrogen or sulfur. High levels of these compounds can result in vegetation damage through acidification or nutrient loading to ecosystems or through disrupting metabolic processes, creating an extra stress to resources. Air quality can also impact visibility, which is significant to many national park visitors. In 2003, a visitor study was conducted at the monument and 94% of visitors stated that sightseeing was their main activity while visiting the monument. If visibility is impacted by poor air quality in the form of haze, visitor experiences will be greatly impacted and the sweeping views afforded from the top of the monument's volcano will be obscured.

Status and Trends

There are different facets to air quality including ozone levels, visibility conditions, and atmospheric wet deposition levels. Currently, the monument staff monitor atmospheric wet deposition levels directly on site, and the ozone and visibility conditions are assessed by the NPS Air Resources Division scientists by interpolating data collected throughout the United States.

Atmospheric wet deposition monitoring began at the monument in 1984 as part of the National Atmospheric Deposition Program/ National Trends Network atmospheric deposition monitoring program. Weekly samples are collected and sent to a chemical lab where analyses are performed to determine the levels of nitrogen, sulfur, and ammonium at the monument. These levels are annually averaged, providing results in kilograms per year per hectare. To date, nitrogen, sulfur, and ammonium levels have been high enough to be of a moderate concern. Currently, the condition for ozone and visibility at the monument is also of moderate concern.

Discussion

The monument's air quality is largely influenced by activities and operations that occur outside its boundary. As a result, monitoring for damages related to higher levels of ozone or nitrogen, sulfur, or ammonium may provide insight into resource impact. For example, the monument contains four known ozone bioindicators, which are plants that are more susceptible to injury from higher ozone levels. Increased uptake of ozone can result in leaf stippling (browning), weakening a plant's resistance to other stressors. But as with many living systems, it is not just the presence of high ozone levels that induce injury. Other conditions, such as degree of moisture, length of ozone exposure, and existing stressors to the plants, such as competition from non-native plants, also play critical roles in the possibility of damage when higher levels of ozone are present. Ultimately, the current and future condition of the monument's air quality condition is primarily dependent on local, regional, and even national planning.

Capulin Volcano
Geology Resource Brief

Importance

The "striking example of the recently extinct volcano" is the very reason Capulin Volcano was proclaimed as a national monument by President Woodrow Wilson in 1916. Capulin Volcano is a cinder cone and is part of the Raton-Clayton Volcanic Field that covers 7,500 square miles of northeastern New Mexico. The volcano erupted approximately 59,100 years ago (± 6,000 years) and is unique in that it reaches an approximate height of 1,300 feet (396 m) and is nearly intact in spite of its explosive origin. Visitors are offered a unique sightseeing opportunity by driving Volcano Road, which spirals around this extinct volcano, ending at the top. The sweeping vistas from the top of the volcano not only include the surrounding High Plains and distant Rocky Mountains, but also the different types of volcanic features, such as lava flows and tumuli-small, dome-shaped mounds on the surface of a lava flow-that add to the beauty and uniqueness of Capulin Volcano National Monument.

Status and Trends

There are many geologic features throughout the monument, but the condition assessment focused on the cinder cone since it is the most prominent feature in the monument and comprises over half (56%) of the monument acreage. Erosion is a natural process and can be expected to occur on a feature such as the volcano, especially due to its highly erodible soils and steep slopes. But the acceleration of erosion, specifically below Volcano Road, and the severity of erosion are the result of the road's impervious surface and the concentrated runoff. Much of the accelerated erosion that is occurring below the road is typically located where culverts have been placed, concentrating and increasing the velocity of the rainfall and snowmelt, scouring the mountainside. Accelerated erosion also occurs where sheets of runoff flow off of the road's surface. Sixty-six percent of the 29 culverts are showing signs of accelerated erosion. Additionally, many of these areas are exhibiting severe erosion, with some gullies extending all the way down the mountainside to the bottom grasslands. Gully widths were also measured to determine erosion severity, showing high variability, with the widest gully measured at 390-feet across. Overall, the high proportion of culverts exhibiting accelerated and severe erosion indicate a significant concern for the condition of the cinder cone.

Discussion

The geologic resources located throughout the monument are unique and varied, however, none are as prominent nor possess the steep slopes and loose soils as found on the volcano.

Additionally, the volcano itself is the reason it was proclaimed a national monument, elevating the significance of this resource to the monument's establishment. As with many situations, coupling preservation with resource access is a fine balance. This is the situation with preserving the volcano, while providing access to the top via Volcano Road-the very development that is causing the accelerated and sometimes severe erosion to the cinder cone.

Capulin Volcano
Groundwater Resource Brief

NPS

Importance

Capulin Volcano National Monument's groundwater originates from the aquifer known as the Capulin basin. The basin is not fully mapped but covers at least an area 150 miles square and mainly extends to the north, south, and west of the monument. The groundwater provides fresh drinking water to visitors and local residents, as well as to the vegetation that is found growing throughout the monument. The monument is located in a semi-arid region of New Mexico, which increases the demand for groundwater, and the New Mexico Office of Engineers expects the state's population will nearly double to 3.68 million by 2060, also increasing the demand for this precious resource.

Status and Trends

United States Geological Survey scientists have developed a national network of water monitoring and have been monitoring three wells located in the Capulin basin since the 1950s. Both water levels and water level elevations are recorded, at least annually, which are used to assess the change in groundwater level. The data suggest that water level elevations (i.e., how far the water rises in the well) are declining, and that, in fact, depths to the water are increasing in two of the three wells. The third well shows the opposite circumstance, which may simply be a result of localized water usage. It is very possible that localized water level fluctuations occur depending upon its ability to recharge by transmitting more water to the basin if precipitation is available or if demand for groundwater has increased within that area.

At this point, there is very weak evidence suggesting a possible overall decline in the trend of groundwater level but additional monitoring over the next several years will help to shed some light on this possibility.

Discussion

The most common livelihood surrounding the monument is ranching, which requires far less groundwater than that required for agricultural purposes. New Mexico water planning officials in the local counties surrounding the monument predict that groundwater supply will continue to meet local demand, provided populations do not drastically increase. Also land subsidence, a settling or sinking of the Earth's surface, and vegetation browning due to a reduction in groundwater would suggest a significantly depleted aquifer but are not evident throughout the area. Given the fact that groundwater decline is a national concern, the Capulin basin represents an exception to the general concern of groundwater depletion.

Capulin Volcano
Piñon-Juniper Resource Brief

Importance

Piñon pine (*Pinus edulis*) and Rocky Mountain juniper (*Juniperus scopulorum*) (piñon-juniper) is one of the major habitat types found within Capulin Volcano National Monument and comprises approximately 59% of the monument's total area. Piñon-juniper habitats have considerable value to wildlife by providing cover, particularly during the winter for large mammals such as mule deer (*Odocoileus hemionus*) and elk (*Cervus elaphus*), and food in the form of piñon nuts and juniper berries for many bird species, including the Pinyon Jay (*Gymnorhinus cyanocephalus*). Piñon-juniper habitats also contribute to biological diversity in other ways. For example, along the monument's east crater rim a distinctive community of well-developed foliose lichens grow. These lichens are relatively uncommon and are only found on a few isolated mountain tops in New Mexico where clouds and mist provide moisture to support the growth of these lichens.

Status and Trends

There are four types of piñon-juniper habitat throughout the monument including persistent piñon-juniper woodland, piñon-juniper shrubland, piñon-juniper savanna, and piñon-juniper persistent woodland patches interspersed among grassland. Through repeat photography analysis of photos from the early 1900s to present day, as well as interviews with long-time local residents, it is evident that piñon-juniper habitats were present, and even well established in some areas (i.e., south and east sides), on the cone at least since the turn of the century. A fire study conducted within the monument revealed that out of seven trees examined along the cinder cone, no fire scars for a 250-year period (1790-2004) could be found. In fact, some trees sampled were ≥485 years old, indicating the presence of piñon for some time. Piñon-juniper experts visited the monument to assess the overall condition of all four piñon-juniper habitat types. They determined the overall condition was good, and that the species present, age class distributions, stand densities, and current level of insects or diseases were all within the normal range of variability for the monument's piñon-juniper habitats.

Discussion

Piñon-juniper habitat, in general, has often been misunderstood as being an "unnatural" habitat that has degraded other habitats, such as grasslands, by infilling previously unoccupied areas. This has been the prevailing view for some time for the monument's piñon-juniper habitat, but based upon recent information and discussions with researchers who have studied this plant community throughout the United States, it is believed that the piñon-juniper habitat types throughout the monument are healthy systems, supporting a wide variety of native plants and animals that helps make the monument a truly unique area.

Capulin Volcano Grasslands Resource Brief

ROBERT BENNETTS

Importance

The central grassland region of North America is one of the largest contiguous grassland environments on earth. Capulin Volcano National Monument (NM) is located within the region generally classified as shortgrass steppe, which is located in the warmest and driest area and is the least productive of all grassland types, uniquely adapted to survive drought conditions. Grassland as a whole is the second largest habitat type found within the boundaries of the monument and comprises approximately 26% of the total area based on recent vegetation mapping efforts by Muldavin et al. (2011). The monument's grassland habitat is located along a transition zone, "where the Rocky Mountains meet the High Plains". It is also situated within the Raton-Clayton Volcanic Field, creating an ecotone whose plant assemblages do not necessarily "fit" other Rocky Mountain or shortgrass prairie molds. As a result, there is considerable variation in the types of grasslands found throughout the monument.

Status and Trends

Scientists with the National Park Service Southern Plains Inventory and Monitoring Network, along with the Southern Plains Fire Group, have been annually monitoring the grasslands at the monument since 2010. Using the data from this monitoring effort, the biotic integrity of the grasslands were assessed, including plant mortality, the presence of exotic plants, and the species composition of the grasslands. The plant mortality was within the expected range of variability, in spite of the fact that sampling occurred during a drought period at the monument. The species that were most commonly found included little bluestem and blue grama grasses. The total number of perennials (n = 56) accounted for 76.7% of the total of species recorded (n = 73). With the exception of the widespread invasive exotic bromes, the species present throughout the monument's grasslands are consistent with what might be expected given the ecological conditions at Capulin Volcano NM. Another aspect of grassland condition is its soil stability, which is a site's ability to limit redistribution of its soil/substrates by wind and water. This aspect was assessed in 2010 by Dr. Pete Biggam, a soil scientist with the NPS Geologic Natural Resources Program Center Geoscience and Restoration Branch, and he determined the overall condition of the monument's grasslands relative to site stability to be in good condition.

Discussion

Grasslands are a dynamic system with much annual variability. The amount (or lack of) rainfall, temperatures, and diseases can have a dramatic effect on some plants, which in turn, affects interpretation of grassland condition. The relatively unique ecological conditions of Capulin Volcano NM, with its volcanic influence, make comparisons to other grassland sites difficult. The absence of any multi-year datasets from a site with similar conditions additionally limits our ability to assess the "normal range of variability" for plant species composition. However, the most significant threat to the condition of the monument's grasslands is the proliferation of invasive exotic plants. Monitoring over a longer period of time is necessary to better understand the complexity and natural variation that occurs within a grassland community, such as that found at Capulin Volcano National Monument.

Capulin Volcano
Exotic Plants Resource Brief

FOREST & KIM STARR, STARR ENVIRONMENTAL, BUGWOOD.ORG

Importance

Exotic plants represent one of the most significant threats to natural resources in national parks. Exotic plants are a concern due to their abilities to reproduce prolifically, rapidly colonize new areas, displace native species, alter ecosystem processes across multiple scales, and detract from the interpretive value of park resources. In the Great Plains, grasslands have been increasingly degraded and fragmented, which results in increasing chances of exotic plant species invasions.

Status and Trends

The Southern Plains Inventory and Monitoring Network began annual monitoring for exotic plants throughout Capulin Volcano National Monument in 2009. High priority vectors (e.g., roads and trails) were identified based on their potential risk for invasion by exotic plants, and the highest priority vectors were surveyed in 2009 and 2010. Species that posed the greatest risk to the monument based on their significance of impact and feasibility of control/management were determined. Not only did the exotic bromes have the highest ranking for their significance of impact, but they also were among the most widespread within high-risk areas (i.e., those along the high priority vectors). Collectively, at least one of the three exotic bromes was observed in 92% of the high-risk blocks surveyed in 2009 and 2010. Even individually, the exotic bromes had three of the highest four overall percentages of occurrence. The relative order of proportion of plots infested was similar to the high priority blocks with a few notable exceptions. For example, mullein was found in the highest proportion of any species, regardless of whether it was found in high priority or interior sites. In contrast, smooth brome, which was detected on 54% of the high priority blocks was not detected on any of the interior plots; thus, suggesting that its present distribution is largely limited to along roads and trails. Both bindweed and kochia are currently not widespread but are becoming well established, particularly along the entrance road and along the southern and eastern monument boundary.

Discussion

There is often a time lag between the initial establishment of an invasive exotic and its rapid expansion toward local carrying capacity. Therefore, early detection and subsequent eradication is essential. The exotic brome species are of high concern not only because of their potential ecological impact, but also because their distribution is widespread, and they are continuing to spread throughout the monument. It is also worth noting that the distribution of exotic bromes is not known to be widespread on the surrounding landscape adjacent to the monument. Exotic plant control efforts at the monument have been ongoing, with the help of a local youth organization and the NPS Chihuahuan Desert/Southern Shortgrass Prairie Exotic Plant Management Team. Continued work towards detecting and controlling exotic plants will help protect the plants and wildlife that depend upon those habitats for their survival.

Capulin Volcano
Capulin Goldenrod Resource Brief

Importance

Capulin Volcano National Monument is located within a vegetative transitional zone between the Rocky Mountains and shortgrass prairie, supporting a relatively high diversity of habitats for wildlife and plants not found elsewhere in the surrounding grasslands. Capulin goldenrod (*Solidago capulinensis*), is a rare plant found at the monument, and was first described and collected in 1936 by Cockerell and Andrews. It has not been included in any subsequent account of the New Mexico or United States flora. Capulin goldenrod was rediscovered at the Pueblo Colorado Nature Center, Pueblo, Colorado, which prompted a new survey within the monument in September 2010 by Dr. Tim Lowrey of the Museum of Southwestern Biology at University of New Mexico. Dr. Lowrey found Capulin goldenrod growing throughout the monument and re-identified it as a rare endemic plant. It is the only known rare vascular plant species found to occur within the monument.

Status and Trends

Floristic surveys throughout the monument are limited and only include two. Parmenter at al. (2000) conducted a rare-species inventory and Johnson et al. (2003) completed a comprehensive floristic survey. Results from both surveys reported no rare plants found within the monument. Between 2005 and 2009, Natural Heritage New Mexico completed a vegetation classification and mapping project for the monument. Plant species were recorded from within vegetation plots but did not include Capulin goldenrod. The intention of the Natural Heritage study was to detect dominant plant species versus a detailed floristic survey, detecting rare species.

To date, two informal surveys have been conducted to specifically document the presence of Capulin goldenrod in the monument, however, its abundance and distribution are not well known at this time.

Discussion

Rare plants have a mystique about them that perhaps more abundant plants don’t possess. It’s most likely due to the fact that they are in fact different from all those other surrounding plants and that the rare plants have evolved in a certain unique way, responding to environmental influences unlike any other. Typically, rare plants have a narrow geographic range, restricted habitat, and small populations. These factors can sometimes limit the knowledge base regarding its ecology and potential threats, creating a situation that is harder to manage for. With a species like Capulin goldenrod, local planning and conservation efforts become more important to furthering the understanding of a rare species such as this, as well as its continued survival.

Capulin Volcano Landbirds Resource Brief


ROBERT SHANTZ

Importance

The National Park Service's mission is to manage park resources "unimpaired for future generations." Protecting and managing some of our nation's most significant natural resources requires basic knowledge of the condition of ecosystems and the species that occur in national parks. Landbirds are a conspicuous component of many ecosystems and changes in their populations may be indicators of changes in the biotic or abiotic components of the environment upon which they depend. Relative to other vertebrates, landbirds are also highly detectable and can be efficiently surveyed with the use of numerous standardized methods.

Status and Trends

In 2009, Rocky Mountain Bird Observatory (RMBO) began systematic surveys of birds at Capulin Volcano NM as part of the Southern Plains Inventory and Monitoring program. In total, there have been 147 bird species reported at the monument on previous checklists, however, 86 of those species have not been observed during the 2009-2011 RMBO surveys. This is not surprising since the RMBO surveys are conducted during the breeding season, whereas the checklists include all seasons. Further, the monument is not within (or close to) the primary breeding range of 34 of those species and lacks breeding habitat for an additional 33 species. Thus, only 19 species were not observed on recent RMBO surveys that are within (or close to) their primary breeding range with some reasonable breeding habitat found within the monument. Of the 19 species not observed by RMBO, there were only two species (Bushtit and Black-throated Gray Warbler) to have what we considered good breeding habitat conditions at the monument, and both of those species are on the edge of their breeding ranges and both have always been considered uncommon or rare at the monument based on previous checklists.

There are no bird species listed by the U.S. Fish & Wildlife Service as endangered or threatened (in New Mexico) that occur at Capulin Volcano NM. In addition, there are no bird species that occur at the monument that are listed as endangered by the state of New Mexico; however, there are three species (Bald Eagle, Peregrine Falcon, and Gray Vireo) that are listed as threatened. Of these, only the Gray Vireo has sufficient habitat to warrant attention, but the monument is generally considered outside of its breeding range.

There have been a myriad of organizations that focus on the conservation of bird species. Differences among such lists in the species they include reflect the varied goals and priorities of the sponsoring organization. This has, and continues to be, a source of confusion and perhaps frustration, for managers that need to make sense and apply the applicable information. We present lists of species of concern for several of the more prominent organizations, and then attempt to summarize them in the context of condition at the monument. Of the 60 species listed by one or more organizations as being of conservation concern, we believe that 11 have sufficient habitat at the monument to be considered as having high conservation potential, and most of these have been observed at the monument during recent years. Only two species two (Black-throated Gray Warbler and Gray Vireo) have not been observed on recent RMBO surveys, and both of these two are thought to be outside (but on the edge of) their primary breeding range. Both of these species have also never been considered more than rare or transient at the monument.

Discussion

Currently, the assessment of landbirds at Capulin Volcano NM is based on limited data (three years), however, nothing to date warrants any concern for birds at the monument. Comparing recent surveys to previous species checklists for the monument, the few species that were reported to have been common or abundant that were not seen during recent RMBO surveys are not especially surprising and are more likely to reflect anomalies in the previous checklists rather than a major shift in the occurrence of those species. Similarly, there was nothing particularly surprising or alarming when comparing species observed during recent RMBO surveys to the species observed in piñon-juniper and grassland habitats within the surrounding region. We found 11 species that we believe have relatively high conservation potential, and most of these have been observed numerous times at the monument during recent years. Overall, we consider the condition of birds at the monument to be good. Unfortunately, we do not have sufficient data to justify a trend in that condition, although ongoing monitoring should provide such an estimate for future assessments.

Capulin Volcano
Capulin Alberta Arctic Butterfly Resource Brief

ROBERT SHANTZ

Importance

North American butterflies belonging to the genus *Oeneis* may be referred to as "arctics" in recognition of the windy, often high-elevation, tundra-like habitats they generally inhabit. The Capulin Alberta arctic butterfly (*Oeneis alberta capulinensis*) is one such species and was first found by Brown, an entomologist with the American Museum of Natural History, at Capulin Volcano National Monument's (NM) crater rim in 1969. It was soon determined to be a new subspecies that is known only to Capulin Volcano NM and some nearby areas on the Raton Mesa complex (Union and Colfax counties, New Mexico), but it is not listed as a state or federally threatened or endangered species. It is, however, identified as a Species of Greatest Conservation Need in New Mexico's Department of Game and Fish Comprehensive Wildlife Conservation Strategy.

Status and Trends

The Alberta arctic butterfly is described as small and as having variable coloration, from light to darker grayish-brown. The butterfly's underside is lighter than the upper side, and the female may appear brighter in color than the male. The monument's habitat for the Capulin Alberta arctic butterfly has been identified as Arizona fescue-mountain muhly grassland that is located at the top of the volcano.

Since it was first identified in 1969, it has been observed an additional six times at the monument, with the last observation occurring in 1996. A formal survey was last conducted in 2004 to determine its abundance and distribution. Although none were detected throughout the monument during the 2004 survey, they were observed at other locations throughout Johnson Mesa, but in lower numbers compared to previous years' surveys.

Discussion

The Capulin subspecies of the Alberta arctic butterfly faces potential threats in its range. Because of the population's small size, natural or human impacts could threaten the existence of this subspecies. Additionally, there are several types of uncertainties involving the natural history/biology of the Capulin Alberta arctic butterfly and its occurrence at the monument. The lack of professionally conducted, systematic surveys, along with the species' natural variability, makes it very difficult to determine presence/absence. Additionally, wind and other climatic factors can affect when and/or whether the butterflies fly (and therefore are observable). Even aspects of the butterfly itself may make it difficult to survey. Brown described the Capulin Alberta arctic butterfly as rarely flying "until it is kicked out of the grass clumps". When the butterfly does fly, its flight is erratic, rapid, and low, often less than a foot above the grass. Additionally, Brown reported only males flying; female butterflies seen on the ground were either crawling among the grass clumps or disappearing into crevices among the cinders. The butterfly also flies in only one generation per year (completes one breeding cycle). Systematic surveys for the Capulin Alberta arctic butterfly, both locally and regionally, may help provide the information that is necessary to assist with the conservation of this rare species.

5.5 Implications of resource conditions to the monument

The NPS NRCAs are not intended to recommended what management actions should or should not be taken at a given park; however, we do feel that it is important to discuss what we believe are some of the management implications of certain resource conditions, along with other factors, so management can determine appropriate potential future action.

What we discovered for the viewshed topic is that often times the greatest viewshed impact was from man-made features within the closest proximity of a viewing area. This was true for the monument since its visitor and park facilities are all located within the foreground distance class zone (<1 mile). Having a better understanding of how color/shape/size/object movement influences visitor response may provide valuable information for future local planning related to choices and actions and regional planning related to larger development.

For night sky condition, local choices such as where or where not to light, as well as choosing night sky compliant lighting, will help maintain the monument's very dark night sky resource. In addition, interaction and involvement with local and regional planning may help guide decisions related to night sky preservation. For example, Clayton Lake State Park has been involved with a dark sky preservation program to raise awareness and to protect its dark sky resource throughout its local community.

We believe the main concern for the geologic resources at the monument is the ongoing erosion along Volcano Road and also believe that finding ways to mitigate this erosion is extremely important to the continued preservation of the cinder cone. And finally, for exotic plants, grasslands, and piñon-juniper habitats, an understanding of the efficacy of alternative exotic plant control methods/treatments is important for the continued preservation of vegetation communities throughout the monument.

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Appendix A: Team Members and Subject Matter Experts

Table A.1. Capulin Volcano NM NRCA Project Team Members

Capulin Volcano National Monument NRCA Project Team
Jeff Albright, NPS Water Resources Division's Coordinator of the NRCA Series
Peter Armato, NPS Capulin Volcano NM Superintendent
Rob Bennetts, NPS Southern Plains Inventory and Monitoring Network Program Manager
Lynn Cartmell, NPS Capulin Volcano NM Park Ranger
Zachary Cartmell, NPS Capulin Volcano NM Resource Management
Tomye Folts-Zettner, NPS Southern Plains Inventory and Monitoring Network Biologist
Almeta Helmig, NPS Capulin Volcano NM, Biological Science Aide
Rebecca Richmond, NPS Capulin Volcano NM, SCA Intern
Heidi Sosinski, NPS Southern Plains Inventory and Monitoring Network Data Manager
Kim Struthers, NPS Capulin Volcano NM Natural Resources Program Manager
Patty Valentine-Darby, University of West Florida, Biologist and Writer/Editor
Emily Yost, Utah State University Science Communication Specialist

Table A.2. Capulin Volcano NM NRCA Subject Matter Experts

Subject Matter Expert	Topic	Project Deliverables
Jeff Albright, National Park Service Water Resources Division, Natural Resource Condition Assessment Series Coordinator	All	Program Level Review
Cheryl McIntyre, Sonoran Institute Ecologist	Viewshed	Viewshed analyses
Melanie Myers, Colorado State University GIS Analayst	Viewshed	Viewshed analyses
Carol McCoy, National Park Service Chief, Policy and Regulations Branch, Geologic Resources Division; Natural Resource Program Center	Viewshed	NPS Guidance on viewshed
John Reber, National Park Service Intermountain Regional Office, Physical Scientist	Viewshed	NPS information on windfarms and viewsheds
Mark Brunson, Professor & Department Head, Environment and Society; Utah State University	Viewshed	Review of viewshed section
Darcee Killpack, Regional GIS Coordinator National Park Service Intermountain Region	Viewshed	Review of viewshed section
Bob Sullivan, Argonne National Laboratory; Department of Energy	Viewshed	Review of viewshed section
Chad Moore, National Park Service Night Sky Program Manager	Night Sky	NPS guidance on night sky monitoring and review of night sky section
Kurt Fristrup National Park Service Natural Sounds Program Scientist	Soundscape	Review of soundscape section
Lelaina Marin National Park Service Natural Sounds Program Planner	Soundscape	Review of soundscape section
Ellen Porter, National Park Service Air Resources Division	Air Quality	Review of air quality section
Tim Connors, National Park Service Geologic Resources Division Geologist	Geology	Review of geology section
Bruce Heise, National Park Service Geologic Resources Division Geologist	Geology	NPS guidance on geology, site visit May 2011, and review of geology section

Table A.2. Capulin Volcano NM NRCA Subject Matter Experts (cont.)

Subject Matter Expert	Topic	Project Deliverables
Katie KellerLynn, Colorado State University, Research Associate	Geology	Review of geology section
Dave Steensen, National Park Service Geologic Resources Division, Division Chief	Geology	Review of geology section
Deanna Greco, National Park Service Geologic Resources Division, Geologist	Geology and Pinon-Juniper	NPS guidance on geology and site visit April 22, 2010 to assess piñon-juniper vegetation relative to volcanic cone erosional processes
Pete Biggam, National Park Service Geologic Resources Division Soil Scientist	Geologic Resources, Grasslands, and Pinon-Juniper	NPS guidance on soils, site visit to conduct soils rapid assessment November 2010
Colleen Filippone, National Park Service Sonoran Desert Inventory and Monitoring Network Regional Hydrologist	Groundwater	NPS guidance on groundwater and reviewed groundwater section
Craig Allen, U.S. Geological Survey Fort Collins Science Center Jemez Mountain Field Station Research Scientist	Piñon-Juniper	Provided expert opinion on piñon-juniper ecology during July 2010 field visit
Brain J. Jacobs, National Park Service Bandelier NM Vegetation Ecologist	Piñon-Juniper	Provided expert opinion on piñon-juniper ecology during April 22, 2010 field visit and submitted trip report
William H. Romme, Department of Forest, Rangeland, and Watershed Stewardship, Colorado State University Professor	Piñon-Juniper	Provided expert opinion on piñon-juniper ecology during April 22, 2010 field visit and submitted trip report. Reviewed pinon-juniper section.
Alan Knapp, Colorado State University Department of Biology Professor	Grasslands	Provided expert opinion about grasslands during a September 2010 visit to Colorado State University
William Lauenroth, University of Wyoming Plant Community Ecology and Ecohydrology Professor	Grasslands	Provided expert opinion about grasslands during a September 2010 visit to University of Wyoming
Patrick Wharton, National Park Service Chihuahuan Desert/Southern Shortgrass Prairie Exotic Plants Management Team Acting Liason and Team Leader	Exotic Plants	Provided expert opinion on exotic plants and reviewed Exotic Plants section
Tomye Folts-Zettner National Park Service Southern Plains Inventory and Monitoring Network Biologist/ Botanist	Grasslands and Exotic Plants	Provided expert opinion on grasslands and exotic plants and reviewed both the Exotic Plants and Grasslands sections
Dr. Timothy Lowrey, Museum of Southwestern Biology at University of New Mexico, Professor of Biology, Curator for University of New Mexico Herbarium,and Associate Chair for the Department of Biology and Museum of Southwest Biology	Capulin Goldenrod	Conducted a survey for Capulin goldenrod at the monument in September 2010.
Guy Nesom is a researcher, writer, editor, and teacher in biological science since 1980.	Capulin Goldenrod	Expert on goldenrods of western North America.
Ross Lock Rocky Mountain Bird Observatory Wildlife Biologist	Landbirds	Assembled regional landbird information, provided consultation and review of landbirds section
Chris White, Rocky Mountain Bird Observatory Wildlife Biologist	Landbirds	Assembled regional landbird information, provided consultation of landbirds section
Steven Cary is the former Chief Naturalist for New Mexico State Parks	Capulin Alberta Arctic Butterfly	Provided information on regional surveys for the butterfly and habitat at Capulin Volcano NM and reviewed Butterfly section.

Appendix B: Viewshed Analysis Steps

The process Cheryl McIntyre used to complete the Capulin Volcano NM's viewshed analyses is listed below.

Downloaded spatial data from Internet.

Downloaded 1/3 arc second national elevation dataset (NED) grid (roughly equivalent to a 30 m digital elevation model [DEM]) from The National Map Seamless Server (http://seamless.usgs.gov/). The x and y values for the NED are in arc seconds while the z data are in meters. Projected NED into NAD83 UTM 13 to get all data in meters.

Downloaded Capulin Volcano National Monument boundary, roads, and trails layers from NPS Data Store (www.nps.gov/gis).

Prepared Observation Point layers for Viewshed Analyses.

Created point layers for entrance and upper parking lot.

Used Edit > Create New Feature tool to create 36 points for the entrance shape file (Entrance.shp) and 64 points for the upper parking lot shapefile (ParkingLot.shp).

Extracted Volcano Road from "roadstrails" layer downloaded from NPS Data Store to create one shape file for the Volcano Road (CAVO_road.shp).

Added field named "OFFSETA" (type = double) to shapefile and set value to 1.68 for each record in the attribute table. The value of 1.68 in the field "OFFSETA" represents an observer height of 1.68m (~5'6").

Ran Viewshed Analysis using ESRI 3D Analyst Viewshed Tool.

Using the Viewshed Tool in ESRI's ArcGIS 9.3, 3D Analyst Toolbox, ran viewsheds using the following inputs.

Input raster = 1/3 arc second NED.

Input polyline observer feature = CAVO_road.shp.

After the viewshed analyses were complete, housing and road density data were obtained and modified to depict past, present, and future densities around the monument. These datasets were created by the NPS's Natural Resource Program Center by compiling and analyzing landscape-scale US Census Bureau data that linked measurable attributes of landscape (i.e., road density, population and housing density, etc.) to resources within natural resource based parks. This resulted in the creation of a dataset titled NPScape (Budde et al. 2009; Gross et al. 2009). The following modifications were made to NPScape data for purposes of this assessment:

Downloaded spatial data from Internet.

Downloaded monument-specific NPS-cape data from NRInfo (http://nrinfo).

Simplified NPScape Housing Density Projections.

Converted Capulin Volcano NM 30 km housing density projection rasters to polygon shape files.

Deleted records categorized as "Private Undeveloped" and "Urban-Regional" Park.

Combined classes to reduce number of original classes to five (Table B.1).

Table B.1. The original classes from NPScape and new classes assigned to housing densities for this assessment of the viewshed at Capulin Volcano NM

Original Class	New Class
Private undeveloped	Private undeveloped
<1.5 units/square km	<1.5 units/square km
1.5–3 units/square km 4–6 units/square km	1.5–6 units/square km
7–12 units/square km 13–24 units/square km 25–49 units/square km 50–145 units/square km 146–494 units/square km 495–1234 units/square km	> 6 units / square km

Appendix C: Culvert Erosion Photos

ALMETA HELMIG

Culvert 1 - Top

ALMETA HELMIG

Culvert 1 - Top

ALMETA HELMIG

Culvert 2 - Top

ALMETA HELMIG

Culvert 4 - Top

ALMETA HELMIG

Culvert 4 - Top

ALMETA HELMIG

Culvert 7 - Top

Culvert 8 - Top

Culvert 9 - Top


ALMETA HELMIG

Culvert 10 - Top


ALMETA HELMIG

Culvert 10 - Top

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Culvert 10 - Top

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Culvert 15 - Top

Culvert 16 - Top

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Culvert 22 - Bottom

Culvert 23 - Top

Culvert 24 - Top

Culvert 24 - Top

ALMETA HELMIG

Culvert 25 - Top

ALMETA HELMIG

Culvert 26 - Top

Culvert 27 - Top

Culvert 27 - Bottom

Culvert 28 - Top

Culvert 28 - Bottom

Culvert 29 - Top

Appendix D: Trip Reports from Piñon-Juniper Subject-Matter Experts

It was not the intention of this condition assessment to evaluate management options for natural resources at Capulin Volcano N.M.; however, during the site visits by our subject-matter experts, there was interest by CAVO staff in their views of management options. As such, some discussion of management options was included in the trip reports of William H. Romme and Brian Jacobs, which have been included in their entirety, as submitted, below:

D.1 Trip Report from William H. Romme (23 April 2010)

Assessment of Vegetation Conditions and Impacts of Past Fire Exclusion at Capulin Volcano National Monument, New Mexico

William H. Romme, Department of Forest, Rangeland, and Watershed Stewardship,
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-- April 23, 2010 --

A widespread perception of southwestern piñon-juniper woodlands is that these ecosystems were grassy savannas maintained by periodic fire prior to Euro-American settlement, and that trees have become unnaturally dense as a consequence of fire exclusion during the past century. In this view, recent high-severity fires in piñon-juniper are regarded as unfortunate side-effects of unnatural vegetation and fuel conditions. Thus, it is often recommended that woodlands be restored to their presumed former low-density structure by mechanically thinning the trees and conducting prescribed low-severity burning. However, a recent workshop brought together 15 fire scientists from across the West, all of whom have worked extensively in piñon-juniper vegetation, to evaluate historical dynamics of southwestern woodlands. The group concluded that the low-density, fire maintained savanna is only one of three unique types of natural piñon-juniper woodland (Romme et al. 2007, 2009). The other types include persistent piñon-juniper woodlands, in which historical fires were infrequent and naturally high-severity, and wooded shrublands, in which tree abundance waxed and waned in response to climatic fluctuation and disturbance by fire and insects. This group of scientists emphasized the importance of identifying which type of piñon-juniper vegetation is present in any particular area, and of applying management appropriate to that type.

Previous assessments of the piñon-juniper vegetation in Capulin National Monument have assumed that this is a former savanna that has become unnaturally dense because of fire exclusion. However, this assumption has not been critically evaluated in the context of the three different types of piñon-juniper vegetation identified by the scientists' recent synthesis. I visited Capulin on 4/22/2010 to evaluate the historical conditions and dynamics of the Monument's piñon-juniper woodlands. I toured the area with Monument staff and discussed management history and other issues related to the likely ecological effects of fire exclusion during the past century. The following is my assessment of historical and current vegetation conditions in the Monument, and the ecological significance of changes that have occurred during the past century.

historical and current vegetation conditions in the Monument, and the ecological significance of changes that have occurred during the past century.

I determined that two different types of piñon-juniper vegetation (Romme et al. 2009) are present on the Monument. A ***piñon-juniper savanna*** is found on the flat or gently-sloping terrain surrounding the cinder cone, and a ***persistent piñon woodland*** covers the cone itself. The evidence for this interpretation is as follov gentle terrain surrounding the cone has a relatively well-developed soil that supp grass cover in this climatic setting. The climate also is conducive to tree growth scattered trees are present within the grassland matrix. There is evidence (Guye Stambaugh, undated) that fires recurred periodically in this area prior to the onse cattle grazing ca. 1860 (although fires were not as frequent as has been assumed below). All of these characteristics are consistent with a ***pinon-juniper savanna*** tree density fluctuated in response to climatic variability and episodic fire.

Soils on the cinder cone are very coarse-textured, with high cover of bare rock, do not support a dense grassland. However, this kind of soil within this climatic ideal for trees. The relatively sparse herbaceous cover is not conducive to sprea severity surface fires, but high-severity crown fires can spread from tree to tree windy conditions. All of these characteristics are consistent with a ***persistent pi juniper woodland*** in which tree density fluctuated with climatic variation and in disease caused mortality, and in which severe fires periodically killed most of th and initiated a slow re-establishment of dense woodland.

The most striking vegetation change since the Monument was established in 191 dramatic increase in tree density that has occurred on the cinder cone. This incr very apparent in comparisons of photos from the early 20th century with photos more recently. A key question is what ecological mechanism has driven this inc tree density. A more intensive investigation would be required to answer this qu definitively, but based on my observations and discussions during this one day o investigation, I offer and evaluate four hypotheses for the mechanism driving th in tree density on the cinder cone. Two of these hypotheses seem likely and two unlikely, as follows.

The two ***unlikely hypotheses*** are (i) increased tree establishment and survival be exclusion of frequent low-severity fires that formerly burned the slopes of the ci cone, and (ii) extensive wood-cutting by local 19th century residents who remov of a formerly dense woodland. The fire exclusion hypothesis seems unlikely be there is no evidence that low-severity fires were ever frequent on the slopes of th cone. Guyette and Stambaugh (undated) searched the cone for fire scarred trees, are the most definitive evidence of previous low-severity fire, and reported that scarred trees were extremely rare. This is not surprising, because the soils, terra vegetation structure are not conducive to spreading low-severity fires. The woo hypothesis seems unlikely because local populations probably were not high enc other local wood resources probably were not limiting enough to lead people to the cinder cone so completely. Moreover, the old photos show remnant trees on the lower slopes while some of the upper slopes appear completely treeless; it is unlikely that people would have so thoroughly harvested the steep upper slopes while more easily obtainable wood remained on the gentler lower slopes.

The two ***likely hypotheses*** for the observed increase in tree density during the last century are (i) natural woodland recovery from a stand-replacing fire in the 18th or 19th century, and (ii) increased tree establishment and survival because of favorable climatic conditions during the 20th century. These two hypotheses are not mutually exclusive; in fact, both probably are operative. Direct evidence of a previous stand-replacing fire would be charred juniper snags and old charred wood on the ground. We did not see such evidence on our brief visit, although more intensive searching might discover charred remnants of this kind. However, it is possible that no such evidence remains from the last stand-replacing fire on the cinder cone because most of the trees at this elevation are piñon, which tend to decompose within a few decades after death (in contrast to dead junipers which often persist for centuries). Indirect evidence to support the hypothesis of recovery from a pre-1900 stand-replacing fire comes from studies in persistent piñon-juniper woodlands elsewhere in the Southwest. Extensive fires in the mid-19th century burned persistent woodlands on Mesa Verde in southwestern Colorado (Floyd et al. 2000). Today, some 150 years after the fires, piñon and juniper trees are just beginning to become prominent in the shrublands that developed after the 19th century fires, and full recovery of persistent piñon-juniper woodlands in Mesa Verde is thought to require ca. 300+ years. Thus, the largely treeless appearance of the Capulin cinder cone in the early 20th century would be consistent with the effects of a high-severity fire 100-150 years previously. Evidence for the favorable climate hypothesis comes from studies elsewhere in the Southwest that document increasing tree establishment (especially piñon) during moist climatic periods that have occurred periodically over the past several centuries (Shinneman and Baker 2009). The climate in most of the Southwest was exceptionally moist during the first three decades of the 20th century and again from the mid-1970s through mid-1990s. Pinon densities increased during these periods on Mesa Verde, on the Uncompahgre Plateau, and in many other places in the Southwest (Floyd et al. 2004, Shinneman and Baker 2009). It seems likely that we are seeing a similar process of natural woodland recovery from an early, undocumented, stand-replacing fire on the Capulin cinder cone, a recovery that was accelerated by the favorable climate that prevailed throughout much of the 20th century.

If this interpretation is correct, it would follow that intensive mechanical thinning and prescribed low-severity fire are not needed to restore natural ecological conditions in the vegetation of the Capulin cinder cone. It is true that the vegetation structure today is somewhat different than at the time of Monument establishment, but there is no reason to expect this kind of vegetation to be static. I see no indication that today's vegetation on the cinder cone is degraded or unhealthy or unnatural. In fact, thinning and burning treatments potentially could interfere with the ecological process of re-establishing a fully stocked, persistent piñon-juniper woodland on the steep slopes of the cinder cone. It should be noted that a stand-replacing crown fire may occur on the cinder cone sometime in the future. Such a fire would occur under dry, windy conditions, and would not represent a failure of management but would be an expected, natural ecological event in a persistent piñon-juniper woodland of this kind.

What about thinning and burning treatments in the piñon-juniper savanna that covers the gentler lower slopes of the cinder cone and surrounding lands outside the Monument? This is an area where low-severity fire may have played a significant role in vegetation dynamics prior to disruption of the previous fire regime ca. 1860. However, even in this area, fires probably were less frequent than is often assumed. Guyette and Stambaugh (undated) documented 15 fire years between 1702 and 1860 in the Boca area near the western foot of the cinder cone. A simple calculation using these data indicates a mean fire interval of 11 years (Table 1), i.e., a fire occurred somewhere in the study area on average every 11 years. It is often assumed that such a statistic means that the entire area was burned every 11 years, and that we should burn the area at this frequency if our objective is to restore a natural fire regime. However, this is faulty reasoning, and if implemented would lead to excessively frequent fire in the area. Many, or even most, of the fire years documented in fire-scarred trees represent tiny fires that burned only in the immediate vicinity of the recorder tree. These fires did not affect all or even most of the study area. Recent fire records from throughout the western U.S. (Baker 1989) reveal that the great majority of fire ignitions extinguish on their own, even without active suppression, because fuels are often too wet or too discontinuous to permit spread from the ignition point. These numerous tiny fires are interesting from the standpoint of fire-climate relationships, but they should not form the basis of a prescribed burning program designed to restore the prehistoric fire regime.

How can we interpret the fire-scar record to determine a more ecologically meaningful interval between fires that burned a large enough portion of the study area to influence the vegetation as a whole? A technique that is frequently used for this purpose is to "filter" the fire-scar data (Baker 2009). We compute a mean fire interval using only the fire years in which a specified proportion of the trees recorded the fire; these are the years in which the fire burned a relatively large proportion of the study area (although, again, not necessarily the entire study area). As shown in Table 1, the average interval between fires that scarred at least 20% of the trees that were sampled for fire scars was 40 years during the period 1702-1860. This number indicates that, prior to the disruption of the historical fire regime with the arrival of cattle around 1860, two or three fires per century burned through a large enough portion of the Boca area to significantly influence vegetation dynamics. (This disruption of the previous fire regime is evident in the fire-scar record from the Boca area which shows the last fire occurring in 1860; the heavy and uncontrolled grazing of the late 19th century removed fine fuels that formerly carried grassland fires and essentially eliminated widely spreading fires throughout much of the West.) This relatively long average interval between fires that affected a significant portion of the Boca area, even before the effects of EuroAmerican settlement, is not surprising considering the numerous rock outcrops and talus fields in the area that would have functioned as barriers to fire spread. Many of the fires recorded in the Boca area probably were ignited in the grasslands to the west of the Monument boundary, or in the ponderosa pine woodlands of the Morrow Ranch where Guyette and Stambaugh (undated) found even more frequent 18th and 19th century fire than was recorded in the

Boca area. This interpretation of fires spreading into the current Monument area from the west is based on the fact that the prevailing winds in this area tend to be from the west.

Many or most of the pre-1900 fires that burned through the Boca area probably went out when they reached the less continuous herbaceous fuels on the rocky slopes of the cinder cone. Only when fires occurred following a prolonged dry period, when the live canopy fuels of the trees on the slope became dry enough to be ignited, would the fire move up the side of the cinder cone, and probably only when driven by strong winds that could blow the flames from crown to crown. It is impossible to say how often such conditions occurred historically, but the typical interval between crown fires on the cinder cone probably was measured in centuries. Fires also may have been ignited on the slopes of the cone itself, but most of these ignitions likely extinguished without spreading because of the discontinuous fuels on the rocky slopes. The west side of the cone probably burned more frequently than the east side because of the prevailing westerly winds. Evidence supporting this interpretation includes Guyette and Stambaugh's (undated) finding of very old trees on the upper east side of the cone (>400 years) and the predominantly younger trees on the east side.

Are mechanical thinning and prescribed burning needed to reduce fire hazards and to restore pre-1860 conditions in the savanna vegetation that surrounds the base of the cinder cone? I suggest that the answer is no, for two reasons. First, even though fires have been excluded for 150 years, tree densities still do not appear exorbitant. Certainly tree cover has not suppressed the grassland component of the vegetation except in localized areas; on the contrary, well developed grassland still is found on the Monument lands around the base of the cinder cone. Second, in many of the places where thinning and prescribed burning have been conducted recently, non-native plant species have invaded the treated areas, including such undesirables as cheatgrass, mullein, and houndstongue.

In sum, based on my brief assessment conducted on April 22, 2010, I conclude that the vegetation in Capulin Volcano National Monument has not been degraded or altered adversely by fire exclusion. The vegetation structure is different today than it was when the Monument was established in 1916, but probably is still within its historical range of variability when viewed from the perspective of the past thousand or so years. Persistent piñon-juniper woodlands and piñon-juniper savannas both are non-equilibrium ecosystems in which tree densities have naturally waxed and waned over the centuries in response to climatic variability and disturbance. It is possible that dense woodland such as we see today on the slopes of the cinder cone has been a relatively uncommon state during the past thousand years, because of the potential for fires to have spread onto the cone from surrounding grasslands prior to disruption of the grassland fire regime in the late 1800s, coupled with the naturally slow rate of woodland recovery after fire. Nevertheless, the woodland vegetation on the cone almost certainly is one of several natural states for this ecosystem. The current vegetation structure provides habitat for diverse woodland fauna and flora. Notably, many of the tree branches in the dense woodland on the east rim of the crater are covered with a distinctive community of well developed foliose lichens—a relatively uncommon feature found on a few isolated mountain tops in New Mexico where frequent clouds and mist provide extra moisture that supports a comparatively lush growth of epiphytic plants. Other cinder cones in the Raton volcanic field are mostly treeless, so habitat for species of more open conditions also is present in the larger region.

The most urgent fire-related issue on the Monument probably is to ensure that buildings and other infrastructure are defensible in the event of a wildfire. From my brief visit, it appears that this has already been accomplished for the most part. Another issue is the potential danger of a wildfire being ignited on the Monument and then spreading onto surrounding private lands. Extensive burning of adjacent lands appears unlikely, however, because the grazing regime on these private lands maintains generally low fuel loads and continuity. It should be acknowledged that a high-severity crown fire could occur in the dense woodlands of the cinder cone during a prolonged dry period with high winds, and that suppression of such a fire might be impossible. However, a severe wildfire of this kind would represent a natural event in this ecosystem, and would not represent any failure of management. A severe wildfire on the steep slopes could lead to a significant erosion event if a locally intense rainstorm occurred within the two or so years after the fire, but again, such an erosion event would be a natural geological consequence of a high-severity fire on terrain of this kind.

Table 1. Calculation of mean fire interval (MFI) in the Boca area of Capulin Natural Monument, based on my visual interpretation of the fire history data reported on page 13 of Guyette and Stambaugh (undated). Calculation methods are from Baker (2009).

-- Basic formula for computation: MFI = (no. years) / (no. fires – 1)

-- **MFI (all fires)*** = (1860 – 1702) / (15 – 1) = 158 years / 14 intervals
= **11 years** between fires

* This calculation includes all fire years recorded on the trees sampled in the Boca area (1860, 1848, 1841, 1815, 1808, 1800, 1793, 1772, 1764, 1752, 1750, 1727, 1719, 1716, 1702). It is a *misleading* indicator of historical fire frequency, because most of these fires scarred only one or two trees and probably burned no more than a small portion of the total Boca study area.

-- **MFI (20% filter) **** = (1860 – 1702) / (5 – 1) = 158 / 4
= **40 years** between fires

** The 20% filter computes MFI using only the fire years in which 20% or more of the potential recorder trees in the Boca area were scarred by fire (1860, 1815, 1808, 1752, 1702). This is a far more reliable indicator of the frequency of ecologically significant fires that burned a substantial portion of the area.

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Romme, W, C. Allen, J. Bailey, W. Baker, B. Bestelmeyer, P. Brown, K. Eisenhart, L. Floyd-Hanna, D. Huffman, B. Jacobs, R. Miller, E. Muldavin, T. Swetnam, R. Tausch, and P. Weisberg. 2009. Historical and modern disturbance regimes of piñon-juniper vegetation in the western U.S. Rangeland Ecology and Management 62:203-222.

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Response from Romme to Brian regarding regarding trip report in Section B.2.

Hi Brian,

Thank you for your comments. I think that your two clarifications at the end make good sense -- the vegetation in the Boca area is better characterized as a fine-grained mosaic of persistent woodland on the lava breaks and grassland on the depositional soils; and it is certainly possible that vegetation on the cinder cone is not uniformly a persistent woodland but was historically a shrubland on the west side maintained by relatively more frequent fire. You also put a bit more emphasis overall on the effects of grazing-mediated fire exclusion than

I did, and I think that this is appropriate -- I may have downplayed the grazing & fire exclusion effects a bit more than is appropriate. Overall, however, our interpretations are very much in agreement.

Rob and Kim, please let us know if you need anything else from us at this point.

Bill

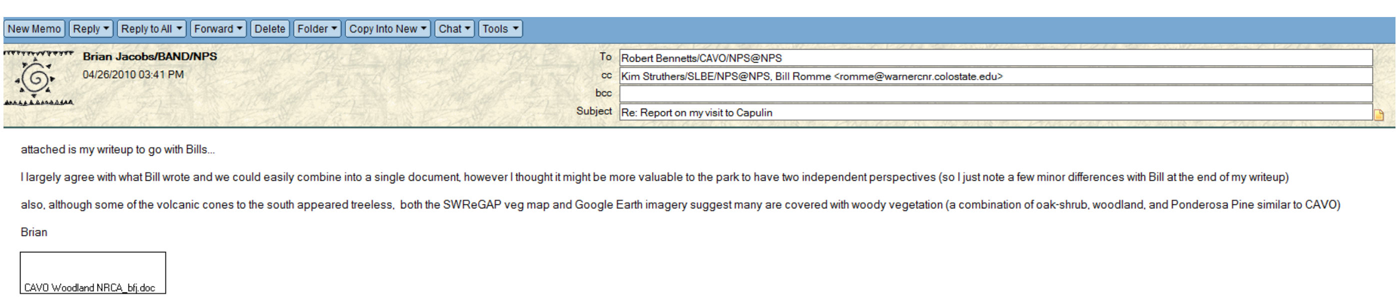
D.2 Trip Report from Brain F. Jacobs (22 April 2010)

CAVO NRCA for Vegetation

Comments from B. Jacobs, 4/22/10

CAVO is a relatively small (~800 acre) NPS unit, established (ca. 1916) primarily for preservation and interpretation of a recent (~60kya) and well formed volcanic cinder cone geologic feature. The park boundary is drawn closely around the primary feature of interest, encompassing the cinder cone proper and some small areas of adjacent lava flow (Boca) below the mouth of the crater on the western side; in addition, since the rectangular fence line bounds a circular cone feature, it incidentally incorporates some linear corner strips of short-grass prairie on the southern and eastern sides. The western lava flow is a heterogeneous mix of rocky outcrops (dominated by Rocky Mountain juniper, Ponderosa Pine, and gambel oak) interspersed with depositional soil patches (supporting grassland vegetation). The cinder cone proper supports Colorado piñon – Rocky Mountain juniper woodlands on the lower slopes, grading rapidly above into pure piñon stands with variable (mostly shrub) understories; the monument area is largely above 7000 feet and relatively mesic (~460mm MAP) from a woodland perspective (one-seed juniper was not observed) and located within a strongly monsoonal climate area. Notably the woodland on the west-facing slope below the road and crater parking area looks very young, i.e. <100 years (either successional post-disturbance or invading former shrublands) and are growing on deeper cinder-soil substrates; these young dense woodlands grade into open shrublands and then grasslands on the slopes and ridges below. On portions of the north-east to south-east facing slopes the woodland generally looks much older, i.e. >200 years and includes some very old individuals growing on relatively barren or exposed rocky substrates. The Boca lava flow supports some scattered older juniper and Ponderosa, although many of the juniper trees appear relatively young in age; since these are interspersed with grassland patches also experiencing recent juniper encroachment it is reasonable to think that absence of fire disturbance historically is an important driver of recent tree establishment patterns in both.

The park is managed as a natural area within the context of the larger Raton volcanic field; however most of the adjacent lands are privately owned and actively managed as rangeland. Thus the parks ecological context has been altered by long-term (since ca. 1800's) and perhaps intensive livestock grazing practices, the latter reducing fuel continuity and potential for ignition from these adjoining areas. Since settlement the park area has effectively become a small island ecosystem, with dramatic increases in tree cover documented by historic photos occurring in the absence of fire disturbance. This pattern (i.e. scattered old trees with abundant younger tree cover on lava breaks and adjacent grasslands was widely observed in the general vicinity of CAVO (and corresponds with predictive modeling outputs) suggesting cessation of fire associated with historic grazing was an important driver of recent landscape changes locally. Contributing mechanisms for historic increases in tree cover also include: favorable weather patterns for establishment, and/ or recovery from prior disturbances (e.g. drought-beetle mortality, crown fire and/ or mechanical harvest). The entire CAVO cinder cone represents suitable habitat for persistent shrub and/ or woodland growth; in absence of recurring fire disturbance, succession would be expected to proceed to persistent woodland types (tree ages exceeding 400 years were reported from upper southeastern slopes, presumably in fire safe sites where substrate is relatively barren). Fire effects in most of the woodland areas observed would be expected to result in patchy to continuous mortality of overstory trees.



New Memo | Reply | Reply to All | Forward | Delete | Folder | Copy Into New | Chat | Tools

Brian Jacobs/BAND/NPS
04/26/2010 03:41 PM

To: Robert Bennetts/CAVO/NPS@NPS
cc: Kim Struthers/SLBE/NPS@NPS, Bill Romme <romme@warnercnr.colostate.edu>
bcc:
Subject: Re: Report on my visit to Capulin

attached is my writeup to go with Bills...

I largely agree with what Bill wrote and we could easily combine into a single document, however I thought it might be more valuable to the park to have two independent perspectives (so I just note a few minor differences with Bill at the end of my writeup)

also, although some of the volcanic cones to the south appeared treeless, both the SWReGAP veg map and Google Earth imagery suggest many are covered with woody vegetation (a combination of oak-shrub, woodland, and Ponderosa Pine similar to CAVO)

Brian

CAVO Woodland NRCA_bfj.doc

Management Recommendations

Mechanical thinning and associated prescribed fire treatments designed for maintenance of open vegetation systems characterized by low severity surface fire regimes are inappropriate for persistent woodlands, especially on steep slopes. Recent thinning will likely exasperate overstory tree mortality if slash is burned within next five years; in any case these thinning treatment are unlikely to be an effective treatment for mitigating crown mortality on steep slopes of cinder cone (even if slash were pile burned which is not recommended). Similarly the lava outcrops in Boca area represent suitable habitat for persistent shrub, woodland, and pine growth; only the adjacent grass patches would likely benefit from prescribed burning. In addition, mechanical thinning and slash mulch treatments appear to be unwarranted and ineffective treatments for mitigating soil erosion control on steep, but well armored, slopes of the volcanic cinder cone.

Prescribed fire could be an appropriate tool for maintenance of open grasslands, savannas, and grass patches within the lava outcrops; however, pre-mechanical treatment of young trees in these locations is probably unnecessary since juniper is so easily killed by fire-heat effects. While fire should be allowed to propagate into rocky lava fields from grass patches as fuels allow, there is no need (or ecological rationale) to mechanically treat or intentionally light off these vegetated rocky patches.

Specific recommendations:

-manage natural ignitions for resource benefit (do not suppress unless life or property is threatened);
(crown fire in persistent woodland and shrublands on steep slopes of the volcano cinder cone is inevitable and thinning cannot mitigate this outcome)

-the only areas where prescribed surface fire appears warranted are grassland patches within Boca lava flows and grassland-savanna areas around perimeter toe-slope of cinder cone; one could intentionally run fire up eastern facing slope to clear out young tree growth (i.e. maintain a oak shrub fire climax community) but probably best to wait for a natural ignition

-reconstruct vegetation changes using repeat imagery; inform imagery reconstruction by dating numerous cut stumps; supplement sample with cores of larger leave trees

-mechanical thinning (of woodland or shrubs) is generally unwarranted and even counter productive for management of CAVO vegetation systems; if burned anytime soon current slash loads will likely enhance overstory mortality through heat kill even if fire is kept on the ground

Clarification re: notes from WHR

-I provide an alternative interpretation of Boca lava break-grassland patch habitat; instead of grassland savanna, I would interpret this as heterogeneous mosaic of persistent RM juniper woodland on lava breaks with grassland patches in depositional settings between. However, I concur with the potential for savanna on toe-slope of cinder cone at interface with grassland on south side.

-I recognize potential for oak shrub-land fire maintained climax community on western slopes of cinder cone as alternative scenario to persistent woodland recovering from past crown fire (similarly, the abundance of young RM juniper in many -seemingly fire safe- rocky lava break habitats locally may suggest fire effects formerly maintained these as oak shrub dominated sites historically with only scattered trees able to persist in the most protected locations within individual lava breaks); young RM juniper stands in CAVO area will progress to full dominance (i.e. persistent woodland) on both the cinder cone western slope and lava outcrops; I agree with WHR that this is within HRV although perhaps the current expression an artifact of grazing mediated fire suppression.

B.3 Follow-up Report from William H. Romme (13 July 2010)

Characteristics of a Healthy Forest

-- characteristics taken from Edmonds, Agee, and Gara, 2000/2011, Forest Health and Protection, 2nd Edition, Waveland Press, Long Grove, IL, p. 4-6 … with an associated assessment for CAVO for each characteristic --

(William H. Romme, July 13, 2010)

1. "Trees and understory plants should be vigorous and healthy in appearance. Species, age class distributions, and stand densities should be within historical ranges for the site, and growth and mortality should be consistent with the ecosystem type and the age of dominant trees."

> CAVO – Trees and understory plants are generally healthy in appearance. Few insects or disease organisms are apparent. Vegetation is dominated by native trees, shrubs, and herbs, especially on the cinder cone; some non-native species (e.g., cheatgrass, mullein, and houndstongue) are locally present in portions of the grasslands surrounding the cone, especially in some places where prescribed burning has been conducted within the past few years. Woodland density today is far greater than in 1900 (based on historic photos), but is comparable to stand densities in other mature piñon-juniper woodlands on the Colorado Plateau (e.g., Mesa Verde). We lack data on age class distribution of the piñon, but the trees probably are predominantly <200 years old (based on historic photos), which is what we would expect in a population recovering from a severe disturbance ca. 200 years previously. Growth rates and mortality in the piñon population apparently both are low, but typical of a dense piñon-juniper woodland.

2. "Vegetation diversity should be balanced between the supply and demand of light, water, nutrients, and growing space."

> CAVO – The woodland on the cinder cone is strongly dominated by piñon, with relatively little juniper, but this is typical of woodlands at this elevation in the region. Species diversity of the herbaceous ground layer beneath the dense piñon canopy on the cone may be relatively low, but the ground layer vegetation is dominated by native species and appears typical of dense piñon-juniper woodlands in the region. Similarly, vegetation diversity in the grasslands and in the Boca area appear typical for the region.

3. "The forest should be capable of tolerating and recovering from known disturbances (such as fire and wind)."

> CAVO – Extensive burning of the cinder cone probably would occur only under conditions of extremely low fuel moisture and high wind; most ignitions (occurring under less extreme fire weather conditions) probably will go out by themselves because of the lack of horizontal fuel continuity. If a large fire does occur on the cone, the woodland in this area probably will be severely damaged or destroyed. However, this is the normal/natural fire regime for this kind of persistent piñon-juniper woodland in the region. Fires are more likely to occur in the grasslands surrounding the cone, and may burn under less severe burning conditions because the grassland fuels are more continuous and quicker to dry out. A fire in the grasslands probably will kill some

severely damaged or destroyed. However, this is the normal/natural fire regime for this kind of persistent piñon-juniper woodland in the region. Fires are more likely to occur in the grasslands surrounding the cone, and may burn under less severe burning conditions because the grassland fuels are more continuous and quicker to dry out. A fire in the grasslands probably will kill some trees, but this is a normal/natural fire effect in a piñon-juniper savanna of this kind. The native grasses and forbs can be expected to recover very quickly (within 1-2 years) after a fire, primarily via re-sprouting from surviving below-ground plant structures. Recovery of the piñon-juniper woodland after a severe fire would be very slow (requiring decades or centuries), but this would be typical of persistent piñon-juniper woodlands in the region.

4. Soil erosion should be minimal. Clean water should flow from streams except during extraordinary runoff events, and stream banks need to be stable and riparian vegetation ample."

CAVO – I didn't look closely for erosion, so can't comment confidently on this. However, I note that some amount of erosion is normal/natural on a steep landform like the CAVO cinder cone, especially after the intense local rainstorms that occur periodically in this region. Most of the erosion that is occurring actually may be coming from the road.

5. "Aquatic species should be diverse …."

CAVO – not relevant here.

6. Wildlife diversity and presence need to be appropriate for the ecosystem, especially in riparian zones."

CAVO – I don't have any insights here.

7. "Insect, disease, and fire frequencies should be within the normal ranges for the ecosystem."

CAVO -- Recent fire intervals are somewhat longer than intervals before 1900, especially in the grasslands and perhaps also on the cone. However, centuries-long intervals between high-severity fires are normal/natural for persistent piñon-juniper woodlands in the region, so the largely fire-free 20th century probably is within or barely outside the historical range of variability for the woodland on the cone. Many or most or all of the 20th-century ignitions on the cone that have been suppressed probably would have burned only a small area even if they had been left to burn without interference; the low fuel continuity in the woodland would limit fire spread under moderate fire weather conditions, and if fires had occurred under extreme fire weather conditions they probably could not have been suppressed (suppressing fires is very difficult under extreme fire weather conditions, even with modern technology, and would have been even more problematic using the technology of the early and middle 20th century). The piñon-juniper woodlands in CAVO appear not to have been subjected to the high piñon mortality that occurred elsewhere in the region during the past decade. Nevertheless, the dense woodlands on the cinder cone are susceptible to future piñon mortality due to drought and/or insects; however, period mortality events are normal/natural in dense persistent woodlands of the region.

8. "Ecological processes are operating within a natural range of variability."

CAVO – I saw no evidence of any large departure from the natural/historical range of variability. Two small departures worth noting are (i) localized invasion by non-native plant species, especially in the grassland portions of CAVO, and (ii) somewhat longer fire intervals than was typical of the pre-1900 period in the grassland areas. However, neither of these departures appears to pose any significant threat to long-term ecological integrity of the ecosystem.
piñon

Appendix E: Biggam Trip Report

National Park Service
U.S. Department of the Interior

Natural Resource Program Center
Geologic Resources Division

National Park Service, Natural Resource Program Center (NRPC)
Geologic Resources Division (GRD), Geoscience and Restoration Branch (GRB)
Denver, Colorado

Memorandum

To: Robert Bennetts, Southern Plains Network Coordinator

Through: Dave Steensen, Chief, Geologic Resources Division, (GRD)
Harold Pranger, Chief, Geoscience and Restoration Branch, (GRD)

From: Pete Biggam, Soil Scientist, Geoscience and Restoration Branch, (GRD)

Subject: Trip Report – Performance of Rapid Soil Assessments in Support of Natural Resource Condition Assessment at Capulin Volcano National Monument

PURPOSE

The Geologic Resources Division was contacted by Robert Bennetts, Southern Plains Network (SOPN) on behalf of Capulin Volcano National Monument with a request for technical assistance from the Geologic Resources Division (GRD) to perform a rapid soil resource assessment and help identify appropriate reference conditions in relation to grassland and pinyon-juniper habitats that may have been impacted by accelerated soil erosion. This rapid assessment will be used as part of an ongoing Natural Resources Condition Assessment (NRCA) for Capulin Volcano National Monument. On November 2, 2010, Pete Biggam, Soil Scientist, GRD, performed the rapid soil assessments.

SUMMARY

The technical assistance and rapid soil assessments consisted of evaluating four selected sites within the park. The methodology used for these assessments followed an approach modified from those described in the qualitative assessment protocol “Interpreting Indicators of Rangeland Health (Version 4.0) (http://usda-ars.nmsu.edu/monit_assess/index.html), in which Soil/Site Stability qualitative indicators were used to assess the ability of an area to limit redistribution and loss of soil resources by wind and water.

Qualitative indicators can provide land managers and technical assistance specialists with a good communication tool, and when used in association with quantitative monitoring and inventory information, they can be used to provide early warnings of resource problems on upland rangelands.

These indicators were used in conjunction with soil survey information and ecological site descriptions for the four selected evaluation areas, each of which were approximately 1/3 acre in

size. It is important to note that only the Soil/Site Stability qualitative indicators were observed and documented on site, and these were what were used to perform the rapid soil assessments.

The following table lists the qualitative assessment indicators used to determine current soil/site attributes.

Attribute	**Qualitative Assessment Indicator**
Soil/Site Stability	Rills
	Water flow patterns
	Pedestals and/or terracettes
	Bare ground
	Gullies
	Wind-scoured, blowout, and/or depositional areas
	Litter movement
	Soil surface resistance to erosion
	Soil surface loss or degradation
	Compaction layer

OBSERVATIONS

Three sites were selected to represent the grassland communities within the park. An additional site was located on the volcanic cone in an area that had previously been subjected to a mechanical thinning, and is now under a very sparse overstory of pinyon-juniper, representing what was once a shrub community. A graphic depicting the location of these four sites can be found in Attachment 1 – Soil/Site Evaluation Locations.

Site 1

This site was located north of the Visitor Center in an area referred to as the Boca. It was located in an area of soil map unit Fr – Fallsam – Rock outcrop complex, with a designated Ecological Site of Malpais Upland (R070XA007NM). A brief soil observation was made to confirm the Fallsam soil was present. Fallsam soils consist of deep and very deep, well-drained, slowly permeable soils that formed in fine textured materials mixed with basalt fragments on basalt flows around the base of volcanic flows or vents. The Malpais Upland (R070XA007NM) Ecological Site was confirmed to be present at the site. Present vegetation was little bluestem (*Schizachyrium scoparium*), blue grama (*Bouteloua gracilis)* and western wheatgrass (*Pascopyrum smithii*), which is an expected plant community within the Malpais Upland Ecological Site. Also, present on the site was a native annual sunflower (*Helianthus annuus*). These are present in the site images of the Soil/Site Stability Evaluation Matrix, Site 1 – Boca Site found in Attachment 2. The site in which the rapid soil assessment was performed was traversed over an area of approximately 1/3 acre, and was determined to be consistent with the Fallsam soil landscape and the Malpais Upland Ecological Site. Qualitative assessment indicators for the soil/site attribute were observed and documented. (The results can be found in Attachment 2 - Soil/Site Stability Evaluation Matrix, Site 1 – Boca Site)

The rapid soil assessment performed at this site determined that the departure from the expected soil/site stability attributes was ***None to Slight***

Site 2

This site was located south of the Visitor Center, and north of the southern boundary fence, just upslope of the park access road, on the lower toe slope of the volcanic cone. It was located in an area of soil map unit Bd – Bandera association, with a designated Ecological Site of Cinder (R070XA011NM). A brief soil observation was made to confirm the Bandera soil was present soil was present. Bandera soils consist of very deep soils with subsurface horizons dominated by greater than 70% alluvial and colluvial cinders. These soils are somewhat excessively drained moderately permeable soils on volcanic cone landscapes. The Cinder (R070XA011NM) Ecological Site was confirmed to be present at the site; however, the site appeared to have been affected in the past by fire, as evident on fire scars on adjacent pinyon and junipers on the site. Present vegetation was little bluestem (*Schizachyrium scoparium*), blue grama (*Bouteloua gracilis)* and several annual grasses and forbs that were not identified. Also on the site were small patches of rocky mountain juniper (*Juniperus scopulorum)* two needle pinyon (*Pinus edulis*) Gambel oak (*Quercus gambelii*) and serviceberry (*Amelanchier alnifolia)* which is an expected plant community within the Cinder Ecological Site. The site in which the rapid soil assessment was performed was traversed over an area of approximately 1/3 acre, and was determined to be consistent with the Bandera soil landscape and the Cinder Ecological Site, however it was on a lower slope phase, and appeared to have been affected by fire in the past. The adjacent road allowed for a soil disturbance that allowed what appeared to be invasive annual grasses and forbs (Russian thistle) to extend onto the site, and there was evidence of disturbance by fire on the site. Qualitative assessment indicators for the soil/site attribute were observed and documented. (The results can be found in Attachment 2 - Soil/Site Stability Evaluation Matrix, Site 2 – Southern Toe slope Site)

The rapid soil assessment performed at this site determined that the departure from the expected soil/site stability attributes was ***None to Slight***

Site 3

This site was located just south of the park entrance, and south of the park road. It was located in an area of soil map unit Fr – Fallsam – Rock outcrop complex, with a designated Ecological Site of Malpais Upland (R070XA007NM). A brief soil observation was made to confirm the Fallsam soil was present. Fallsam soils consist of deep and very deep, well-drained, slowly permeable soils that formed in fine textured materials mixed with basalt fragments on basalt flows around the base of volcanic flows or vents. The Malpais Upland (R070XA007NM) Ecological Site was confirmed to be present at the site. Present vegetation was little bluestem (*Schizachyrium scoparium*), blue grama (*Bouteloua gracilis)* and western wheatgrass

(*Pascopyrum smithii*), which is an expected plant community within the Malpais Upland Ecological Site. The site in which the rapid soil assessment was performed was traversed over an area of approximately 1/3 acre, and was determined to be consistent with the Fallsam soil landscape and the Malpais Upland Ecological Site. Qualitative assessment indicators for the soil/site attribute were observed and documented. (The results can be found in Attachment 2 - Soil/Site Stability Evaluation Matrix, Site 3 – Park Entrance Site)

The rapid soil assessment performed at this site determined that the departure from the expected soil/site stability attributes was ***None to Slight***.

Site 4

This site was located approximately 2/3 up the volcanic cone, and upslope from the park road. It was located in an area of soil map unit Bd – Bandera association, with a designated Ecological Site of Cinder (R070XA011NM). A brief soil observation was made to confirm that both the Bandera soil and the Cinder land miscellaneous land type were present. Most of the Bandera soil would be best categorized as an “eroded phase”, as much of the site has been disturbed due to the removal of most of the pre-existing pinyon-juniper shrub overstory, as evident from the stumps on the site, and the placement of slash piles perpendicular to the slope. In this particular area, the Cinder land component is higher than the normal 20 % composition described in the soil map unit. Cinder land is a term used to denote areas that have little or no soil and vegetation, are best described as areas of loose cinders and other scoriaceous ejecta, and have a very low water holding capacity. The Bandera soils consist of very deep soils with subsurface horizons dominated by greater than 70% alluvial and colluvial cinders. These soils are somewhat excessively drained moderately permeable soils on volcanic cone landscapes. The Cinder (R070XA011NM) Ecological Site was confirmed to be present at the site; however, the site has been subjected to a mechanical thinning treatment, with most of the pre-existing shrub canopy having been removed. There are still some standing pinyon and juniper shrubs within the site, but the overall canopy has greatly been reduced. Although erosion was occurring prior to thinning, opening up the canopy exposes the site to influences of raindrop impact, sheet, rill and gully erosion, and loss of existing herbaceous material, litter, and organic matter.
The site in which the rapid soil assessment was performed was traversed over an area of approximately 1/3 acre, and was determined to be a greatly disturbed example of the Bandera soil landscape and the Cinder Ecological Site. Qualitative assessment indicators for the soil/site attribute were observed and documented. (The results can be found in Attachment 2- Soil/Site Stability Evaluation Matrix, Site 4 – Volcanic Cone Shrubland Site - Disturbed)

The rapid soil assessment performed at this site determined that the departure from the expected soil/site stability attributes was ***Moderate to Extreme***

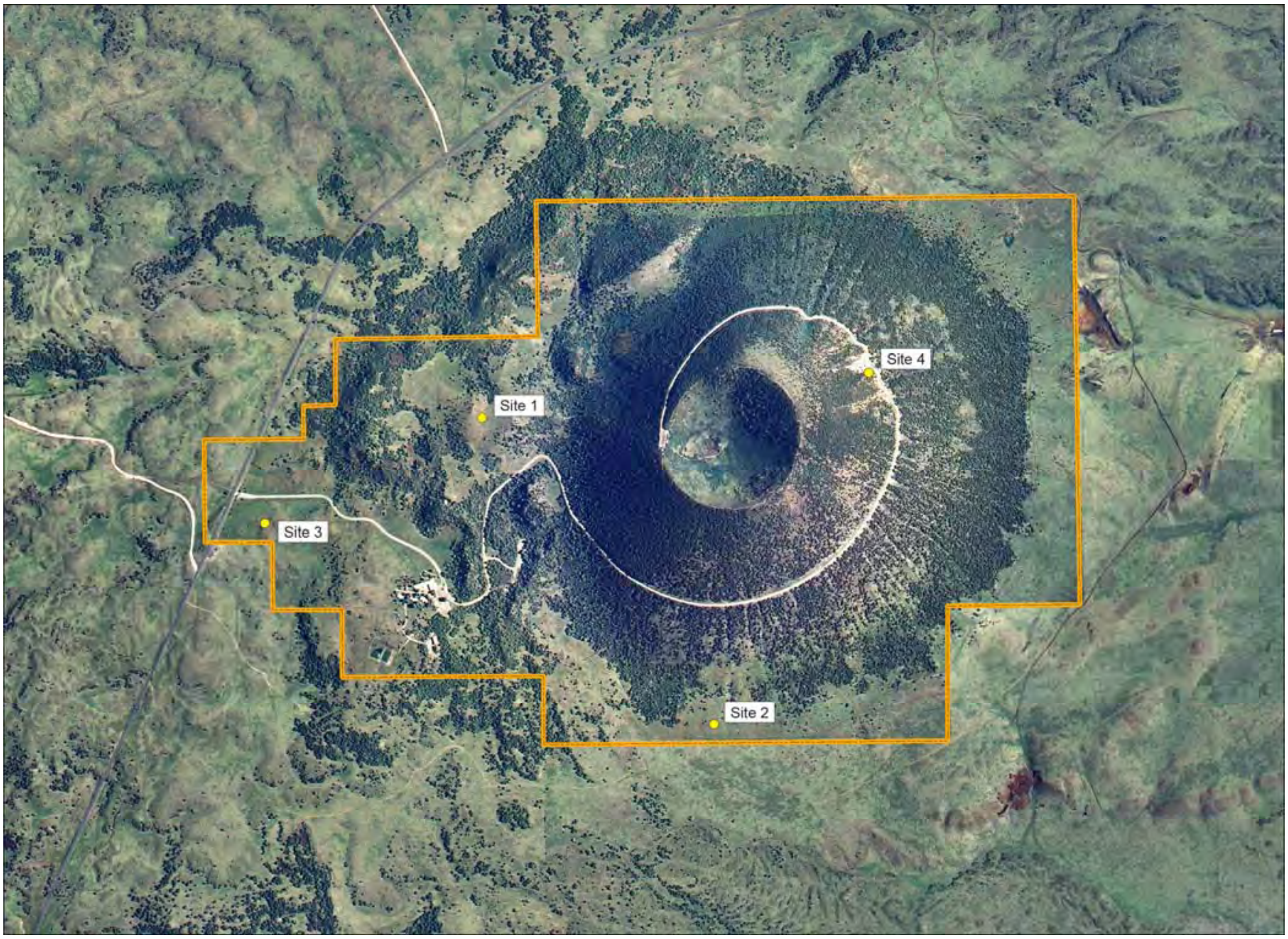
CONCLUSION

GRD staff remains committed to continued assistance on this issue. Pete Biggam is available to provide additional assistance regarding soil resources and ecological sites as part of the ongoing Natural Resource Condition Assessment activities at Capulin Volcano National Monument.

Attachments
cc:

GRD – Steensen, Pranger

Attachment 1 – Soil/Site Evaluation Locations



Attachment 2 – Soil/Site Evaluation Matrix Worksheet

Site 1 – Boca Site
Soil map unit – Fr- Fallsam – rock outcrop complex
Ecological Site – Malpais Upland (R070XA007NM)

Indicator	**Departure From Reference Sheet**
Rills	**None to Slight –** Current or past formation of rills as expected for the site
Water flow patterns	**None to Slight –** Matches what is expected for the site; minimal evidence of past or current soil deposition or erosion
Pedestals and/or terracettes	**Slight to Moderate –** Active pedestalling or terracette formation is rare; some evidence of past pedestal formation around base of bunchgrasses is present on downslope side
Bare ground	**None to Slight –** Soil surface contained approximately 10 - 15 % gravel size cinders, with plant litter present. Very little actual bare ground is present, with what was recognized as an exposed soil surface in small patches, and not connected
Gullies	**None to Slight –** None present
Wind-scoured, blowout, and/or depositional areas	**None to Slight –** None present
Litter movement	**Slight to Moderate –** Slightly more than expected for the site, with only small size classes (grass) of litter being displaced
Soil surface resistance to erosion	**None to Slight –** Soil surface has been stabilized by surface cinders and litter. Biological soil crust is present and intact.
Soil surface loss or degradation	**None to Slight –** No apparent loss of surface A horizon, with soil structure and organic matter distribution about what is expected for the site
Compaction layer	**None to Slight –** None present

Site 1 Images

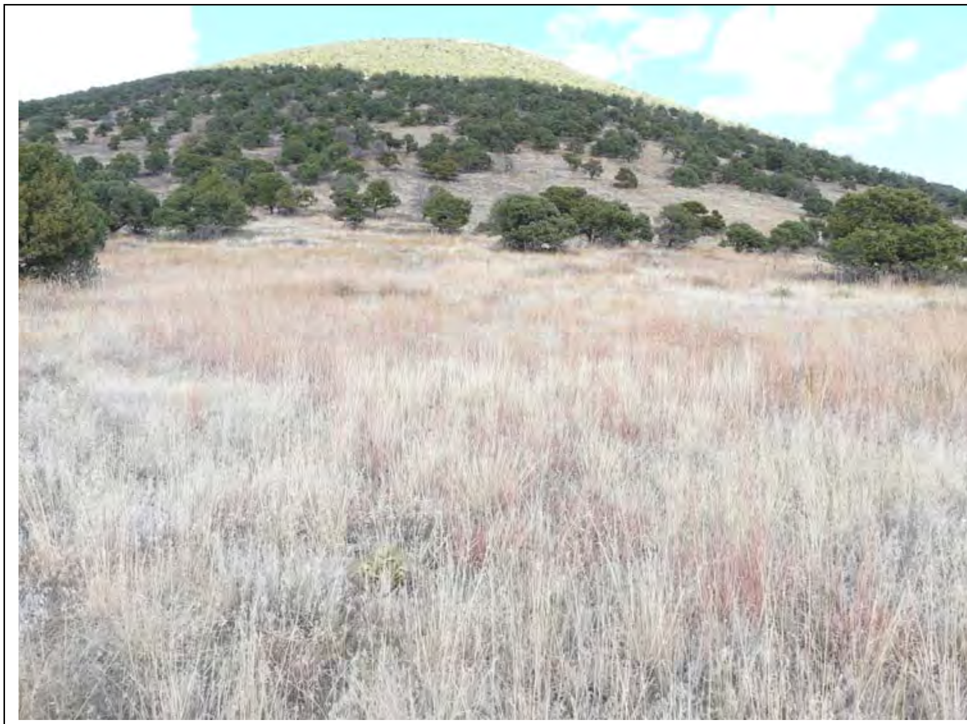
Looking North

Looking East

Site 2 – Southern Toe slope off Volcanic Cone near Park Southern Boundary Site
Soil map unit – Bd – Bandera association
Ecological Site – Cinder (R070XA011NM)

Indicator	**Departure From Reference Sheet**
Rills	**None to Slight** – None present. Current or past formation of rills as expected for the site
Water flow patterns	**None to Slight** – None present. Matches what is expected for the site; minimal evidence of past or current soil deposition or erosion
Pedestals and/or terracettes	**None to Slight** – Current or past evidence of pedestalled plants or rock fragments as expected for the site. Terracettes absent or uncommon.
Bare ground	**Slight to Moderate** – Soil surface contained approximately 15-35 % gravel size cinders, with plant litter present. Slightly to moderately higher than expected for the site, with bare ground present in small areas, and rarely connected. Bare ground was more evident in areas with invasive annual grasses and forbs present.
Gullies	**None to Slight** – None present
Wind-scoured, blowout, and/or depositional areas	**None to Slight** – None present
Litter movement	**Slight to Moderate** – Slightly more than expected for the site, with only small size classes (grass) of litter being displaced
Soil surface resistance to erosion	**None to Slight** – Soil surface has been stabilized by surface cinders and litter. Biological soil crust is present and intact, but is not uniform on the site due to the amount of surface cinders. Biologic crusts found adjacent to bases of bunchgrasses.
Soil surface loss or degradation	**None to Slight** – No apparent loss of surface A horizon, with soil structure and organic matter distribution about what is expected for the site
Compaction layer	**None to Slight** – None present

Site 2 Images



Looking North

Looking West

Site 3 – Park Entrance Site
Soil map unit – Fr- Fallsam – Rock outcrop complex
Ecological Site – Malpais Upland (R070XA007NM)

Indicator	**Departure From Reference Sheet**
Rills	**None to Slight –** Current or past formation of rills as expected for the site
Water flow patterns	**None to Slight –** Matches what is expected for the site; minimal evidence of past or current soil deposition or erosion
Pedestals and/or terracettes	**Slight to Moderate –** Active pedestalling or terracette formation is rare; some evidence of past pedestal formation around base of bunchgrasses is present on downslope side
Bare ground	**None to Slight –** Soil surface contained approximately 10 - 15 % gravel size cinders, with plant litter present. Very little actual bare ground is present, with what was recognized as an exposed soil surface in small patches, and not connected
Gullies	**None to Slight –** None present
Wind-scoured, blowout, and/or depositional areas	**None to Slight –** None present
Litter movement	**Slight to Moderate –** Slightly more than expected for the site, with only small size classes (grass) of litter being displaced
Soil surface resistance to erosion	**None to Slight –** Soil surface has been stabilized by surface cinders and litter. Biological soil crust is present and intact.
Soil surface loss or degradation	**None to Slight –** No apparent loss of surface A horizon, with soil structure and organic matter distribution about what is expected for the site
Compaction layer	**None to Slight –** None present

Site 3 Images

Looking West

Looking East

Site 4 –Volcanic Cone Shrubland Site - Disturbed
Soil map unit – Bd – Bandera association
Ecological Site – Cinder (R070XA011NM)

Indicator	Departure From Reference Sheet
Rills	**Moderate to Extreme** – Rill formation is moderately active and well defined throughout most of the site
Water flow patterns	**Moderate to Extreme** – Water flow patterns more numerous and extensive than expected; deposition and cut areas common; occasionally connected
Pedestals and/or terracettes	**Moderate** – Slight active pedestalling; most pedestals are in flow paths and interspaces and/or on exposed slopes; occasional terracettes present
Bare ground	**Moderate to Extreme** – Much higher than expected. Surface cinders or gravels are absent, leaving soil surface unprotected to raindrop impact and vulnerable to detachment by wind erosion. Bare areas are large and connected, and in some cases, soil has eroded down to the surficial geologic deposits of welded cinders.
Gullies	**Moderate to Extreme** – Moderate in number with indications of active erosion; vegetation is intermittent on slopes of gullies and absent in most of the gully beds. Head cuts appear to be active. Sediment is being delivered off site, and onto roadbed.
Wind-scoured, blowout, and/or depositional areas	**Slight to Moderate** – Due to coarse texture of the soil, it appears that most of the finer silt sized particles may already been detached by wind and transported off site. No evident signs of deposition onto plants.
Litter movement	**Moderate to Extreme** – As this is within a mechanically treated unit, much of the fine to medium sized litter that was once contained in the slash piles show movement downslope, and contained within sediment deposits. Some of the slash piles that were originally layered perpendicular to the slope show evidence of rills and gullies cutting thru them, moving all sizes of litter down slope. Within the areas between rills and gullies, the herbaceous litter from grasses seems to be staying on site.
Soil surface resistance to erosion	**Moderate to Extreme** – Due to the rapid removal of overstory plants as part of the mechanical thinning, the soil surface was left unprotected, except in those areas immediately underneath slash piles. Plant canopy interspaces have been greatly increased, and stabilizing agents are only present in areas between rills and gullies, primarily in areas with better grass vegetation. Biological soil crusts appear to be absent from the site.
Soil surface loss or degradation	**Moderate to Extreme** – Soil loss and degradation is severe throughout site, with original surface horizons (O, A) missing for most of the site, except in areas with existing herbaceous cover. Much of the soil organic material has been lost from the site.
Compaction layer	**None to Slight** – None present

Site 4 Images

Looking West, Convex upslope position

Looking West, Concave upslope position

Appendix F: Handbook for Ranking Exotic Plants for Management and Control

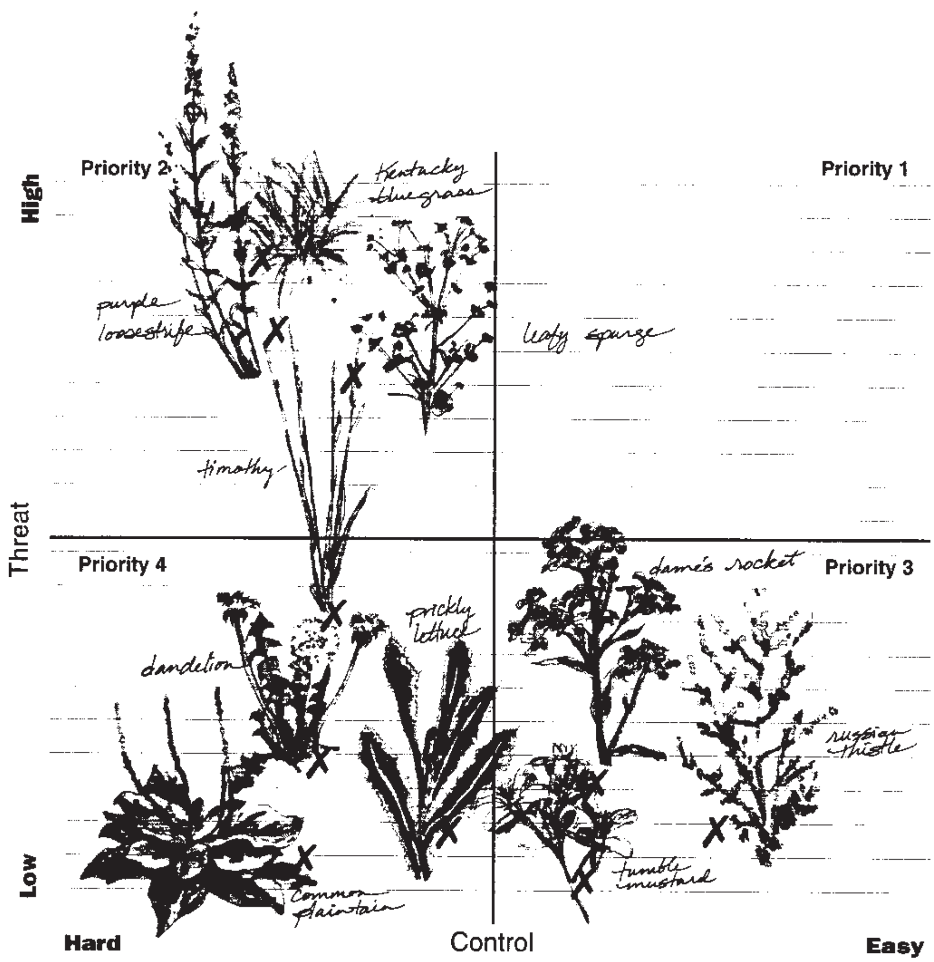
Handbook for Ranking Exotic Plants for Management and Control

Ronald D. Hiebert

and

James Stubbendieck

Natural Resources Report NPS/NRMWRO/NRR-93/08



United States Department of the Interior • National Park Service • Midwest Regional Office

Handbook for Ranking Exotic Plants for Management and Control

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Natural Resources Report NPS/NRMWRO/NRR-93/08

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National Park Service
Natural Resources Publication Office
Denver, Colorado

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Introduction

Exotic, alien, introduced, nonindigenous, and nonnative are all synonyms for species that humans intentionally or unintentionally introduced into an area outside of a species' natural range. The National Park Service (NPS) defines exotic species as those occurring in a given place as a result of direct or indirect, deliberate, or accidental actions of humans. Thus, species native to the North American continent if outside their normal range due to the actions of humans are considered exotics by the National Park Service. The reader is directed to the *Natural Resources Management Guideline* (U.S. Department of the Interior, National Park Service 1991, NPS-77) to further clarify the definition.

Most exotic plant species cause minor effects on natural ecosystems. For example, Great Smoky Mountains National Park has approximately 1,500 vascular plant species, 400 of which are exotics--10 species are considered to be threatening to park resources. Of the 1,400 vascular plants at Indiana Dunes National Lakeshore, 300 are exotics, 14 of which are considered to be major threats. However, some exotic species can be extremely disruptive, such as disrupting the accurate presentation of a historic scene, damaging historic or archeological resources, interfering with natural processes, and threatening the survival of naturally evolved plant assemblages and individual native species.

Exotic species are often major roadblocks to managing natural resources in parks and other natural areas. Managing exotic plants is an extremely expensive, labor-intensive, and almost always a long-term proposition. Managers must not only be concerned with the level of impact that an exotic can cause but must also consider the impact of removing the species. Removal can often disturb areas that are easily colonized by the same or other exotic species (Westman 1990). The intensity and longevity of a control program are also important factors to consider in managing exotic plants. Therefore, managers must make sound decisions on where to place one's effort.

NPS policies, as they relate to managing natural resources, require that managers implement programs to maintain, restore, and perpetuate fundamental ecological processes as well as individual species and features. Managers are directed to manage not only for individual species but to maintain all the components and processes of naturally evolving park ecosystems (U.S. Department of the Interior, National Park Service 1988). Specific NPS policy on exotic species directs park managers to give high priority to controlling and managing exotic species that have substantial impacts on park resources and that are believed to be easily managed. High priority should also be given to managing and monitoring exotic plant species that presently may not cause major impacts to park resources but have life history characteristics associated with colonizing or weedy species (Baker 1965) or are known to cause major impacts in other natural areas. Low priority should be given to species that cause little impact, are virtually impossible to control, or both.

A ranking system has been developed for resource managers to sort exotic plants within a park according to the species level of impact and its innate ability to become a pest. This information can then be weighed against the perceived feasibility or ease of control. The Exotic Species Ranking System is designed to first separate the innocuous species from the disruptive species. The separation allows researchers to then concentrate further efforts on species in the disruptive category. The system is also designed to identify those species that are not presently a serious threat but have the potential to become a threat and, thus, should be monitored closely. Finally, the system asks the park manager and the ecologist to consider the cost of delaying any action.

This handbook describes the rationale of the ranking system and its components and how to adapt the system to different situations and different areas of the country. The handbook also describes the information that is needed to apply the system, what the user should know, and how to use the system. Examples of products are given, along with suggestions of their application to management.

An Exotic Plant Ranking System

Why Use an Analytical Approach?

Several sound reasons exist for using an analytical approach as the basis of prioritizing exotic species. One of the basic reasons for using a decision analysis process is to get scientists involved in the decision-making process. Using a consistent and logical decision-making process prevents a biologist from compromising scientific excellence by becoming involved in environmental decisions based on incomplete information. Selecting an action alternative is similar to selecting a hypothesis. The action becomes an experimental manipulation to test the validity of the "hypothesis." A decision analysis process not only adds validity to a decision, but this process often demonstrates that inaction due to lack of complete information can have serious consequences (Maguire 1991).

If an analytical approach was not employed, decisions would most likely be based on the opinion of an individual or a group of individuals or decisions would be based on precedent. Granted, many field ecologists have a good idea of which exotic species are impacting natural ecosystem processes or impacting species composition. However, decisions based on judgment alone are rarely based on defined criteria, do not usually document the reasoning process, and give no assurance that the full array of significant factors were considered. Such decisions may suffer from personal biases and political whims. Decisions are hard to defend if challenged, and proposals for funding are hard to justify. Decisions based on precedent may be easier to defend but are not responsive to the variation in exotic species or natural system interactions over space and time. Thus, priorities set for managing exotic species based on precedent may not reflect current ecological and economic realities.

On the other hand, consistently using an analytical toot such as the Exotic Species Ranking System, can ensure that ecological knowledge is applied to the decision process and can remedy some of the problems associated with decisions based on judgment and precedent alone. An analytical framework encourages researchers to consider the full range of factors and consequences of their decisions. An analytical framework documents the procedures and the reasons for the decisions made, thus reducing the risk aversion characteristic of park managers. Decisions are defendable. Solid justification for program authorization and funding is at hand.

Origin

An earlier version of the system presented here was developed by Ron Hiebert. The system was modeled after a ranking system that was developed at Point Reyes National Seashore (Self 1986). The purpose of this system was to rank the effects of exotic species on the natural recovery of former residential sites at Indiana Dunes National Lakeshore. Hiebert (1990) observed that some exotic species were found only in severely and recently disturbed areas and seemed to have little effect on the succession process. Other exotic species were persistent but did not reproduce or spread, while others were persistent and had high rates of reproduction. Populations of some exotics were expanding within disturbed areas, while others were observed to invade surrounding undisturbed sites. Some of the most invasive and disruptive species were those with life history characteristics (high seed output, long-distance dispersal adaptations, ability to reproduce vegetatively) consistent with those related to weediness (Baker 1965). The present system was developed to support general NPS and park-specific policy, giving high priority to species causing major impacts (and are easily controlled) and giving low priority to species causing little impact (and extremely difficult to control).

Also, the system is designed to identify species that are currently rare and causing little impact but have a high potential to become a problem in the future.

The ranking system presented in this handbook has since been applied to ranking the exotic plants of Indiana Dunes (Klick et al. 1989) and six small national park system areas dominated by prairies and savannahs (Stubbendieck et al. 1992). As part of the latter, 14 plant ecologists reviewed the system. The system was modified to rank exotic plants in Olympic National Park (Olson et al. 1991) and was modified and used to rank both exotic plants and animals in the state of Minnesota (Minnesota Department of Natural Resources 1991). The system has been revised based on the above experiences and recommendations of users and expert reviewers.

Rationale For Use

The ranking system provides an ecologist or resource management specialist with a tool to sort exotic plant species based on their present level of impact and their innate ability to become a pest. Based on conscientious consideration of all the factors in the system, a person with good taxonomic and ecological skills should be able to separate those species that are innocuous from those that are disruptive or have a high potential to become disruptive. The resulting species rank can then be weighed against the ease or feasibility of control, and the urgency of action or the cost of delay in action can be determined.

For example, purple loosestrife *(Lythrum salicaria)* is ranked as the most disruptive exotic plant at Indiana Dunes National Lakeshore. Extensive efforts to eradicate or control its spread have not been successful. However, due to the significance of the impact, the National Park Service is funding research on its basic biology and on experimental control methods. In contrast, Scotch pine *(Pinus sylvestris)* is found to rarely reproduce and to cause only minor impacts throughout most of the park. Significant impacts are limited to one small prairie opening. Control is relatively simple--saw the pine down. Therefore, the park decided to eradicate Scotch pine from the prairie opening and to monitor its status in other park locations.

An example of the urgency ranking as applied is European alder *(Alnus glutinosa)*. This species was found at or in close proximity to one razed residential site at Indiana Dunes National Lakeshore. However, the species had spread into a large, dense clone of thousands of ramets in just six years and was also reproducing sexually. The species was reported to be highly invasive and to cause major impacts in other natural areas. Therefore, the National Park Service considered quick action to be prudent.

In summary, the ranking system encourages resource managers to logically apply criteria that address the present impact of a species on ecological processes and structure and on other park resources. The ranking system also predicts the potential of a species to become a pest in the future. Normally, applying the system will greatly reduce the list of exotic species with which a park manager needs to be concerned. The decision to take management action against a species determined to be disruptive then can be weighed on the basis of the level of impact, the feasibility of successful control, and the prediction of the cost of delay in action. The information accumulated in the system's application serves as solid documentation to support management's decisions and to justify program funding

Description

The Exotic Species Ranking System in Table 1 uses numerical ratings, is written in outline format, and is divided into two main sections: I. Significance of Impact and II. Feasibility of Control or Management. Each section is based on a scale of 100 points.

Table 1. Exotic Species Ranking System (Ronald D. Hiebert)

I. Significance of Impact	
A. Current Level of Impact	
1. Distribution relative to disturbance regime	
a. found only within sites disturbed within the last 3 years of sites regularly disturbed	-10
b. found in sites disturbed within the last 10 years	1
c. found in midsuccessional sites disturbed 11-50 years before present (BP)	2
d. found in late-successional sites disturbed 51-100 years BP	5
e. found in high-quality natural areas with no known major disturbance for 100 years	10
2. Abundance	
a. number of populations (stands)	
(1) few; scattered (<5)	1
(2) intermediate number; patchy (6-10)	3
(3) several; widespread and dense (>10)	5
b. areal extent of populations	
(1) <5 ha	
(2) 5-10 ha	2
(3) 11-50 ha	3
(4) >50 ha	5
3. Effect on natural processes and character	
a. plant species having little or no effect	0
b. delays establishment of native species in disturbed sites up to 10 years	3
c. long-term (more than 10 years) modification or retardation of succession	7
d. invades and modifies existing native communities	10
e. invades and replaces native communities	15
4. Significance of threat to park resources	
a. threat to secondary resources negligible	0
b. threat to areas' secondary (successional) resources	2
c. endangerment to areas' secondary (successional) resources	4
d. threat to areas' primary resources	8
e. endangerment to areas' primary resources	10

Table 1 (cont).

5. Level of visual impact to an ecologist		
a. little or no visual impact on landscape		0
b. minor visual impact on natural landscape		2
c. significant visual impact on natural landscape		4
d. major visual impact on natural landscape		5
	Total Possible = 50	
B. Innate Ability of Species to Become a Pest		
1. Ability to complete reproductive cycle in area of concern		
a. not observed to complete reproductive cycle		0
b. observed to complete reproductive cycle		5
2. Mode of reproduction		
a. reproduces almost entirely by vegetative means		1
b. reproduces only by seeds		3
c. reproduces vegetatively and by seed		5
3. Vegetative reproduction		
a. no vegetative reproduction		0
b. vegetative reproduction rate maintains population		1
c. vegetative reproduction rate results in moderate increase in population size		3
d. vegetative reproduction rate results in rapid increase in population size		5
4. Frequency of sexual reproduction for mature plant		
a. almost never reproduces sexually in area		0
b. once every five or more years		1
c. every other year		3
d. one or more times a year		5
5. Number of seeds per plant		
a. few (0-10)		1
b. moderate (11-1,000)		3
c. many-seeded (>1,000)		5
6. Dispersal ability		
a. little potential for long-distance dispersal		0
b. great potential for long-distance dispersal		5
7. Germination requirements		
a. requires open soil and disturbance to germinate		0
b. can germinate in vegetated areas but in a narrow range or in special conditions		3
c. can germinate in existing vegetation in a wide range of conditions		5
8. Competitive ability		
a. poor competitor for limiting factors		0
b. moderately competitive for limiting factors		3
c. highly competitive for limiting factors		5
9. Known level of impact in natural areas		
a. not known to cause impacts in any other natural area		0
b. known to cause impacts in natural areas, but in other habitats and different climate zones		1
c. known to cause low impact in natural areas in similar habitats and climate zones		3
d. known to cause moderate impact in natural areas in similar habitats and climate zones		5
e. known to cause high impact in natural areas in similar habitats and climate zones		10
	Total Possible = 50	

Table 1 (cont).

II. Feasibility of Control or Management	
A. Abundance Within Park	
1. Number of populations (stands)	
a. several; widespread and dense	1
b. intermediate number; patchy	3
c. few; scattered	5
2. Areal extent of populations	
a. > 50	1
b. 11-50 ha	2
c. 5-10	3
d. < 5ha	5
B. Ease of Control	
1. Seed banks	
a. seeds remain viable in the soil for at least 3 years	0
b. seeds remain viable in the soil for 2-3 years	5
c. seeds viable in the soil for 1 year or less	15
2. Vegetative regeneration	
a. any plant part is a viable propagule	0
b. sprouts from roots or stumps	5
c. no resprouting following removal of aboveground growth	10
3. Level of effort required	
a. repeated chemical or mechanical control measures required	1
b. one or two chemical or mechanical treatments required	5
c. can be controlled with one chemical treatment	10
d. effective control can be achieved with mechanical treatment	15
4. Abundance and proximity of propagules near park	
a. many sources of propagules near park	0
b. few sources of propagules near park, but these are readily dispersed	5
c. few sources of propagules near park, but these are not readily dispersed	10
d. no sources of propagules are in dose proximity	15
C. Side Effects of Chemical/Mechanical Control Measures	
1. control measures will cause major impacts to community	0
2. control measures will cause moderate impacts to community	5
3. control measures will have little or no impact on community	15
D. Effectiveness of Community Management	
1. the following options are not effective	0
2. cultural techniques (burning, flooding) can be used to control target species	5
3. routine management of community or restoration or preservation practices (e.g., prescribed burning, flooding, controlled disturbance) effectively controls target species	10
E. Biological Control	
1. biological control not feasible (not practical possible, or probable)	0
2. potential may exist for biological control	5
3. biological control feasible	10
Total Possible = 100	

Urgency

1. Delay in action will result in large increase in effort required for successful control.	High
2. Delay in action will result in moderate increase in effort required for successful control.	Medium
3. Delay in action will result in little increase in effort required for successful control.	Low

7

I. Significance of Impact is further divided into A. Current Level of Impact and B. Innate Ability of Species to Become a Pest. Stubbendieck et al. (1992) considered a species with a combined score of over 50 points for significance of impact to be seriously disruptive and needing appropriate attention. Species receiving high scores for feasibility of control will be easier to control than those receiving lower scores. A step-by-step description of the system follows.

I. Significance of Impact

A. Current Level of Impact: This section concentrates on ranking the species based on the present degree and extent of impact caused by the exotic species. Element 1 addresses where the species is found along a disturbance regime. If the species is found in only sites that are recently or frequently disturbed, the species is not considered a serious threat. If the species is found in mature undisturbed natural communities, the species is considered a serious threat. Element 2 addresses how many populations (stands) are found in the park and the size of the populations. Element 3 rates a species based on its effects on the ecological processes and structure of native communities. Element 4 addresses which park resources are threatened. Finally, element 5 addresses the visual impact as seen by an ecologist.

B. Innate Ability of Species to Become a Pest: This section ranks a species based on the life history traits that preadapt it to become a problem and its known impacts in other areas. Important life history characteristics include potential rate of increase, adaptations for long-distance dispersal, and the breadth of habitats in which the species can colonize and thrive. Element 1 is essentially a screening device. If the species cannot reproduce in the area, the species most likely will not pose much of a threat. Likely species that will not reproduce in an area are horticultural species transferred from areas with different environmental conditions. Element 2 addresses how a species reproduces. The assumption is that vegetative reproduction allows an adapted ecotype to be maintained, resulting in local spread. Sexual reproduction allows for the maintenance of genetic variation and propagules for long-distance dispersal and the possibility of forming highly adapted gene combinations. If the species can reproduce both vegetatively and sexually, that species has the best of both worlds.

Elements 3, 4, and 5 address the factors that determine the intrinsic rate of increase of a species--how many seeds are produced how often. Element 6 deals with the species ability to disperse. This factor can usually be rated based on the presence or absence of special adaptations for seed or fruit dispersal, such as wings and pappi for wind dispersal, bladders for water dispersal, or bristles for animal dispersal. Element 7 asks if the species needs bare soil (disturbed) to germinate or if the species can germinate in a relatively closed (undisturbed) community. Element 8 looks at what the species can do once the species has colonized an area. Is the species able to outcompete native species for light, water, etc.? Finally, scientists should not ignore what the effects of the species have been in other natural areas.

II. Feasibility of Control or Management

Less is known about the feasibility of managing exotic plants in natural areas than what impacts they have on the natural systems. Most research efforts in controlling plants have been in agriculture where the goal is to control all but one species while not harming the single-crop species. In natural areas, the goal is to control one or a few species while not harming diverse assemblages of native species. However, many factors will affect the funds and effort required for control and the probability of success.

A. Abundance Within Park: No explanation is needed here. The larger the populations and the larger the number of populations, the larger the funds and effort required to manage the species.

B. Ease of Control: This section not only deals with life history characteristics that impact the level of effort that will be needed to control the species, but also the probability of success if unlimited funds and personnel are used. Element 1 addresses the seed bank which directly influences the needed duration of a control program. Information on the longevity of viable seeds in soil is not available for many species, therefore making this element hard to score. However, a best estimate should be made based on the information that is available. Element 2 addresses the vegetative reproduction of the species, which influences the number and kinds of treatments required to control the species, whether the underground parts of the plant must be removed, and also dictates the protocol for disposal of plant material. Element 3 not only addresses the level of effort required, but also the kind(s) of control measures required. Element 3 follows the preferred steps of the NPS Integrated Pest Management Program in that mechanical treatment is preferred over chemical treatment. Element 4 deals with the presence or absence of propagules adjacent to the park and the probability of propagules being dispersed into the park. Consideration should be given to the park's ability to control the species outside its boundaries through cooperative control programs.

C. Side Effects of Chemical/Mechanical Control Measures: As stated earlier, researchers must consider what effects eradication or control measures will have on the system being restored or preserved. Will the treatment open up areas for the same species to recolonize or be invaded by other equally or more impacting exotics? In some cases, the lesser of two unsatisfactory options may be not taking any action.

D. Effectiveness of Community Management: Controlling exotic species through sound management of the system based on ecological study is by far the preferred control method. In some cases, controlling trampling by visitors, restoring historical fire regimes, or restoring shoreline processes or natural hydrological regimes will shift the competitive edge to the desired native species.

E. Biological Control: Biological control is ecologically feasible for many exotic species. However, due to the high costs to develop well-tested biological control agents, it is only economically feasible for exotic species causing major impacts over a broad geographical area and normally only if the species are causing an economic impact as well as an ecological impact. Similarly, biological control is not feasible if the species to be controlled has some economic value. Abundance of closely related native species in the area where the exotic is to be controlled also lowers the feasibility because of possible negative side effects. The responsibility of conducting long-term studies involved with selecting and screening possible control agents lies with the U.S. Department of Agriculture.

Urgency: After the species are ranked according to their level of impact and feasibility of control or management, the exotic species that demands the most attention should be addressed first. The cost of delaying an action either financially or in impact to the natural resources of the park is a good criterion to use in making this often difficult decision.

How to Use the System

Work will be conducted both in the field and in the library. Individuals using the Exotic Species Ranking System must have training in biology because the system requires interpreting specific biological information on each species in the field as well as in the literature. A working knowledge of plant taxonomy is required to properly identify species in the field. Identification may be difficult for the less trained because some of the exotic species are members of genera containing native species as well, and proper separation may be made on relatively fine differences between plants.

The first step in using the Exotic Species Ranking System is to inventory the exotic plant species. Names of plant species should be assembled from (1) species lists and research reports for the park, (2) the catalog of specimens from the park herbarium, and (3) a preliminary field survey of the vegetation. Each species on the completed list should be checked in references, especially the flora for the area, to determine if a species is native or exotic.

The second step is to conduct an intensive survey of the park. The survey should include the location and extent of populations of each exotic species. The information obtained in this survey will be used to complete Current Level of Impact (I.A.), a portion of Innate Ability of Species to Become a Pest (I.B.), and Abundance within Park (II.A.) Usually, two surveys are required. One survey should be conducted in late spring when most cool-season species are flowering, and the second should be conducted in late summer to correspond with flowering of warm-season species. The extent and number of populations should be drawn on a map during the survey. The map will be important for managers to locate exotic species for continued monitoring and future control.

The third step is a comprehensive search of the literature for information on the ecology, biology, and control methods for each exotic species. Information from this part of the process will be used for a portion of Innate Ability of Species to Become a Pest (I.B.) and the majority of II. Feasibility of Control or Management. Computer data bases in most libraries simplify the search procedure. Key words for the search should include the scientific and common names for each species. Not all of the articles will be applicable, but the computer-generated titles and abstracts generally will indicate whether the complete article should be located. The most commonly used journals are listed in Appendix A. Making photocopies of the article for both the ranking process and to place in the files for future reference may be helpful. Unfortunately, the amount of information in the literature varies considerably with the species. For example, articles on common exotic species such as Kentucky bluegrass *(Poa pratensis)* are abundant. Many of the articles are related to turf and turf grass management and have essentially no value for the ranking process. Considerable time is required to separate articles with useful information from the available literature. On the other hand, the literature contains few articles on less abundant exotic species. Occasionally, ranking an individual species may be difficult because not enough information can be located. For example, no reference may be available that contains few articles on less abundant exotic species. Occasionally, ranking an individual species may addresses the length of time seeds remain viable in the soil. The person ranking the species may then need to investigate seed bank ecology of other species within the genus or make a decision based on seed morphology.

An additional source of information may be the element stewardship abstracts prepared by The Nature Conservancy. These comprehensive abstracts are available for some of the common species.

The next step of the process is to complete the Exotic Species Ranking System Data Summary Form (see Appendix B for a blank form) for each species by bringing together all of the information that has been gathered in the previous three steps. The person conducting the ranking should read each step of the Exotic Species Ranking System outline in Table 1 and, based on information gathered, select the appropriate numerical value That value is placed on the Data Summary Form.

An Example: Pipestone National Monument

Intensive exotic species surveys at Pipestone National Monument in Minnesota were conducted during 1989-91. Over 70 exotic species were located and ranked using the Exotic Species Ranking System (Table 2); 11 species were ranked as being highly disruptive (a total of 50 or more points for I. Significance of Impact). These results show that a relatively low proportion of the exotic species will be highly disruptive. None of the highly disruptive species was classified as being easy to control (Figure 1).

Of the 11 highly disruptive exotic species, feasibility of control of quackgrass *(Agropyron repens)* scored the least (16), while feasibility of control of white sweetclover *(Melilotus alba)* scored the greatest (48). Based on knowledge of the individual exotic species, control of only Canada thistle *(Cirsium arvense)* was considered to be urgent.

Canada Thistle

A Data Summary Form for Canada thistle at Pipestone National Monument is presented in Table 3. The data summary in Table 3 may be compared to the outline of the Exotic Species Ranking System in Table 1 to see how Canada thistle was evaluated for each step.

Species Abstract

An additional product that may be obtained from the Exotic Species Ranking System is an abstract for each important species. Generally, important species are those ranked as highly disruptive (a total of 50 or more points for I. Significance of Impact). An outline of the format for a species abstract may be found in Table 4. An example of a species abstract prepared for Canada thistle is in Appendix C.

Table 2. Ranking of exotic plant species (arranged alphabetically) at Pipestone National Monument.

	Significance of Impact				
Species	Current Level of Impact	Innate Ability to Become a Pest	Total	Feasibility of Control	Urgency
Agropyron cristatum	-8	27	19	56	Low
Agropyron repens	28	36	64	16	Medium
Agrostis stolonifera	7	25	32	41	Low
Asparagus officinalis	4	25	29	65	Low
Brassica kaber	-8	16	8	65	Low
Bromus inermis	42	43	85	18	Medium
Bromus japonicus	18	20	38	51	Low
Bromus tectorum	17	20	37	38	Low
Campanula rapunculoides	6	26	32	46	Low
Capsella bursa-pastoris	-2	17	15	37	Low
Carduus nutans	19	34	53	31	Medium
Chenopodium album	-5	18	13	56	Low
Cirsium arvense	19	40	59	17	High
Cornilla varia	12	32	44	34	Medium
Dianthus armeria	4	16	20	60	Low
Digitaria sanguinalis	13	24	37	36	Medium
Eleagnus angustifolia	17	30	47	30	Medium
Eragrostis cilianensis	-8	16	8	50	Low
Euphorbia esula	24	48	72	31	High
Hesperis matronalis	-4	19	15	63	Low
Kochia scoparia	-8	31	23	55	Low
Lactuca serriola	-4	17	13	49	Low
Lappula echinata	7	32	39	50	Low
Lappula redowskii	6	30	36	50	Low
Leonurus cardiacea	9	19	28	43	Low
Lepidium campestre	13	20	33	33	Low
Linaria vulgaris	18	29	47	41	Medium
Lithospermum arvense	4	23	27	65	Low
Lolium perenne	-8	19	11	50	Low
Lonicera tatarica	33	39	72	25	Medium
Matricaria matricariodes	-8	17	9	65	Low
Medicago lupulina	-5	24	19	41	Low
Medicago sativa	10	34	44	34	Low
Melilotus alba	17	34	51	48	Medium
Melilotus officianilis	14	34	48	42	Medium
Nepeta cataria	9	21	30	46	Low
Philadelphus coronarius	9	22	31	45	Low
Phleum pratense	10	30	40	36	Low

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Table 2 (cont).

Species	Significance of Impact: Current Level of Impact	Significance of Impact: Innate Ability to Become a Pest	Significance of Impact: Total	Feasibility of Control	Urgency
Plantago major	-8	24	16	30	Low
Poa compressa	33	34	67	21	Medium
Poa palustris	18	20	38	51	Low
Poa pratensis	38	43	81	23	Medium
Polygonum achoreum	-8	22	14	60	Low
Polygonum aviculare	-4	22	18	46	Low
Polygonum hydropiper	3	30	33	30	Low
Polygonum persicaria	13	21	34	45	Low
Populus nigra	6	30	36	45	Low
Portulaca oleracea	10	24	34	31	Low
Potentilla fruticosa	6	25	31	60	Low
Potentilla recta	18	22	40	31	Low
Ranunculus testiculatus	-8	21	13	75	Low
Rhamnus cathartica	45	44	89	18	Medium
Rumex crispus	-6	27	21	35	Low
Salsola iberica	-6	31	25	75	Low
Setaria faberi	-8	26	18	55	Low
Setaria glauca	-8	29	21	55	Low
Setaria viridis	-2	26	24	38	Low
Silene cserei	-8	16	8	60	Low
Silene pratensis	-8	19	11	60	Low
Sisymbrium altissimum	-8	21	13	60	Low
Solanum dulcamara	-1	22	21	50	Low
Sonchus arvensis	20	39	59	22	Medium
Taraxacum officinale	-4	33	29	34	Low
Thalspi arvense	-8	18	10	55	Low
Tragopogon dubius	7	26	33	31	Low
Trifolium hybridum	-8	25	13	50	Low
Trifolium pratense	18	23	41	36	Low
Trifolium repens	11	29	40	36	Low
Ulmus pumila	18	29	47	36	Low
Verbascum thapsus	15	22	37	36	Medium
Veronica arvensis	6	19	25	55	Low

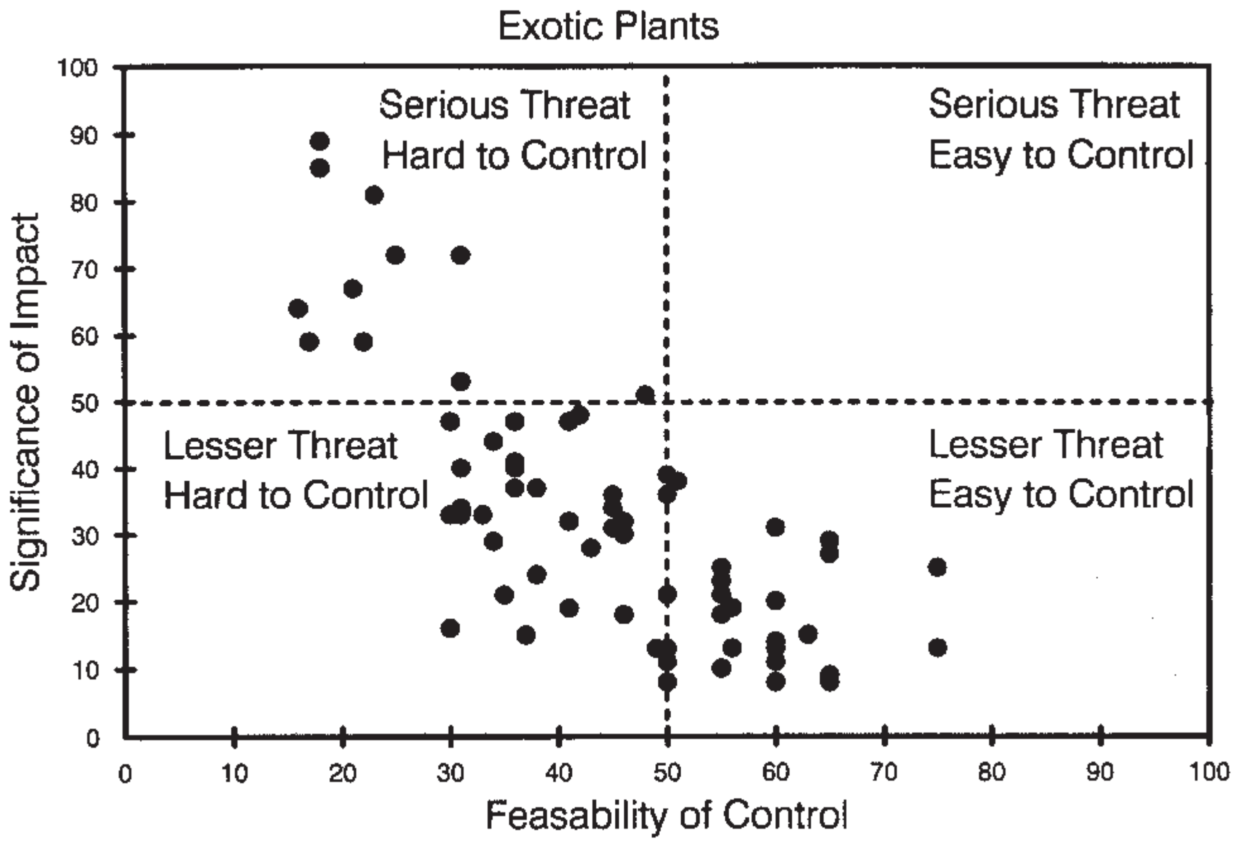

Figure 1. Plot of level of impact vs. feasibility of control for exotic plant species at Pipestone National Monument, Minnesota.

Adaptability

The system presented in this handbook was designed to rank exotic plants in parks and natural areas in the Midwestern states with medium-to-high productivity and fairly rapid successional rates. However, the system is designed to be adaptable for different biogeographical areas or groups of organisms, or to be applied at various scales. To adapt the system to different biogeographical areas, the time scale for disturbance regimes can be modified as appropriate. The system was adapted to rank plants and animals at a statewide scale by the state of Minnesota. This ranking was done by the Minnesota Department of Natural Resources. The Minnesota task force applied the system to plants and animals, including birds, mammals, fish, reptiles, amphibians, insects, mollusks, and crustaceans. Rather than use the methods presented here for a single park or natural area, the task force applied them on a statewide basis using averages per county for the abundances ratings.

Table 3. Completed Exotic Species Ranking Summary Form for Canada thistle *(Cirsium arvense)* at Pipestone National Monument.

Exotic Species Ranking System
Data Summary Form

Park: Pipestone National Monument Species: *Cirsium arvense*

Significance of Impact:			
Current Level of Impact (50)	19		
Innate Ability to Become a Pest (50)	40	Total (100)	59
Feasibility of Control:		Total (100)	17
Urgency:			High

I. Significance of Impact:

A. Current Level of Impact

1. Distribution relative to disturbance regime (-10, 1, 2, 5, 10)	2
2. Abundance	
a. number of populations (1, 3, 5)	3
b. areal extent of populations (1, 2, 3, 5)	1
3. Effect on natural processes and character (0, 3, 7,10, 15)	7
4. Significance of threat to park resources (0, 2, 4, 8, 10)	4
5. Level of visual impact to an ecologist (0, 2, 4, 5)	2
Total (50 possible)	19

B. Innate Ability of Species to Become a Pest

1. Ability to complete life cycle in area of concern (0, 5)	5
2. Mode of reproduction (1, 3, 5)	5
3. Vegetative reproduction (0, 1, 3, 5)	5
4. Frequency of sexual reproduction (0, 1, 3, 5)	5
5. Number of seeds per plant (1, 3, 5)	5
6. Dispersal ability (0, 5)	5
7. Germination requirements (0, 3, 5)	0
8. Competitive ability (0, 3, 5)	5
9. Known level of impact in natural areas (0, 1, 3, 5, 10)	5
Total (50 possible)	40
A + B (100 possible)	59

Table 3 (cont).

II. Feasibility of Control or Management	
A. Abundance Within Park	
1. Number of populations (1, 3, 5)	3
2. Areal extent of populations (1, 2, 3, 5)	3
B. Ease of Control	
1. Seed banks (0, 5, 15)	0
2. Vegetative regeneration (0, 5, 15)	0
3. Level of effort required (1, 5, 10, 15)	1
4. Abundance and proximity of propagules (0, 5, 10, 15)	0
C. Side Effects of Chemical/Mechanical Control (0, 5, 15)	5
D. Effectiveness of Community Management (0, 5, 10)	0
E. Biological Control (0, 5,10)	5
Total (100 possible)	17

Urgency: High

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Table 4. Outline of a species abstract.

Park (full name and abbreviation)

Scientific Name (with authority)

Synonyms (if any)

Common Name(s)

Urgency Ranking

Overall Ranking

Significance of Impact
- A. Current impact
- B. Ability of species to become a pest

Feasibility of Control or Management

Taxonomic Description:
- A. Life form
- B. Height
- C. Vegetative characteristics
  - Stems
  - Underground (roots, rhizomes, etc.)
  - Leaves
    - arrangement
    - type
    - sheaths and ligules (of grasses)
    - size
    - margins
    - surfaces (pubescence)
    - attachment
    - petiole
- D. Floral characteristics
  - Inflorescence
    - type
    - size
  - Flowers of forbs and woody plants
    - type
    - size
    - bracts
    - calyx
    - corolla
    - color
    - anthers and ovary
  - Spikelets of grasses
    - florets
    - glumes
    - lemmas
    - paleas
    - awns

Table 4 (cont).

E. Fruit characteristics
   Type
   Shape
   Size
   Color
   Attachments for dispersal
F. Varieties (if any)

Biology and Ecology:

A. Origin
B. Habitat
C. Distribution (current and historical)
D. Climatic and ecological range
   Soils
   Disturbance
   Temperature
   Precipitation
   Soil moisture
   Light
   Fertility
   Other
E. Reproduction
   Type (asexual or sexual with flowering period)
   Ecological requirements
   Rate
   Seed production (including number per plant)
   Dispersal
   Longevity in seed bank
F. Germination

Distribution:

A. Number in the park
B. Size of populations
C. Location and successional sites
D. Relationship to disturbance
E. Invasion potential
F. Visual impact

Control:

A. Considerations
B. Mechanical
C. Cultural
D. Chemical
E. Biological

References:

Local Control Experts:

A. Extension weed control specialists
B. Department of Natural Resources
C. Other

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Applying Results to Management Action

The logical species to give the highest priority are those that seriously threaten natural resources yet appear to be easy to control. The lowest priority should be given to those species that pose little threat and would be difficult to control. An easy way to categorize the ranked exotics is to plot the level of impact against the feasibility of control. Plots for Pipestone National Monument and Wilson's Creek National Battlefield are in Figures 1 and 2. As demonstrated in these two cases, the majority of the species are not considered to be a serious threat to park resources. This pattern is consistent with all surveys done to date. Also of note is that no species fall in the quadrant of serious threat and easy to control. We predict that this scenario will be the norm. Deciding which species or group of species in which areas need to be targeted for control is not easy. However, the resource manager now has only a few species to consider and should be equipped with most of the information available to guide a decision. The information will also aid in developing at least rough cost estimates and needed time commitments for various control scenarios. The resource manager also has the background information to defend a decision. The urgency ranking should also help indicate the resource and financial costs of delay in action.

The resource manager may determine that the most serious threat is uncontrollable on a parkwide basis. Control efforts may need to be restricted to rare communities or to areas where the exotic species threatens an endangered species. Control efforts may be futile within the park without cooperation from neighbors, as ample propagules for reinvasion exist near park boundaries. The only known successful control may require using an herbicide that has possible serious side effects. A decision to divert at least a portion of the effort towards investigating ways to shift the competitive advantage from the exotic to the native species or developing methods for easy and economic control of selected exotics may be appropriate. A decision often will require selecting the lesser of several evils. However, with diligence, by soundly applying information to management decisions, and documenting and communicating successful and unsuccessful control efforts, progress can be made in managing exotic species in natural areas.

Cautions

As with any tool, this system can be misused.

1. This ranking system provides a tool to resource managers and biologists who are knowledgeable of the area and species under investigation. They will benefit by using the system to consistently consider all of the important ecological and managerial elements for all exotic species. The ranking system provides the information in a format that can serve as a solid foundation on which to base an action plan. However, as is the case with most tools, the system can be misused or even be harmful if not used as intended or if not used by a skillful craftsman.

2. Separating the innocuous species from the disruptive species and consistently generating information on exotic species is the purpose of the system. The actual numeric values have little meaning or value.

3. The information provided by using this system to survey and rank exotic species is good for a specific place and time. Ecological systems are highly dynamic, and the distribution abundance and level and type of impact will change over time and space.

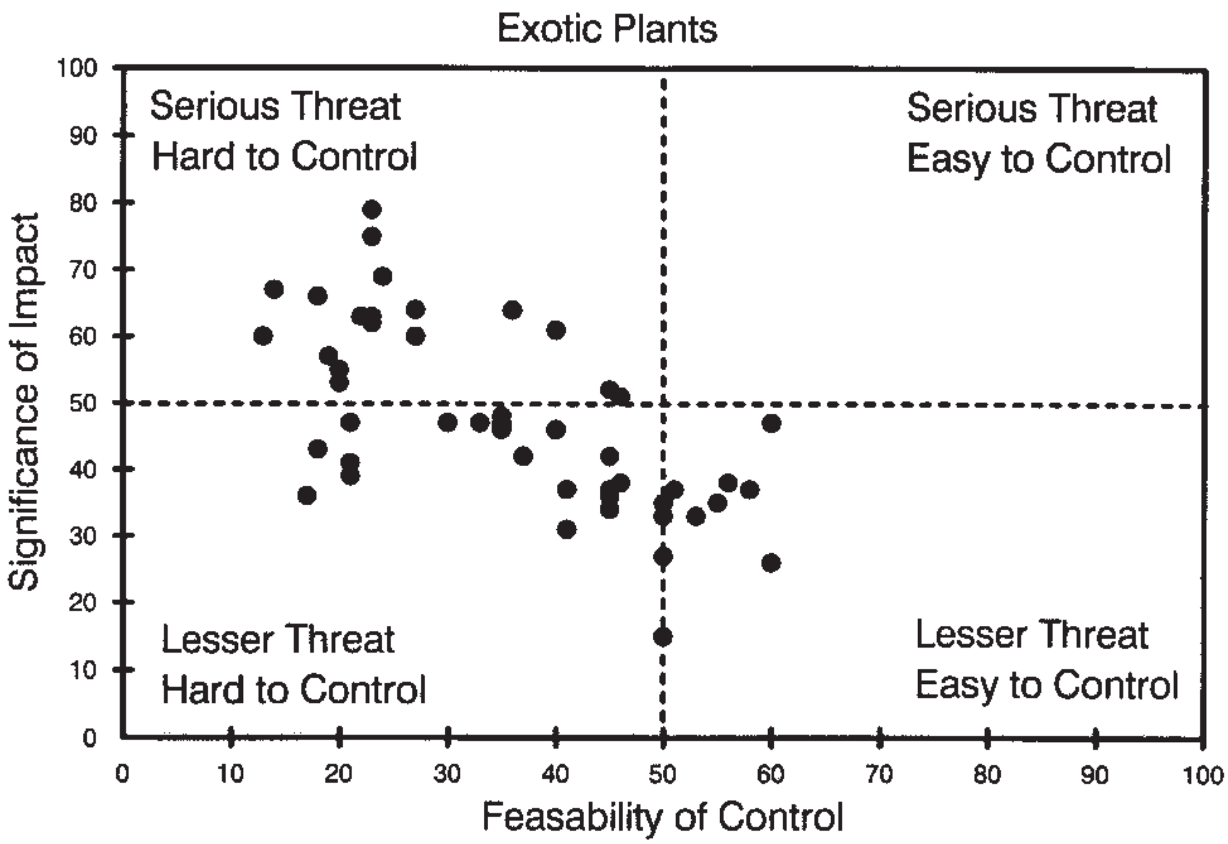

Figure 2. Plot of level of impact vs. feasibility of control for exotic plant species at Wilson's Creek National Battlefield, Missouri.

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Westman, W.E. 1990. Park management of exotic plant species: problems and issues. Conservation Biology 4:251-260.

Names of Journals of Commonly Used Sources of Information for Exotic Species

Journals

Acta Biotheroretica
African Journal of Ecology
Agronomy Journal
American Journal of Botany
American Midlands Naturalist
American Naturalist
Annual Review of Ecology & Systematics
Annuals of Botany
Biological Conservation
Botanical Gazette
Bulletin of the Torrey Botanical Club
Canadian Journal of Botany
Canadian Journal of Plant ScienceWeed Technology
Conservation Biology
Crop Science
Ecological Modelling
Ecology
Environmental Ecology
Environmental Management
Grass and Forage Science
Great Basin Naturalist
HortScience
Journal of Agricultural Economics
Journal of Applied Ecology
Journal of Arid Environments
Journal of Biogeography
Journal of Ecology
Journal of Economic Entomology
Journal of Entomological Science
Journal of Range Management
Journal of Vegetation Science
Natural Areas Journal
New Phytologist
Oecologia
Oikos
Paleobiology
Physiologia Planatarum
Phytopathology
Plant Disease
Plant Physiology
Quarterly Review of Biology

Journals

Rangelands
Restoration and Management Notes
SIDA
Soil Science
Soviet Journal of Ecology
Vegetatio
Weed Research
Weed Science
Weeds

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Exotic Species Ranking System
Data Summary Form

Park: ______________________ Species: ______________________

Significance of Impact:

Current Level of Impact (50) ____

Innate Ability to Become a Pest (50) ____ Total (100) ____

Feasibility of Control: Total (100) ____

Urgency: ____

I. Significance of Impact.

A. Current Level of Impact

1. Distribution relative to disturbance regime (-10,1, 2, 5,10) ____
2. Abundance
   a. number of populations (1, 3, 5) ____
   b. areal extent of populations (1, 2, 3, 5) ____
3. Effect on natural processes and character (0, 3, 7, 10, 15) ____
4. Significance of threat to park resources (0, 2, 4, 8, 10) ____
5. Level of visual impact to an ecologist (0, 2, 4, 5) ____

Total (50 possible)

B. Innate Ability of Species to Become a Pest

1. Ability to complete life cycle in area of concern (0, 5) ____
2. Mode of reproduction (1, 3, 5) ____
3. Vegetative reproduction (0, 1, 3, 5) ____
4. Frequent of sexual reproduction (0, 1, 3, 5) ____
5. Number of seeds per plant (1, 3, 5) ____
6. Dispersal ability (0, 5) ____
7. Germination requirements (0, 3, 5) ____
8. Competitive ability (0, 3, 5) ____
9. Known level of impact in natural areas (0, 1, 3, 5, 10) ____

Total (50 possible) ____

A + B (100 possible) ____

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II. Feasibility of Control or Management

A. Abundance Within Park

1. Number of populations (1, 3, 5) ____
2. Areal extent of populations (1, 2, 3, 5) ____

B. Ease of Control

1. Seed banks (0, 5, 15) ____
2. Vegetative regeneration (0, 5, 15) ____
3. Level of effort required (1, 5, 10, 15) ____
4. Abundance and proximity of propagules (0, 5, 10, 15) ____

C. Side Effects of Chemical/Mechanical Control (0, 5, 15) ____

D. Effectiveness of Community Management (0, 5, 10) ____

E. Biological Control (0, 5, 10) ____

Total (100 possible) ____

Urgency: ____

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Species Abstract of Canada Thistle at Pipestone National Monument, Minnesota

Park:	Pipestone National Monument
Species:	*Cirsium arvense* (L.) Scop.
Common Name:	Canada thistle, field thistle, creeping thistle, California thistle
Urgency Ranking:	High
Overall Ranking:	8
Significance of Impact:	59
A. Current impact:	19
B. Ability to become a pest:	40
Feasibility of Control or Management:	17

Taxonomic Description:

Canada thistle is a dioecious, perennial forb reaching heights of up to 1.5 m. This species's erect stem is highly branched above, green, and glabrescent-to-covered with dense cobweb-like hairs. Canada thistle usually occurs in small to large patches with numerous individuals arising from horizontal, lateral roots bearing adventitious shoots. Leaves are simple and placed alternately on the stem. Lower cauline leaves are 5-18 cm long and 1.5-6 cm wide, oblong to oblanceolate, and entirely or shallowly to pinnately lobed. Each lobe has few to many spines, and some spines are up to 5 mm in length. Both leaf surfaces may be glabrous, or the upper surface may be lightly pubescent while the lower surface is densely pubescent. Cauline leaves are reduced in size upwards and less lobed. Leaves may have a petiole up to 1 cm long, sessile, clasping, or short decurrent. Heads are numerous and occur in terminal corymb-like clusters. Each head is discoid and unisexual or incompletely dioecious. Pistillate flowers are 1-2 cm high and 0.5-1 cm wide, and staminate flowers are somewhat shorter. Bracts are imbricate, in five to six rows, ovate to lanceolate (2-6 mm long and up to 1.2 mm wide), spine-tipped with a spine up to 1 mm long, and glabrous to covered with a dense cobweb-like hair. The corolla is tubular and pink or purple in color (occasionally white). Staminate corolla tubes are 12-14 mm long, and anthers are 3.5-4 mm long and occasionally have vestigial pistillate parts. Pistillate corollas are longer (19-24 mm long) and may have vestigial anthers. Achenes are light brown to straw-colored (2-4 mm long and up to 1.5 mm wide). Each achene has a pappus of numerous white to grayish plumose bristles reaching up to 2.5 cm in length. Four varieties of this species have been recognized: var. *vestitum* Wimm. & Grab., var. *integrifolium* Wimm. & Grab., var. *arvense* (L.) Scop., and var. *horridum* Wimm. & Grab.

Biology and Ecology:

Canada thistle is a highly competitive and noxious weed. It was apparently introduced from Eurasia into North America in colonial times as a contaminate of agricultural seed. Now a naturalized weed, Canada thistle is most commonly found in agricultural lands, pastures, and rangelands. The weed has also become established in forests, riversides, roadsides, lawns, gardens, abandoned fields, and ditchbanks. Canada thistle can now be found in all of the lower 48 states and all of the Canadian provinces.

Canada thistle is most common in open, mesophytic areas. It has a temperature tolerance of -35º to 40º C. Optimal annual precipitation is 400-750 mm. The species grows in a wide variety of soils, including sand dunes, but is most abundant in clayey soils. It can tolerate saline soils and wet or dry soils, but grows best in dry soils. Disturbance is necessary for initial establishment; however, once established it may rapidly spread by both rhizomes and seed. Canada thistle is not generally shade tolerant. Its growth is reduced when light falls to 60-70% of full daylight, and death occurs when light is reduced to 20% of full sun. This tolerance level may explain why Canada thistle does not persist in prairies in good to excellent condition. The species also does not readily tolerate waterlogged, poorly aerated soils. However, it may be found growing in these conditions in a lowered condition.

Extensive rhizomes of Canada thistle make it unique among the thistles. Rhizomes develop at depths far below the zone of rhizome development for most species. Most rhizome development occurs in the first 75 cm of the soil, but has been reported to occur at nearly 7 m. Lateral root growth of up to 6 m in one growing season has been recorded. Root buds are produced on lateral roots at 6-12-cm intervals. With these closely placed buds, root fragments as small as 8 mm in length and 3-6 mm thick have produced new shoots, and root fragments 13 cm in length nearly always produce new shoots. Root fragments can produce viable shoots in as few as five days. Root/shoot elongation increases with temperature and photoperiod. Elongation is greatest at 25º/15º C day/night temperatures, soil temperatures of 30º C, and a photoperiod of 15 hours. Root reserves are lowest just before flowering and are the greatest in early fall when aboveground growth stops.

Shoots begin to emerge in the early spring when soil temperatures reach about 5º C. Development of rosette leaves occurs first followed by vertical elongation in early summer. Flowering is generally from June to September, when day length reaches 14 to 18 hours. Canada thistle is incompletely dioecious, with the staminate and pistillate flowers usually borne on separate plants. Therefore, natural patches are usually of one sex. Flowers are pollinated by insects, primarily honey bees and some wasps. Each plant produces from 30 to 100 heads in a season. Each pistillate head has about 100 fertile florets, and about 83 to 90 will form seeds. One plant has the potential to produce up to 5,200 seeds in a season, but the average seed production is about 1,530 seeds per plant. Seeds are dispersed primarily by wind. Seed size is variable, averaging 650,000 to nearly 1,500,000 per kg.

Germination rates of between 50% and 95% have been observed. An average of 90% of the yearly seed production germinates within one year. Studies have shown that some seeds can remain viable in the soil for up to 21 years and up to four months in water. Optimal germination in the laboratory occurs with temperatures at a constant 30º C or where temperatures alternate between 20º and 30º or 30º and 40º C. Germination is restricted with osmotic pressures above 5 bars. Optimal germination is between pH 5.8 and 7.0. Each crop of seed produces a succession of seedlings. Some will germinate that fall and produce a rosette. These will then flower the next summer. Other seeds will not germinate until the next spring (or later) and may or may not flower that year.

Some evidence indicates that Canada thistle may have an allelopathic effect; however, no specific compound has been isolated. Autotoxicity has been hypothesized in some circumstances.

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Distribution:

An intermediate number of Canada thistle plants are present at Pipestone National Monument. They occur in patches and cover less than a total of 5 ha. Canada thistle plants are found in midsuccessional sites that were disturbed in the last 11 to 50 years. These plants have the potential to invade and modify existing native plant communities and may endanger the secondary successional resources. The plants have a minor visual impact on the park.

Control:

Numerous control options exist for Canada thistle. Biological, chemical, cultural, and mechanical methods have all been used with varying levels of success. An important consideration in controlling Canada thistle is that the seeds have the potential to remain viable in the seed bank for at least 20 years. Thus, removing living plants may not totally eliminate the problem. A further consideration is that many sources of new propagules surround the park.

An important consideration prior to applying any control method is to determine if enough desirable plants are present to replace the Canada thistle. If desirable vegetation is absent or not present in enough numbers, control will be of little value. Most control methods will have a detrimental effect on other plant species, and they all constitute a disturbance that will favor reinvasion by Canada thistle or by other exotic species. Researchers should note that many native thistles are present in the area, and they should not be subjected to control. Proper identification is important.

Frequent mowing over a number of years will control Canada thistle. Mowing has been the primary control method employed at Pipestone. Most studies indicate a need to mow patches of Canada thistle at least twice a year to prevent seed dispersal and reduce root reserves. Systematic monthly mowings may be necessary to prevent lateral flower bud development and to keep root reserves depleted. Tillage may be used to control Canada thistle; however, tillage may result in an increase in abundance due to spreading rootstalks and the subsequent disturbance. Tillage should be to a depth of 10 cm when the elongated shoots are 8 to 10 days old. Tillage should be repeated at a minimum of 21-day intervals. Canada thistle has a relatively high light requirement, and smother crops may provide some measure of control by shading. Smother plants that have been used include sweet clover, alfalfa, millet, sorghum, hemp, and small grains.

No prescribed burning studies have been conducted to specifically control Canada thistle. Supplementary information has shown that repeated burning in May or June reduced thistle abundance in grasslands. In most of these studies, Canada thistle showed an initial increase in abundance, followed by a notable reduction in abundance.

A number of chemical control options exist for Canada thistle. Many herbicides discussed here are not specific to Canada thistle or may not be specifically licensed for this particular type of use. Thus, users must read and follow all label directions. Before "modern" herbicides were introduced, compounds such as sodium chloride, sodium arsenite, calcium arsenite, sodium chlorate, and carbon bisulfide were all used in attempts to control Canada thistle. Numerous herbicides are now available for controlling Canada thistle. Tordon (pidoram) is probably the most effective. Tordon may give a 95% control in the first year when applied at a rate of 0.56-1.23 kg ai/ha in the spring before flowering or in the fall during active rosette growth. Banvel (dicamba) applied at 0.56-6.73 kg ai/ha or 2,4-D (amine) at 0.56 2.24 kg ai/ha will suppress or control Canada thistle. However, more effective control may be achieved by combining the two herbicides in a 1:1 mixture. This mixture should be applied in the spring before flowering or in the fall when the rosettes are actively growing. Roundup (glyphosate) applied at a rate of 1-2 kg ai/ha at the bud stage or during the active growth period in the fall will also control this thistle. Amitrole-T (amitrol) applied at rates of 2.24-4.48 kg ai/ha when the plants are in the bud stage has yielded 70% control in the first year. Most herbicides, except Tordon, should not be applied while the plants are in a moisture-stressed condition. Other herbicides that have shown potential to control Canada thistle are Buctril 2EC (bromoxynil), Curtail (clopyralid plus 2,4-D), and Stinger (clopyralid).

Biological control of Canada thistle has received some attention. Over 80 native species of insects and over 50 species of animals and fungi use Canada thistle to some extent. A few species have the potential for providing same measure of control. Only four insects may be a threat to Canada thistle. These four are composed of two beetles [*Cassia rubiginosa* Muell. (Coleoptera: Chrysomelidae) and *Cleonus piger* (Coleoptera: Curculionidae)], one fly [*Orellia ruficauda* Fab. (Diptera: Tephritidae)], and the painted lady butterfly [*Vanessa cardui* L. (Lepidoptera: Nymphaidae)]. Only *Orellia ruficauda* appears to do significant damage to Canada thistle, and this level of damage is not sufficient for control. Five European insect species [*Ceutorhynchus litura* F. (Coleoptera: Curculionidae), *Rhinocyllus conicus* Froelich (Coleoptera: Curculionidae), *Altica carduorum* Guerin-Meneville (Coleoptera: Chrysomelidea), *Lema cyanella* L. (Coleoptera: Chrysomelidae), and *Urophora cardui* L. (Diptera: Tephritidae)] have all been released in North America for Canada thistle control. To date, only *Ceutorhynchus litura* has become established, spread, and begun to suppress this plant.

Fungus species of the genus *Puccinia* hold some promise as control agents. *Puccinia punctiformis* (Strauss) Roehling (Fungus: Uredinales) has been tested in Europe and New Zealand and has been found to only reduce plant vigor. The best biological control of Canada thistle has come when this fungus has been used in conjunction with either 2,4-D, or *Ceutorhynchus litura.* Plants treated with the fungus followed by weevil introduction had over a 50% increase in damage over nontreated plants.

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Notes

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As the nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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Appendix G: Maps of the Known Distribution of Exotic Plant Species At Capulin Volcano National Monument

Willson et al. (2008) only reported the distribution of *Bromus tectorum* and *Bromus japonicus*. Consequently, distribution maps for species reported only by these authors are not included.

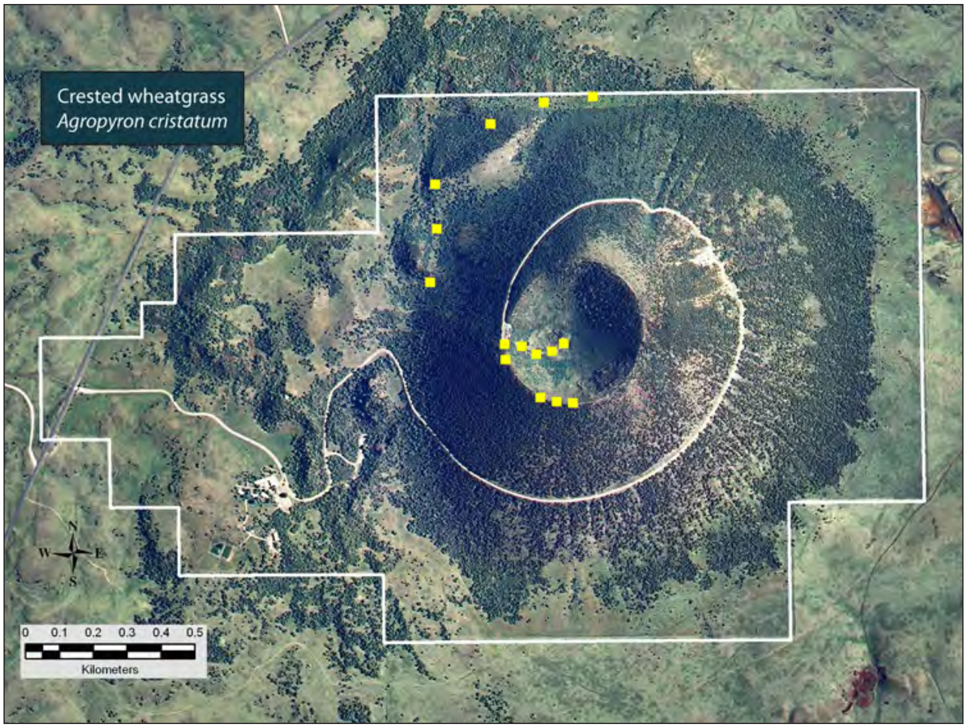

Figure G-1. Crested wheatgrass *(Agropyron cristatum)*

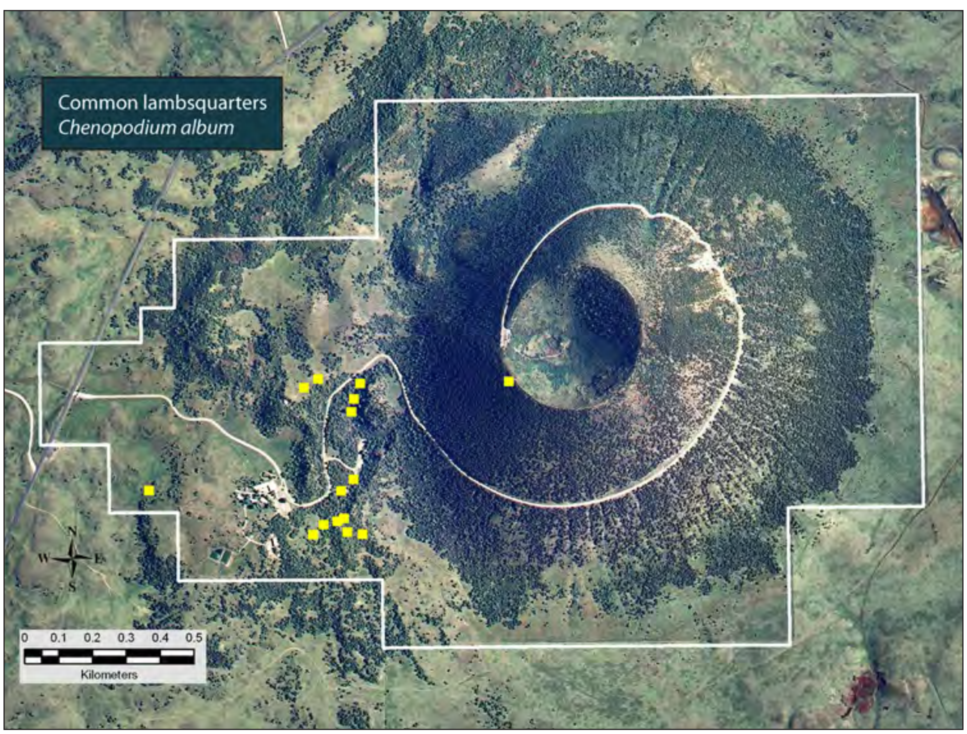

Figure G-2. Common lambsquarters *(Chenopodium album)*

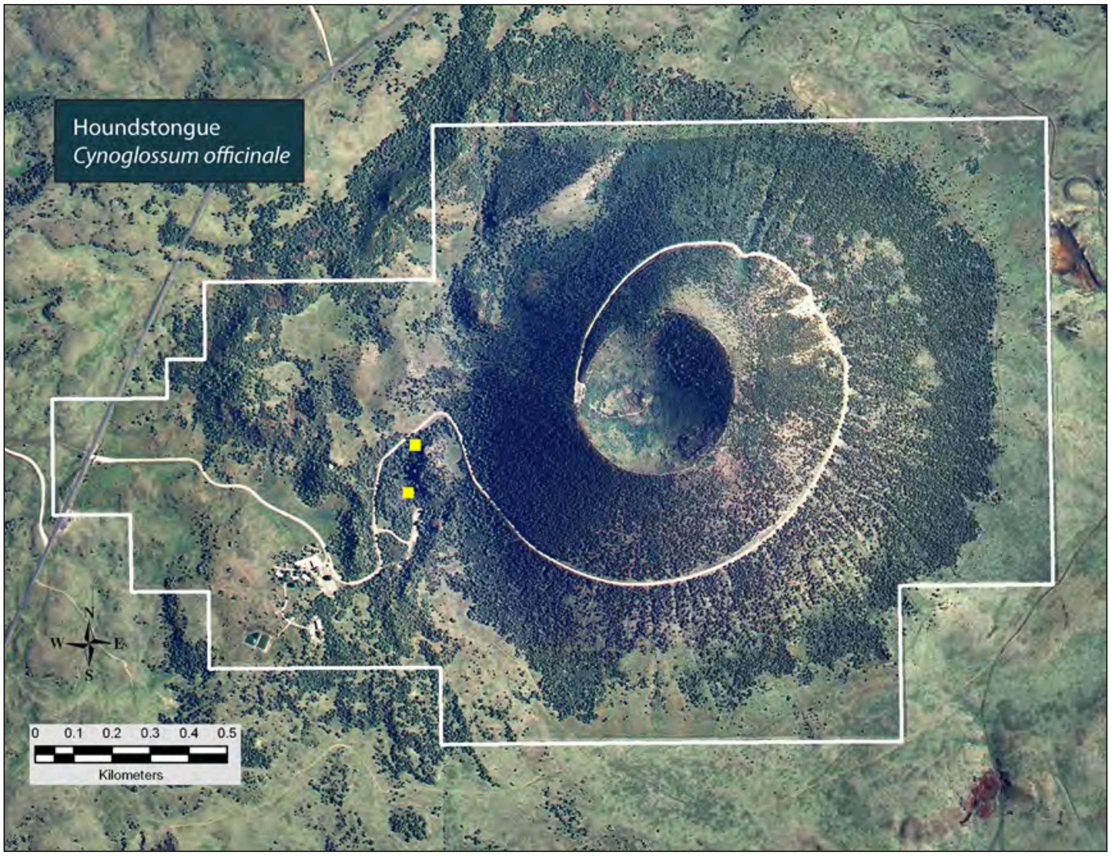

Figure G-3. Houndstongue *(Cynoglossum officinale)*

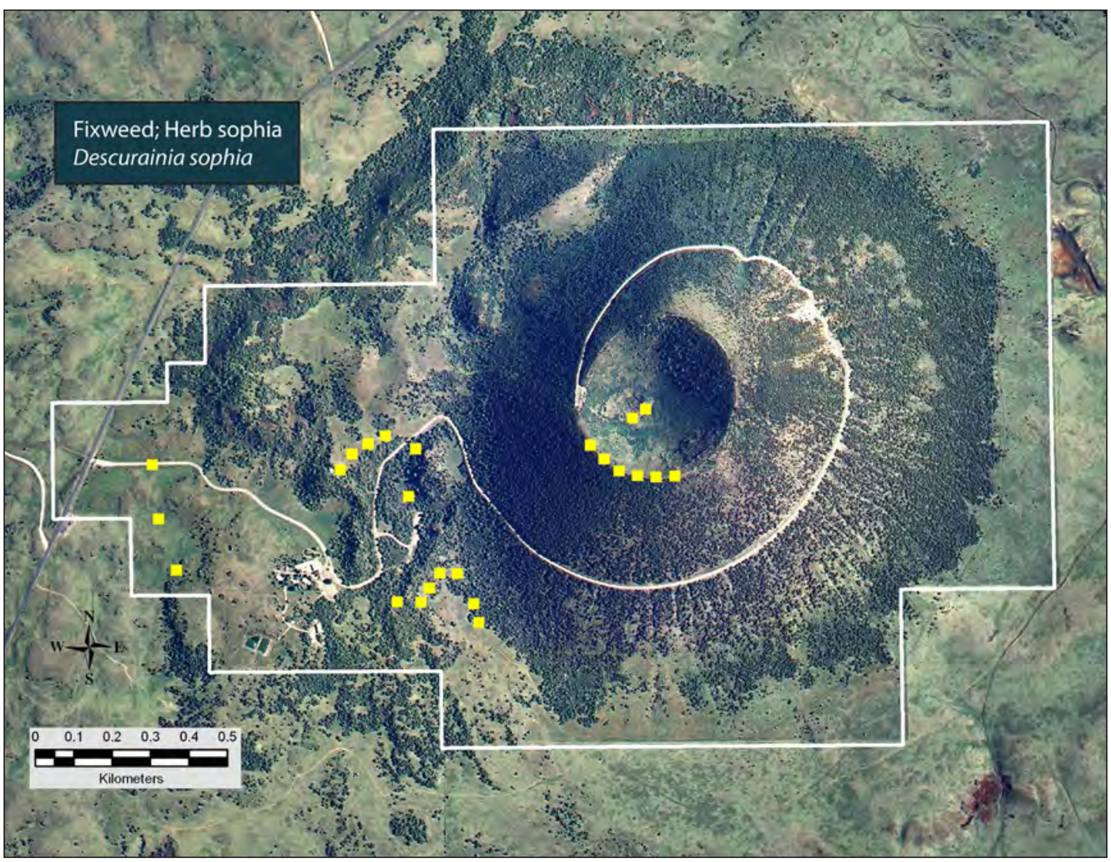

Figure G-4. Flixweed *(Descurainia sophia)*

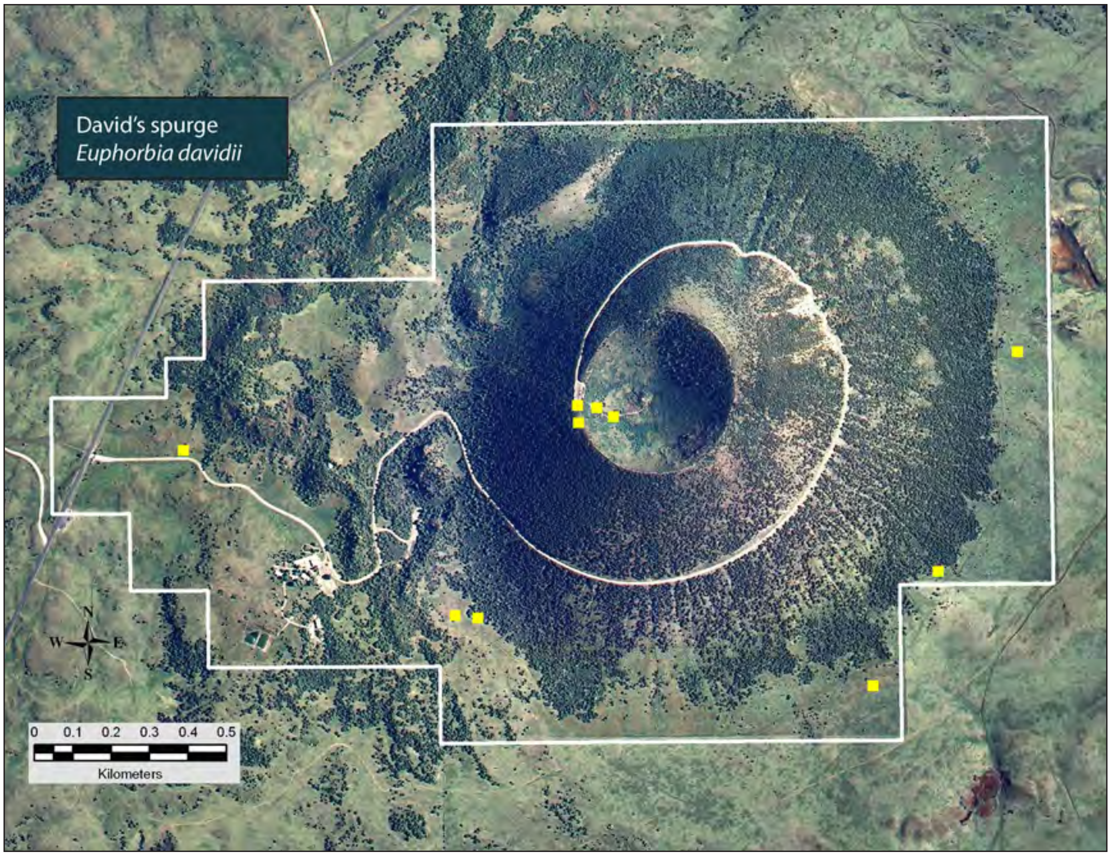

Figure G-5.
Davids spurge
(Euphorbia davidii)

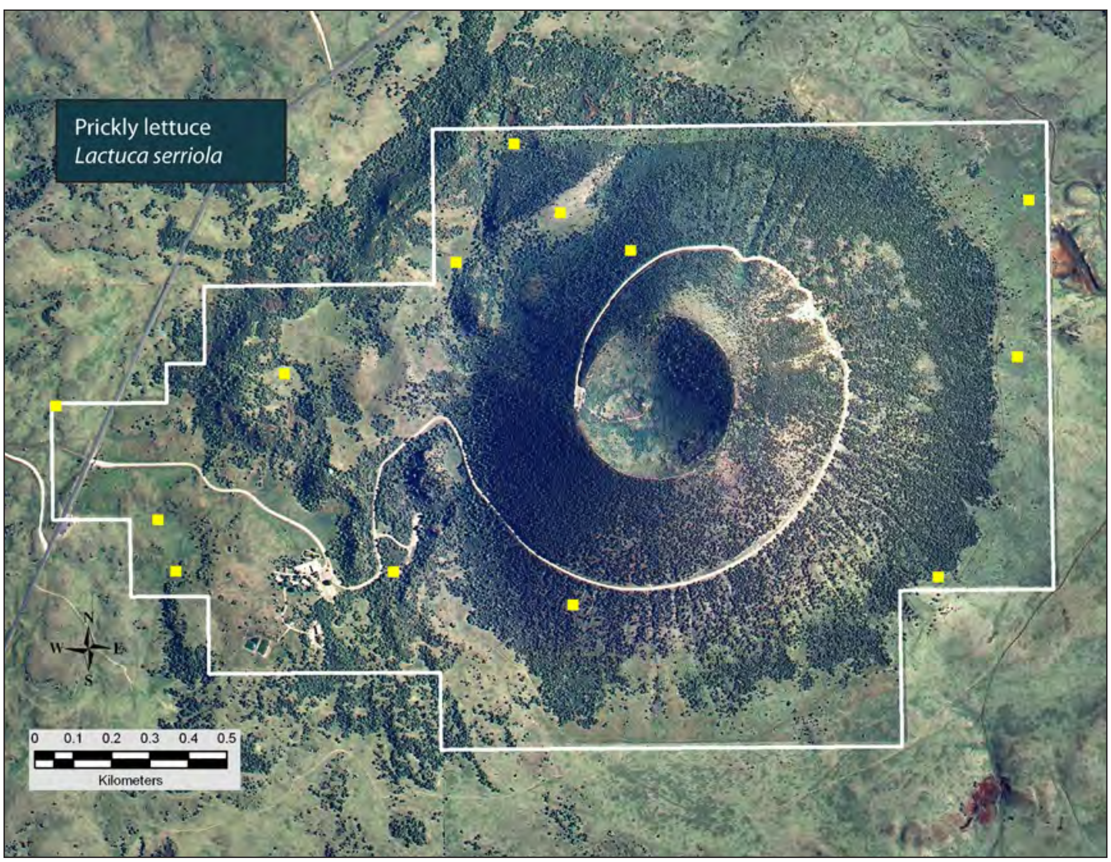

Figure G-6.
Prickly lettuce
(Lactuca serriola)

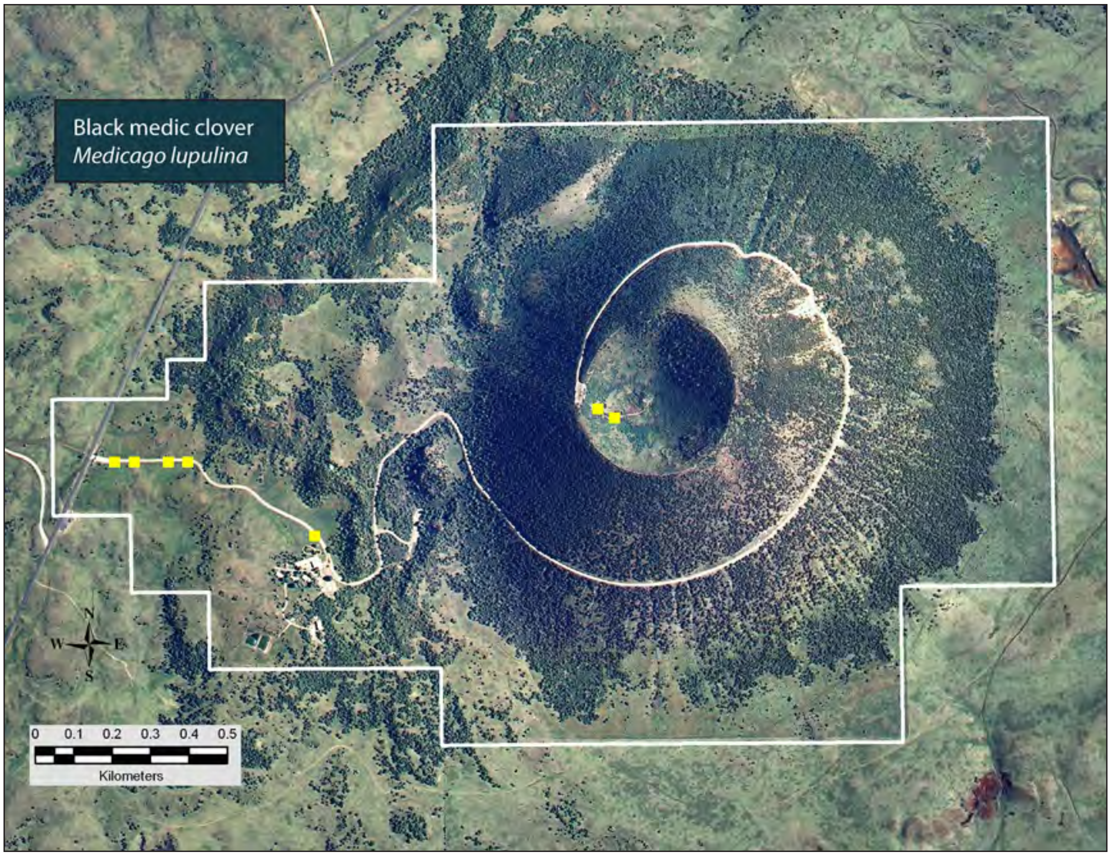

Figure G-7.
Black medic clover
(Medicago lupulina)

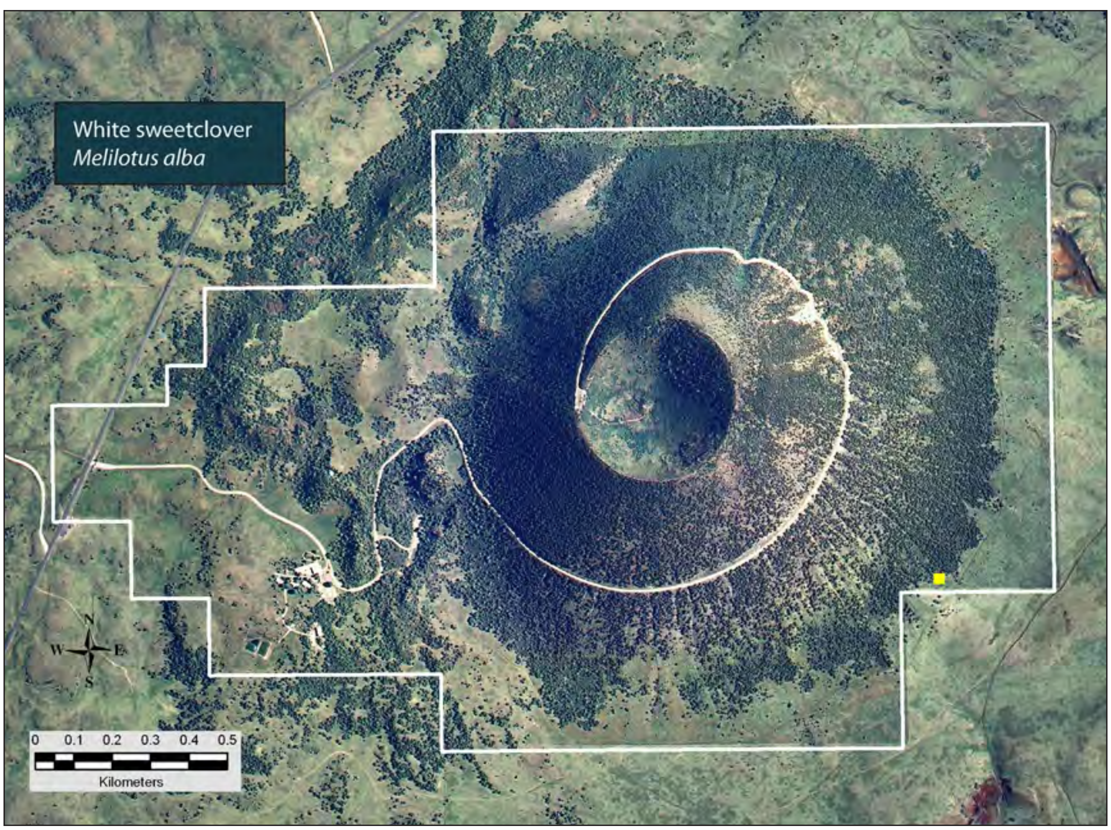

Figure G-8.
White sweetclover
(Melilotus alba)

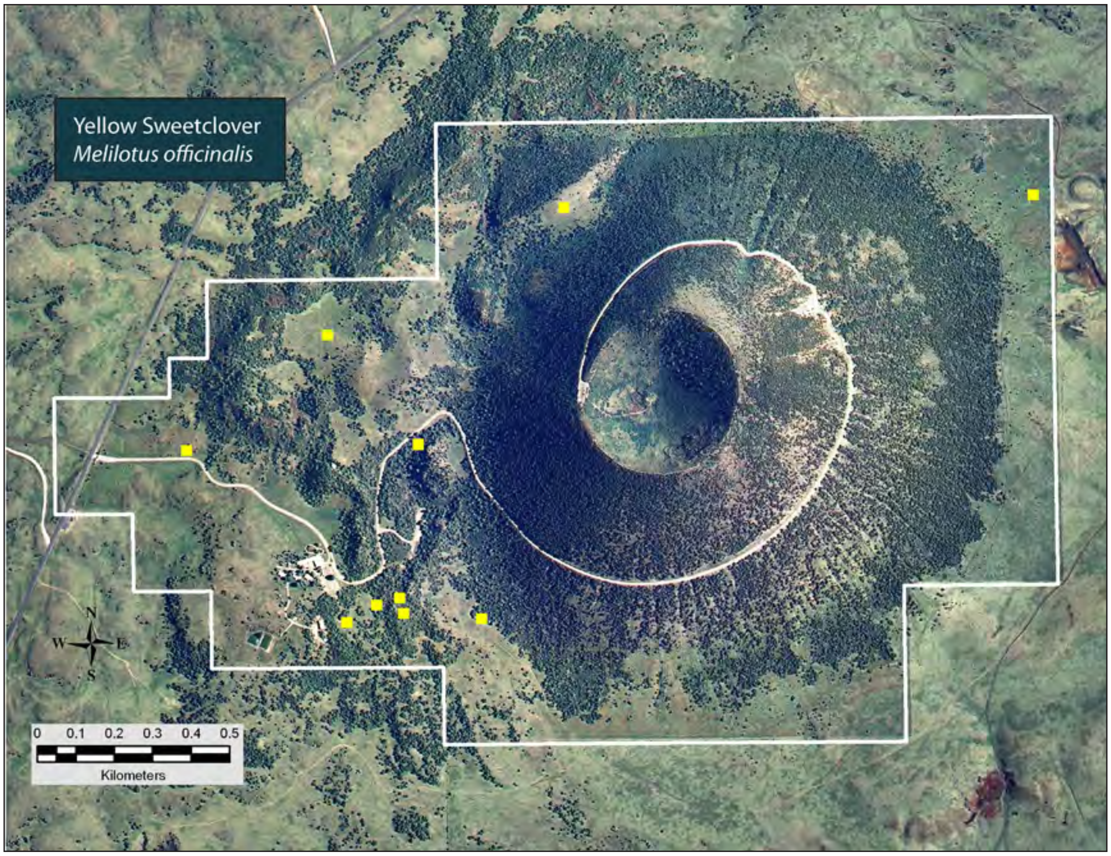

Figure G-9.
Yellow sweetclover
(Melilotus officinalis)

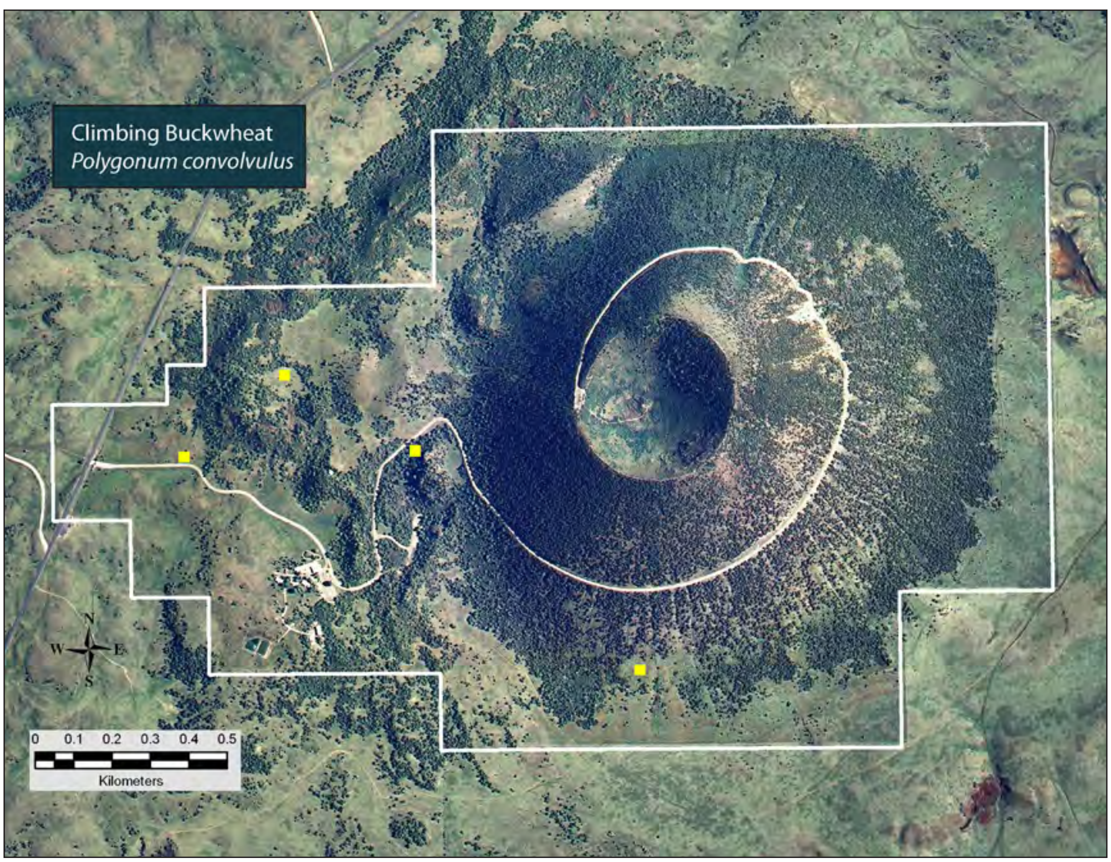

Figure G-10.
Climbing Buckwheat
(Polypogon convolvulus)

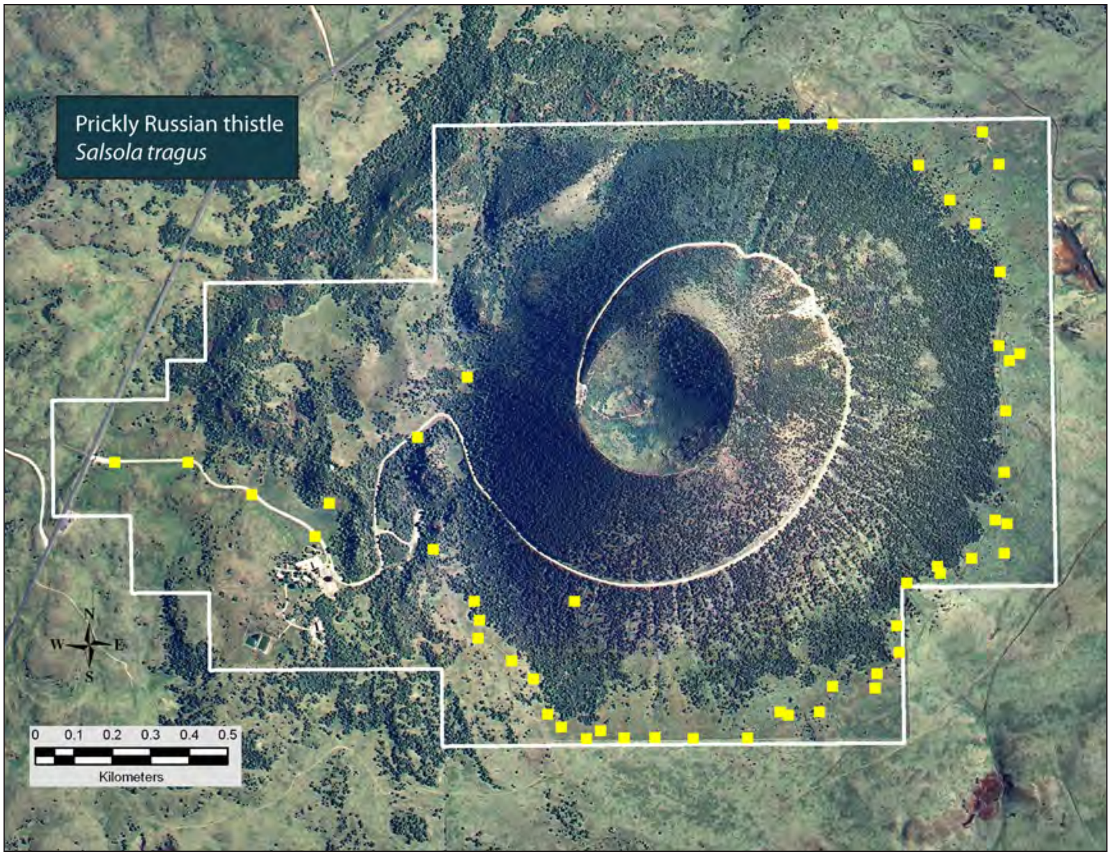

Figure G-11.
Prickly Russian thistle
(Salsola tragus)

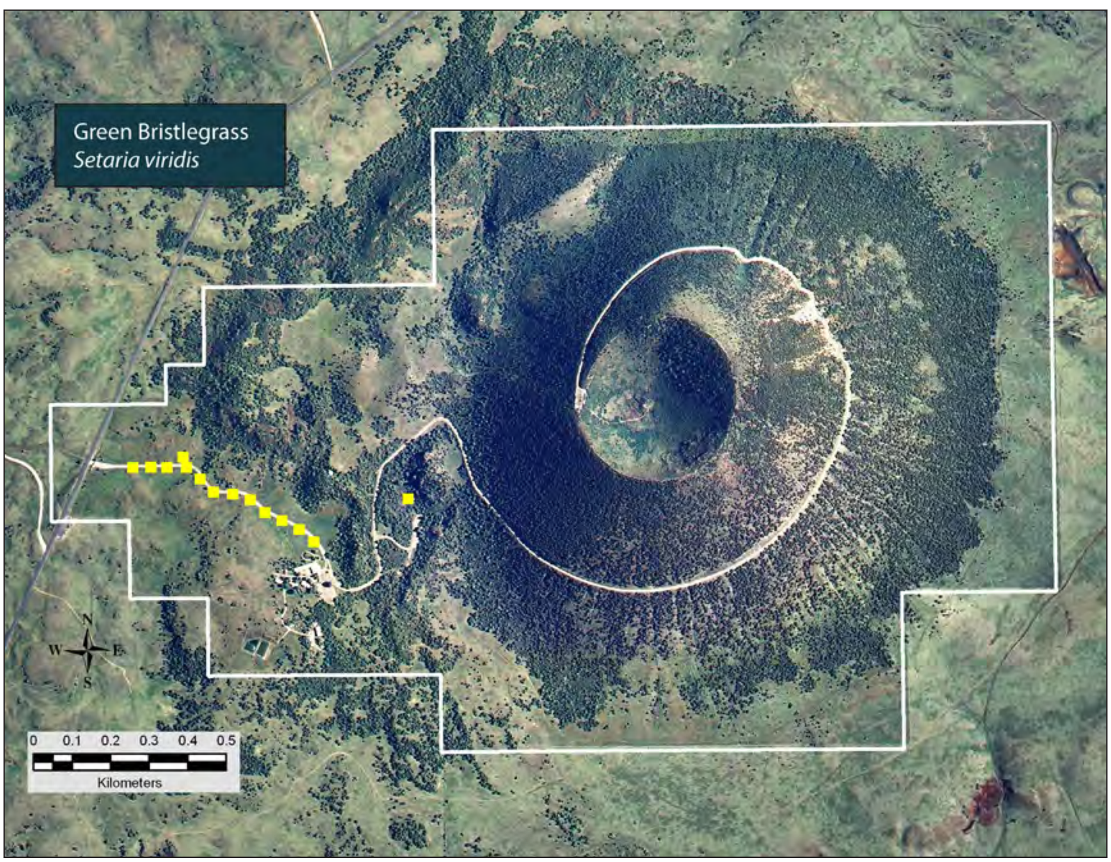

Figure G-12.
Green bristlegrass
(Setaria viridis)

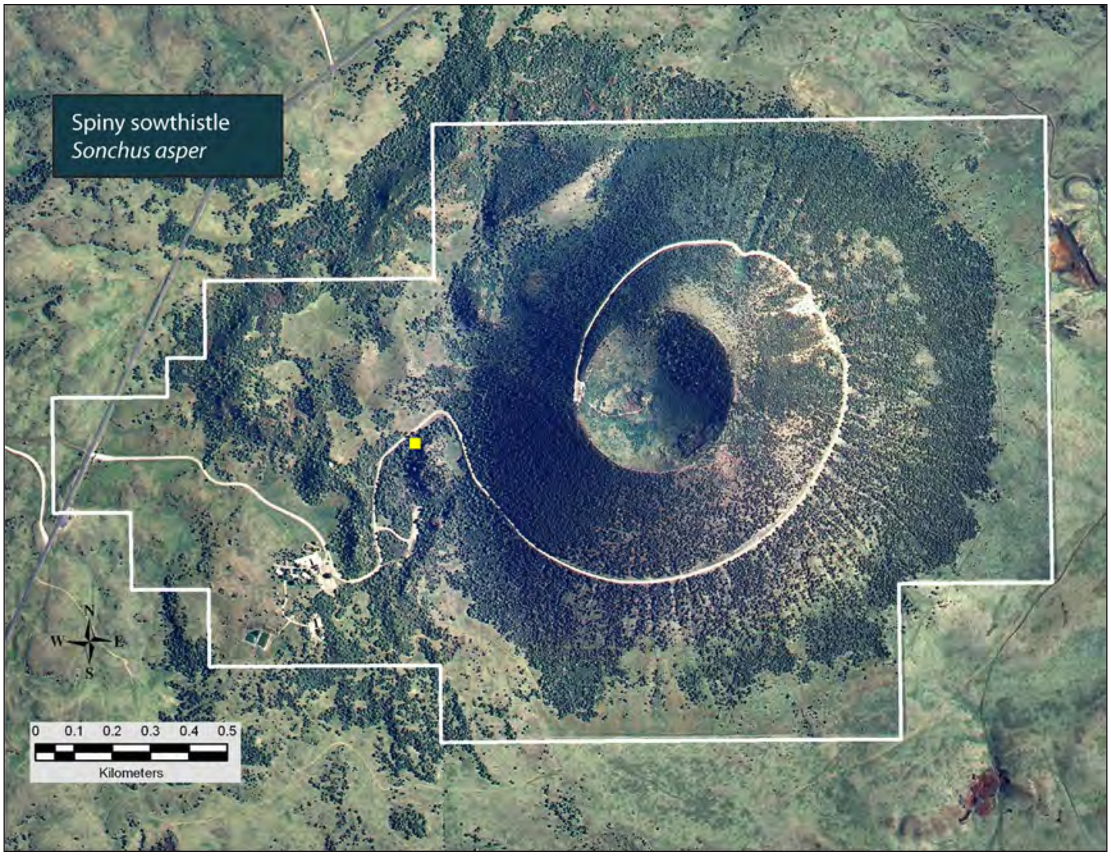

Figure G-13.
Spiny sowthistle
(Sonchus asper)

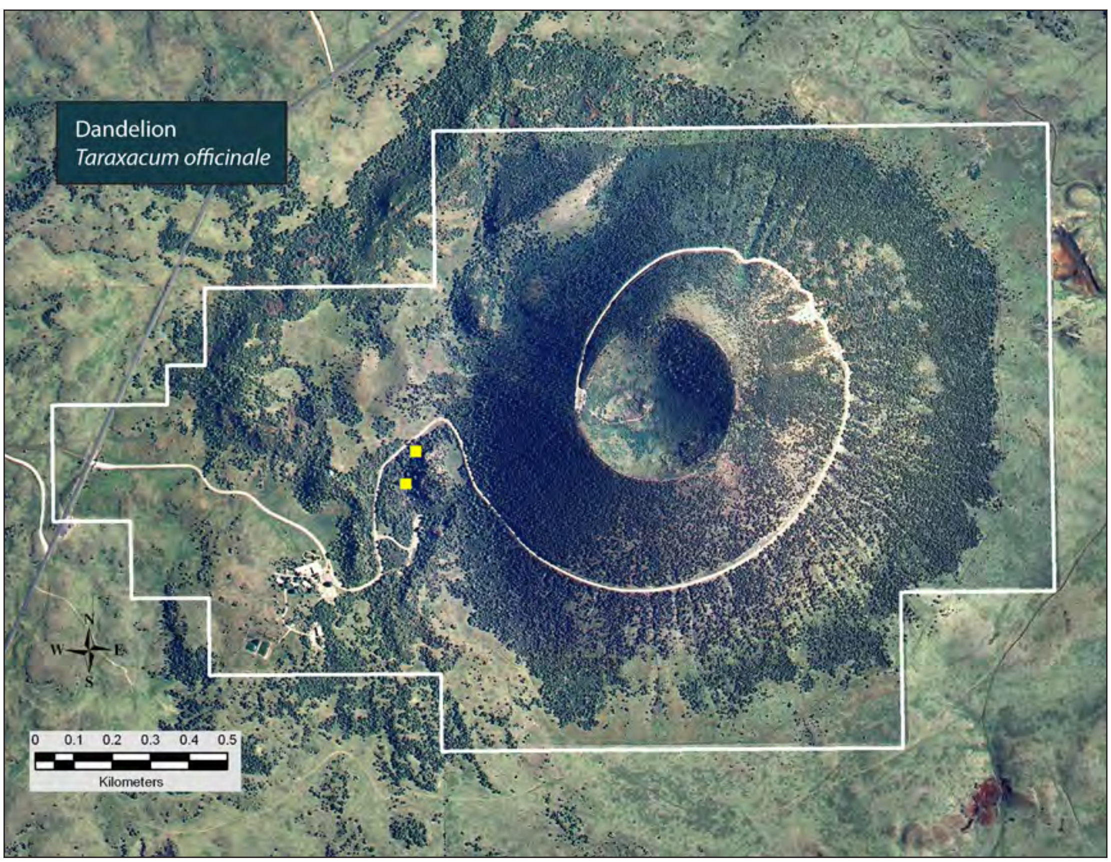

Figure G-14.
Dandelion
(Taraxacum officinale)

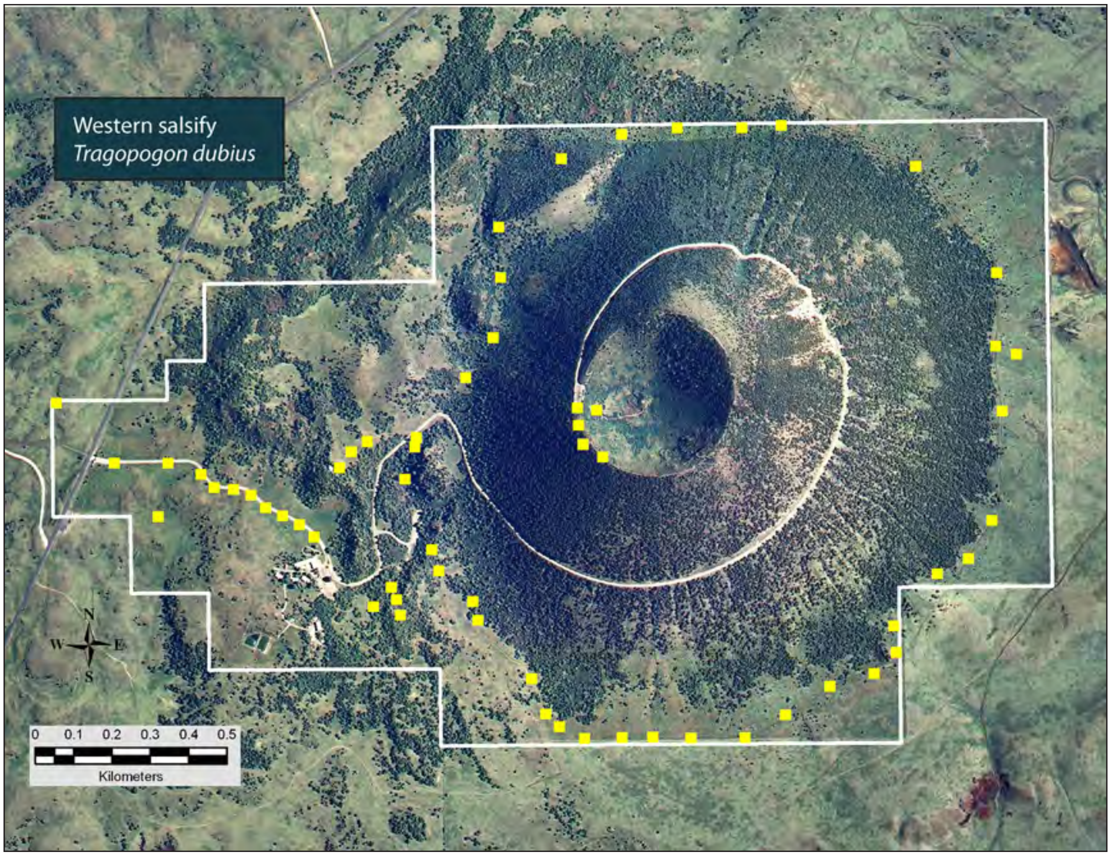

Figure G-15. Western salsify *(Tragopogon dubius)*

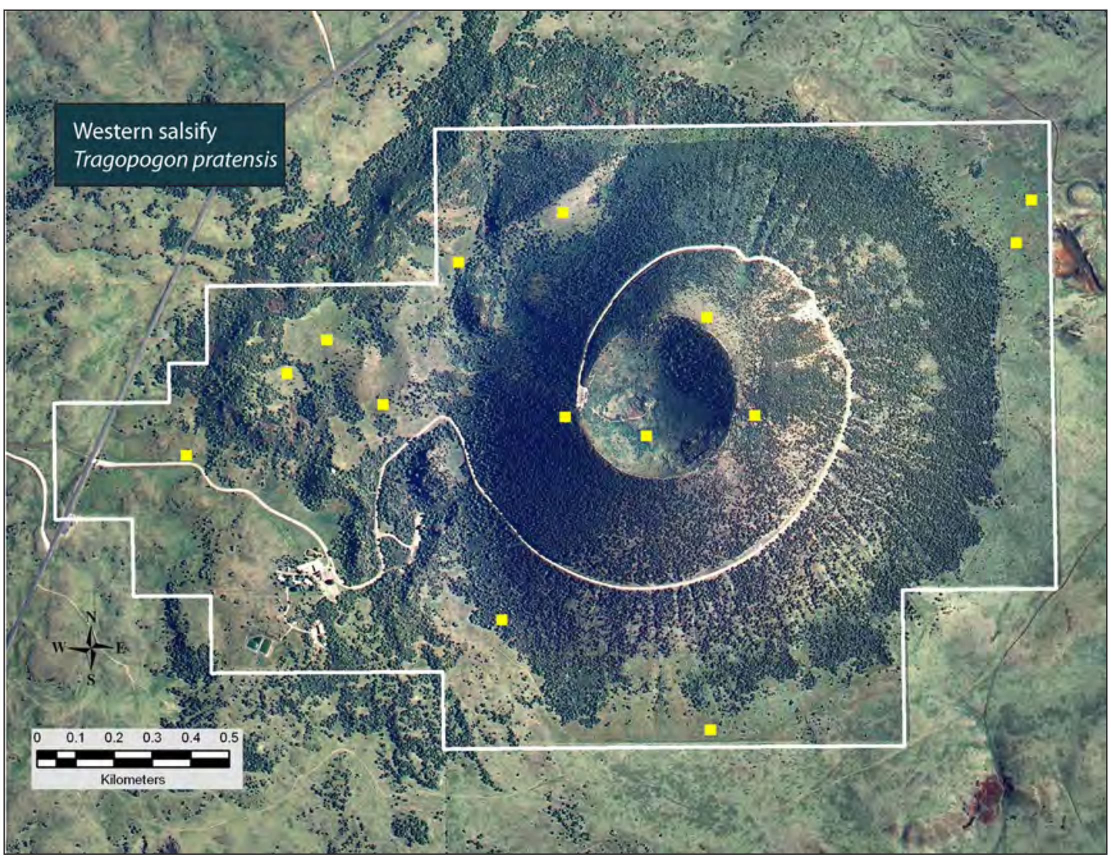

Figure G-16. Meadow salisify *(Tragopogon pratensis)*

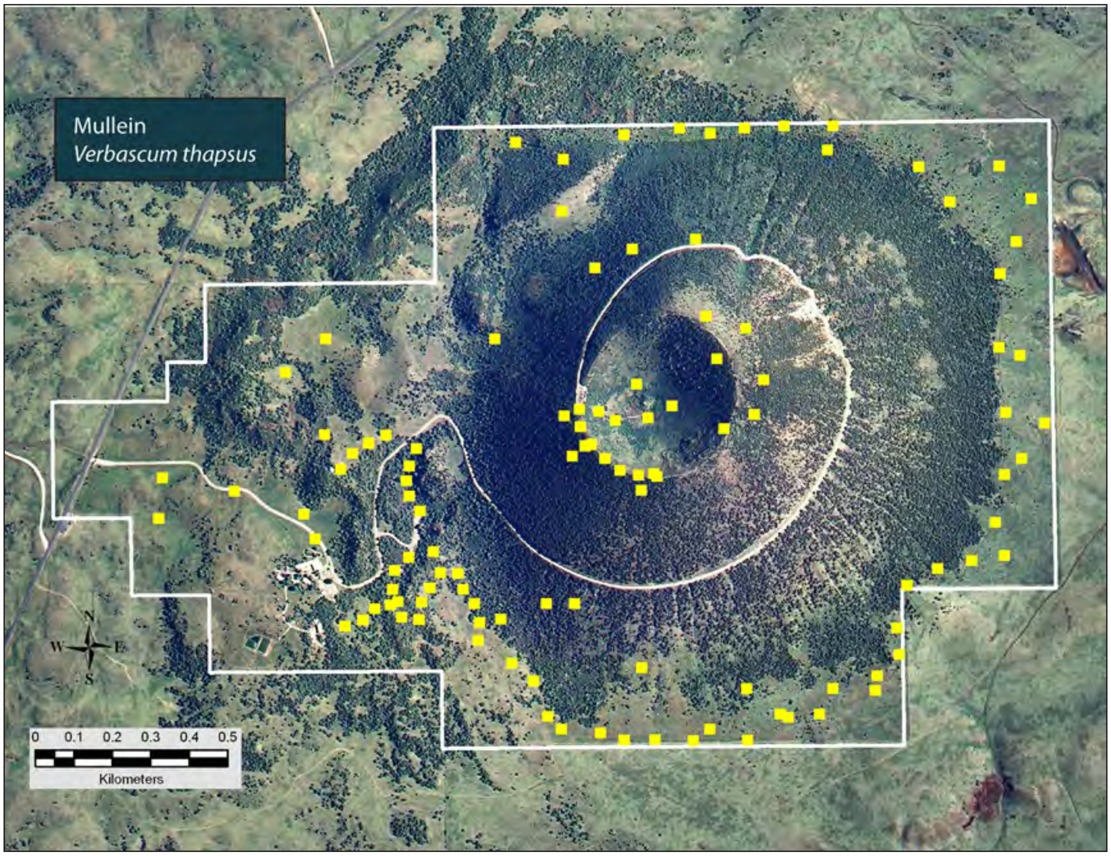

Figure G-17.
Mullein *(Verbascum thapsus)*

Appendix H: Capulin Volcano National Monument Bird List

Listed below is the full list of species reported to occur or have occurred at Capulin Volcano NM. Also shown is the source for each species inclusion and the residency and abundance classes listed by each source

Common Name	Source					
	1966 Checklist (Baily)	1968 Checklist (Jones)	1981 Checklist (Unknown)	1993 Checklist (SWPMA)	2002 Surveys (NHNM)*	2009-2011 Surveys (RMBO)*
American Crow	Pu	Pu	Tu	Tu		
American Kestrel	Pc	Pc	Su	Ru		
American Pipit	Wr	Sr				
American Robin	Pa	Pa	Rca	Rc	Xx	Xx
American Tree Sparrow	Wr	Wr	Tr	Tr		
Ash-throated Flycatcher	Sc	Sc	Tr	Tr	Xx	Xx
Bald Eagle			Tr	Tr		
Baltimore Oriole				Tr		
Barn Swallow			Tr	Tr		Xx
Belted Kingfisher			Tr	Tr		
Bewick's Wren	Pr	Pr	Sr	Sr		Xx
Black Phoebe		Sa	Tr	Tr		
Black-billed Magpie	Pu	Pu	Tu	Tu		
Black-capped Chickadee		Wu	Wr	Wr		Xx
Black-chinned Hummingbird	St	St	Su	Sc		
Black-headed Grosbeak	Sa	Sa	Sc	Sc	Xx	Xx
Black-throated Gray Warbler	Sr	Sr	Sr	Sr		
Blue Grosbeak		Sr	Tr	Tr		
Blue-gray Gnatcatcher	Sr	Sr	Sc	Sc	Xx	Xx
Blue-throated Hummingbird			Tr	Tr		
Blue-winged Teal			Tr			
Bobolink		Sr	Tr	Tr		
Brewer's Blackbird	Pu	Pu		Tr		
Brewer's Sparrow	Sr	Sr	Tr	Tr	Xx	
Broad-tailed Hummingbird			Sc	Sc	Xx	Xx
Brown Creeper			Tr	Tr		
Brown Thrasher			Tr	Tr		
Brown-headed Cowbird	Sr	Sr	Su	Su	Xx	Xx
Bullock's Oriole	Su	Su	Su	Su		Xx
Burrowing Owl	Sr	Sr				
Bushtit	Pu	Pu	Wr	Wr		
Calliope Hummingbird			Sr	Sr		
Canada Goose			Tr			
Canyon Towhee		Wu	Rca	Ra		Xx

* Breeding season only

Residence Class
S = Summer Resident W = Winter Resident R = Resident P = Permanent Resident T = Transient X = Not Provided

Abundance Class
a = abundant c = Common u= Uncommon r = rare t = Transient x = Not Provided

Common Name	Source					
	1966 Checklist (Baily)	1968 Checklist (Jones)	1981 Checklist (Unknown)	1993 Checklist (SWPMA)	2002 Surveys (NHNM)*	2009-2011 Surveys (RMBO)*
Canyon Wren	Pr	Pr	Sr	Sr		
Cassin's Finch	Wt	Wt				
Cassin's Kingbird	Sa	Sr	Sc	Sc	Xx	Xx
Cassin's Sparrow	Sr	Sr				Xx
Chestnut-collared Longspur	Wr	Wr		Tr		
Chihuahuan Raven						Xx
Chipping Sparrow	Sa	Sa	Sc	Sc	Xx	Xx
Chukar			Tr			
Clark's Nutcracker			Tr	Tr		
Cliff Swallow	Sr	Sr		Tr		Xx
Common Nighthawk	Sa	Sa	Sc	Su	Xx	
Common Poorwill	Sr	Pc	Sr	Sr	Xx	
Common Raven	Pc	Pr	Rca	Rc	Xx	Xx
Cooper's Hawk			Tr	Tr		Xx
Cordilleran Flycatcher					Xx	
Dark-eyed Junco	Wa	Wa	Wc	Wa		Xx
Downy Woodpecker			Ru	Ru		
Eastern Kingbird			Tr	Tr		
Eastern Phoebe				Sr		
Eurasian Collared-Dove						Xx
European Starling	Wu	Wu	Wu	Wu		
Ferruginous Hawk	Pr	Pr	Wr	Wr		
Golden Eagle	Pr	Pr	Tr	Tr		
Golden-crowned Kinglet			Tr	Tr		
Gray Catbird	Pr	Pr				
Gray Vireo	St	St				
Great Horned Owl	Pc	Pc	Ru	Ru	Xx	Xx
Greater Roadrunner	Pr	Pa	Rr	Tr		
Green-tailed Towhee	Sc	Sc	Su	Sc	Xx	Xx
Hairy Woodpecker		Pu	Ru	Ru		Xx
Hepatic Tanager			Sr	Sr		Xx
Hermit Thrush	Sr	Sr				Xx
Horned Lark	Pa	Pa	Wu	Wu		Xx
House Finch		Wu	Su	Sc		Xx
House Sparrow	Pu	Pu	Tu	Tu		
House Wren			Sc	Sc	Xx	Xx
Indigo Bunting				Tr		
Juniper Titmouse				Wc		Xx
Killdeer	Pu	Pu	Sr	Sr		
Ladder-backed Woodpecker	Pr	Pr				

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Common Name	Source					
	1966 Checklist (Baily)	1968 Checklist (Jones)	1981 Checklist (Unknown)	1993 Checklist (SWPMA)	2002 Surveys (NHNM)*	2009-2011 Surveys (RMBO)*
Lark Bunting	Su	Su	Tr	Tr		
Lark Sparrow	Sa	Sa	Sc	Sc	Xx	Xx
Lazuli Bunting			Tr	Tr		
Lesser Goldfinch	Sa	Sa	Su	Sc	Xx	Xx
Lewis' Woodpecker			Su	Su		
Loggerhead Shrike	Su	Su	Tr	Tr		
Long-eared Owl			Sr	Sr		
MacGillivray's Warbler			Su	Su		
McCown's Longspur	Wr	Wr				
Merlin	Wr	Wr	Tr	Tr		
Mountain Bluebird	Pa	Pa	Rca	Rc	Xx	Xx
Mountain Chickadee	Wu	Wu	Ru	Rc	Xx	Xx
Mountan Plover			Tr	Tr		
Mourning Dove	Sc	Sc	Sc	Sc	Xx	Xx
Northern Bobwhite	Pr	Pr	Tr	Tr		
Northern Cardinal						Xx
Northern Flicker	Pa	Sc	Su	Su		Xx
Northern Goshawk			Tr			
Northern Harrier	Pu	Pu	Tr	Tr		
Northern Mockingbird	Sr	Sr	Su	Su	Xx	Xx
Northern Rough-winged Swallow						Xx
Olive-sided Flycatcher			Tr	Tr		
Orange-crowned Warbler	Sr	Sr				
Peregrine Falcon	Pr	Pr		Tr		Xx
Pine Siskin	Wc	Wc		Tu		Xx
Pinyon Jay		Tr	Tu	Ru	Xx	Xx
Plumbeous Vireo	Su	Su	Su	Su		Xx
Prairie Falcon	Pr	Pr	Su	Su		Xx
Pygmy Nuthatch			Ru	Ru		
Red Crossbill				Tc		
Red-breasted Nuthatch	Wu	Wu	Tr	Tr		
Red-faced Warbler			Tr	Tr		
Red-headed Woodpecker			Tr	Tr		
Red-tailed Hawk	Pa	Pa	Ru	Rc		Xx
Rock Wren	Sc	Sc	Su	Su		Xx
Rose-breasted Grosbeak			Tr	Tr		
Rough-legged Hawk	Wu	Wu	Su	Su		
Ruby-crowned Kinglet			Sr	Sr		
Rufous Hummingbird			Su	Su		

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Common Name	Source					
	1966 Checklist (Baily)	1968 Checklist (Jones)	1981 Checklist (Unknown)	1993 Checklist (SWPMA)	2002 Surveys (NHNM)*	2009-2011 Surveys (RMBO)*
Rufous-crowned Sparrow			Tr	Tr		
Sage Sparrow	Sa	Sa				
Sage Thrasher	Pr	Pr				
Savannah Sparrow	Sr	Sr	Tr	Tr		
Saw-whet Owl			Su	Rr		
Say's Phoebe	Sa	Wr	Su	Su		Xx
Scaled Quail			Tr	Tr		
Snow Bunting	Wr	Wr				
Spotted Towhee	Pa	Pa	Rca	Ra	Xx	Xx
Stellar's Jay			Tr	Tr		
Summer Tanager			Sr	Sr		
Swainson's Hawk	Sr	Sr				
Swainson's Thrush				Tr		
Townsand's Solitaire	Wu	Wu	Wu	Wc		
Turkey Vulture	Sc	Sc	Sc	Sc		Xx
Vesper Sparrow	Sr	Sr	Su	Su	Xx	Xx
Violet-green Swallow	Sc	Sc	Tr	Tr		Xx
Virginia's Warbler			Tr	Sc	Xx	Xx
Western Bluebird						Xx
Western Kingbird		Sr	Tr	Tr		Xx
Western Meadowlark	Pc	Pc	Sc	Sc	Xx	Xx
Western Scrub-Jay	Pa	Pa	Ru	Rc	Xx	Xx
Western Tanager			Su	Su	Xx	Xx
Western Wood-Pewee	Sc	Sc	Sc	Sc	Xx	Xx
White-breasted Nuthatch		Wu				Xx
White-crowned Sparrow	Wu	Wu	Tr	Tr		
White-throated Sparrow		Sr	Tr	Tr		
White-throated Swift			Tr	Tr		
White-winged Dove						Xx
Wild Turkey	Wt	Wt	Su	Sc		Xx
Wilson's Warbler				Tr		
Yellow-billed Cuckoo			Sr	Tr		
Yellow-headed Blackbird			Tr	Tr		
Yellow-rumped Warbler			Su	Xx		Xx

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Appendix I: Bird Distribution Status

The distribution status of species reported to occur or have occurred at Capulin Volcano NM was determined using Birds of North America species accounts as a general reference. Comparisons with reference conditions were made for species for which the monument was within 100 miles or closer of the primary breeding range.

Common Name	Range Status
American Crow	Breeding and Wintering
American Kestrel	Breeding and Wintering
American Pipit	Wintering*
American Robin	Breeding and Wintering
American Tree Sparrow	Wintering
Ash-throated Flycatcher	Breeding
Bald Eagle	Wintering
Baltimore Oriole	Outside Range
Barn Swallow	Breeding
Belted Kingfisher	Year-Round
Bewick's Wren	Year-Round
Black Phoebe	Outside Range
Black-billed Magpie	Outside Range*
Black-capped Chickadee	Year-Round *
Black-chinned Hummingbird	Breeding
Black-headed Grosbeak	Breeding*
Black-throated Gray Warbler	Outside Range*
Blue Grosbeak	Breeding
Blue-gray Gnatcatcher	Outside Range§
Blue-throated Hummingbird	Outside Range
Blue-winged Teal	Breeding
Bobolink	Outside Range
Brewer's Blackbird	Wintering
Brewer's Sparrow	Outside Range
Broad-tailed Hummingbird	Breeding*
Brown Creeper	Wintering
Brown Thrasher	Outside Range
Brown-headed Cowbird	Breeding

* Within 100 miles of breeding range edge
§ Although considered outside of its range based on the BNA accounts, RMBO’s surveys suggest that it is within or on the edge of its breeding range.
‡ Although considered outside of its range based on the BNA accounts, the State of New Mexico identifies potential habitat within approximately 20 miles.

Common Name	Range Status
Bullock's Oriole	Breeding
Burrowing Owl	Breeding
Bushtit	Year-Round*
Calliope Hummingbird	Outside Range
Canada Goose	Wintering
Canyon Towhee	Year-Round*
Canyon Wren	Year-Round
Cassin's Finch	Year-Round
Cassin's Kingbird	Breeding
Cassin's Sparrow	Breeding
Chestnut-collared Longspur	Wintering*
Chihuahuan Raven	Year-Round*
Chipping Sparrow	Breeding*
Chukar	Outside Range
Clark's Nutcracker	Outside Range‡
Cliff Swallow	Breeding
Common Nighthawk	Breeding
Common Poorwill	Breeding
Common Raven	Year-Round*
Cooper's Hawk	Year-Round
Cordilleran Flycatcher	Outside Range*
Dark-eyed Junco	Wintering
Downy Woodpecker	Year-Round
Eastern Kingbird	Breeding*
Eastern Phoebe	Outside Range
Eurasian Collared-Dove	Outside Range*
European Starling	Year-Round
Ferruginous Hawk	Year-Round
Golden Eagle	Breeding And Wintering
Golden-crowned Kinglet	Wintering
Gray Catbird	Outside Range*
Gray Vireo	Outside Range‡
Great Horned Owl	Year-Round
Greater Roadrunner	Outside Range*

* Within 100 miles of breeding range edge

§ Although considered outside of its range based on the BNA accounts, RMBO's surveys suggest that it is within or on the edge of its breeding range.

‡ Although considered outside of its range based on the BNA accounts, the State of New Mexico identifies potential habitat within approximately 20 miles.

Common Name	Range Status
Green-tailed Towhee	Breeding*
Hairy Woodpecker	Year-Round*
Hepatic Tanager	Breeding*
Hermit Thrush	Breeding*
Horned Lark	Year-Round
House Finch	Year-Round
House Sparrow	Year-Round
House Wren	Breeding
Indigo Bunting	Outside Range*
Juniper Titmouse	Year-Round*
Killdeer	Breeding And Wintering
Ladder-backed Woodpecker	Outside Range*
Lark Bunting	Breeding*
Lark Sparrow	Breeding
Lazuli Bunting	Outside Range*
Lesser Goldfinch	Outside Range*
Lewis' Woodpecker	Year-Round*
Loggerhead Shrike	Year-Round
Long-eared Owl	Year-Round*
MacGillivray's Warbler	Outside Range*
McCown's Longspur	Outside Range*
Merlin	Nonbreeding
Mountain Bluebird	Year-Round
Mountain Chickadee	Year-Round*
Mountan Plover	Breeding
Mourning Dove	Year-Round
Northern Bobwhite	Outside Range*
Northern Cardinal	Outside Range
Northern Flicker	Year-Round
Northern Goshawk	Wintering
Northern Harrier	Year-Round
Northern Mockingbird	Year-Round
Northern Rough-winged Swallow	Breeding
Northern Saw-whet Owl	Wintering

* Within 100 miles of breeding range edge
§ Although considered outside of its range based on the BNA accounts, RMBO's surveys suggest that it is within or on the edge of its breeding range.
‡ Although considered outside of its range based on the BNA accounts, the State of New Mexico identifies potential habitat within approximately 20 miles.

Common Name	Range Status
Olive-sided Flycatcher	Outside Range
Orange-crowned Warbler	Outside Range
Peregrine Falcon	Wintering
Pine Siskin	Year-Round*
Pinyon Jay	Year-Round*
Plumbeous Vireo	Breeding*
Prairie Falcon	Year-Round
Pygmy Nuthatch	Outside Range*
Red Crossbill	Outside Range*
Red-breasted Nuthatch	Year-Round*
Red-faced Warbler	Outside Range
Red-headed Woodpecker	Outside Range*
Red-tailed Hawk	Year-Round
Rock Wren	Year-Round
Rose-breasted Grosbeak	Outside Range
Rough-legged Hawk	Wintering
Ruby-crowned Kinglet	Outside Range*
Rufous Hummingbird	Outside Range
Rufous-crowned Sparrow	Year-Round*
Sage Sparrow	Outside Range
Sage Thrasher	Outside Range*
Savannah Sparrow	Nonbreeding*
Say's Phoebe	Breeding
Scaled Quail	Year-Round*
Snow Bunting	Wintering
Spotted Towhee	Year-Round
Stellar's Jay	Outside Range*
Summer Tanager	Outside Range*
Swainson's Hawk	Breeding
Swainson's Thrush	Outside Range
Townsand's Solitaire	Wintering
Turkey Vulture	Breeding
Vesper Sparrow	Breeding*
Violet-green Swallow	Breeding*

* Within 100 miles of breeding range edge

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‡ Although considered outside of its range based on the BNA accounts, the State of New Mexico identifies potential habitat within approximately 20 miles.

Common Name	Range Status
Virginia's Warbler	Breeding*
Western Bluebird	Outside Range*
Western Kingbird	Breeding
Western Meadowlark	Year-Round
Western Scrub-Jay	Year-Round*
Western Tanager	Outside Range*
Western Wood-Pewee	Breeding*
White-breasted Nuthatch	Year-Round
White-crowned Sparrow	Wintering
White-throated Sparrow	Outside Range
White-throated Swift	Outside Range
White-winged Dove	Outside Range
Wild Turkey	Outside Range*
Wilson's Warbler	Outside Range
Yellow-billed Cuckoo	Outside Range*
Yellow-headed Blackbird	Breeding
Yellow-rumped Warbler	Outside Range*

* Within 100 miles of breeding range edge

§ Although considered outside of its range based on the BNA accounts, RMBO's surveys suggest that it is within or on the edge of its breeding range.

‡ Although considered outside of its range based on the BNA accounts, the State of New Mexico identifies potential habitat within approximately 20 miles.

Appendix J. Bird Breeding Habitat Suitability

The potential for breeding habitat for bird species whose breeding range includes, or is in proximity to Capulin Volcano NM is listed below. For each species we determined whether suitable breeding habitat exists, possibly exists such that their occurrence during the breeding season would not be unexpected, or was sufficiently lacking that their occurrence would not generally be expected (Limited to None). Determination and descriptions of suitable habitat were based primarily on the Birds of North America Species Accounts.

Species	Breeding Habitat	Breeding Habitat Components Relevant to Capulin Volcano NM
American Crow	Possibly Exists	In arid areas, riparian areas with mature trees are typically used for breeding
American Kestrel	Possibly Exists	Suitable foraging habitat, but the monument lacks large dead trees with cavities typically used for nesting.
American Robin	Exists	Nests in wide range of habitats, but often areas of short grass interspersed with trees.
Ash-throated Flycatcher	Exists	Typically nest in arid or semi-arid scrub or woodlands, including piñon-juniper.
Barn Swallow	Limited to None	Typically nests in areas of human habitation (buildings) near water.
Belted Kingfisher	Limited to None	Water is probably the most important habitat requirement.
Bewick's Wren	Exists	Typically nests in open scrublands, including piñon-juniper.
Black-billed Magpie	Limited to None	Typically nests in thickets in or near riparian areas (e.g., along streams).
Black-capped Chickadee	Limited to None	Typically nests in deciduous or mixed-deciduous woodlands.
Black-chinned Hummingbird	Limited to None	Typically nests in mesic habitats including floodplain riparian communities.
Black-headed Grosbeak	Exists	Tends to nest in habitats with well developed understory and large trees; sometimes in piñon-juniper.
Black-throated Gray Warbler	Exists	Typically breeds in open woodlands, including piñon-juniper.
Blue Grosbeak	Limited to None	Typically breeds in areas (fields, etc.) with few trees and low shrub density.
Blue-gray Gnatcatcher	Possibly Exists	Occupies a wide range wooded habitats from shrublands to mature forest. Occurs in pinon-juniper is some regions.
Blue-winged Teal	Limited to None	Typically breeds near shallow ponds or wetlands.
Broad-tailed Hummingbird	Possibly Exists	Typically breeds in more montane regions, but has been known to breed in piñon-juniper.
Brown-headed Cowbird	Exists	Typically breeds in areas with low or scattered trees with grasslands.
Bullock's Oriole	Limited to None	Typically breeds in riparian cottonwoods with larger trees.
Burrowing Owl	Limited to None	Typically breeds in treeless grasslands, usually in association with burrowing rodents such as prairie dogs.
Bushtit	Exists	Typically nest in scrub or woodlands, including piñon-juniper.
Canyon Towhee	Possibly Exists	Most typically found in the desert grass and shrublands of the upper Sonoran Zone, but does occur in piñon-juniper.
Canyon Wren	Limited to None	Typically limited to arid areas with cliffs or steep-sided canyons.
Cassin's Finch	Limited to None	Typically breeds in western coniferous forests of pines and firs, but not typically in piñon-juniper.
Cassin's Kingbird	Exists	Although breeding habitat may vary, this species commonly breeds in piñon-juniper habitats in New Mexico.
Cassin's Sparrow	Possibly Exists	Breeds in arid grasslands with scattered shrubs or low trees, typically yucca or mesquite.
Chihuahuan Raven	Limited to None	Breeds in arid grasslands with scattered shrubs or trees, typically yucca or mesquite. Sometimes ranges into in piñon-juniper, but is generally replaced by Common Ravens in that habitat.

Species	Breeding Habitat	Breeding Habitat Components Relevant to Capulin Volcano NM
Chipping Sparrow	Exists	Breeds in a variety habitats. But prefers nesting in shrubby habitats with conifers.
Clark's Nutcracker	Limited to None	Tends to breed at higher elevations in montane coniferous forests.
Cliff Swallow	Limited to None	Historically nested on cliffs, but now commonly uses artificial structures such as buildings and bridges, typically near a water source.
Common Nighthawk	Possibly Exists	Although somewhat varied, breeding typically occurs in native prairie of low productivity.
Common Poorwill	Possibly Exists	Breeds in open grassy or shrubby areas in arid or semi-arid regions, reportedly including piñon-juniper.
Common Raven	Possibly Exists	Breeds in a wide variety of habitats.
Cooper's Hawk	Limited to None	Typically breeds in mature deciduous, mixed, or evergreen forests.
Cordilleran Flycatcher	Limited to None	Typically breeds in cooler forested areas, often associated with water.
Downy Woodpecker	Limited to None	Typically breeds in deciduous, usually riparian woodlands.
Eastern Kingbird	Limited to None	Breeds in open environments with scattered shrubs, often associated with water.
Eurasian Collared-Dove	Limited to None	Primarily breeds in suburban, urban, and agricultural areas where grain, roost, and nest sites available.
European Starling	Possibly Exists	Breeds in a wide variety of habitats, but highest densities occur in agricultural and settled areas.
Ferruginous Hawk	Possibly Exists	Typically breeds in flat or rolling grassland and shrub-steppe regions, but has been reported to be locally abundant at the interface between piñon-juniper and shrub-steppe habitats
Golden Eagle	Limited to None	Breeds in a wide variety of open habitats, but typically nests on cliffs or in tall trees.
Gray Catbird	Limited to None	Uncommon in areas dominated by conifers, and most typically found in shrubby edge habitats, often along riparian corridors.
Great Horned Owl	Exists	Breeds in a wide variety of generally open habitats.
Greater Roadrunner	Possibly Exists	Breeds in arid and semi-arid open habitats, including piñon-juniper.
Green-tailed Towhee	Exists	Typically breeds in dry shrub-steppe, including piñon-juniper.
Hairy Woodpecker	Limited to None	Typically breeds in mature forest habitats.
Hepatic Tanager	Possibly Exists	Typically breeds in open woodlands, especially pine-oak, but does occur in mature piñon pine woodlands in some regions.
Hermit Thrush	Limited to None	Typically considered a forest interior bird that favors internal forest edges.
Horned Lark	Possibly Exists	Tends to breed in barren open areas that have considerable bare ground and/or with grasses less than a few centimeters high.
House Finch	Possibly Exists	Commonly associated with human habitation, but does occur in a variety of native habitats, typically near edges.
House Sparrow	Limited to None	Typically breed in association with human habitation such as farms, residential, and urban settings.
House Wren	Possibly Exists	Tends to occur in deciduous or mixed deciduous woodlands, but does occur in piñon-juniper.
Indigo Bunting	Limited to None	Breeds in brushy habitats, typically along wooded rivers in the west.
Juniper Titmouse	Exists	Typically occurs in juniper or mixed piñon-juniper woodlands, most commonly where mature trees can provide natural cavities.
Killdeer	Possibly Exists	Natural breeding habitats include sandbars, mud flats, and heavily grazed pastures. Human-modified habitats such as cultivated and athletic fields are also commonly used.
Ladder-backed Woodpecker	Possibly Exists	Typically found in desert and desert scrub environments, but does occur in piñon-juniper.
Lark Bunting	Limited to None	Typically found in grasslands and shrub-steppe of the high plains, typically in association with big sagebrush.

Species	Breeding Habitat	Breeding Habitat Components Relevant to Capulin Volcano NM
Lark Sparrow	Exists	Typically found in grasslands and shrub-steppe commonly shortgrass.
Lazuli Bunting	Possibly Exists	Typically breeds in arid brushy habitats, although not typically in piñon-juniper.
Lesser Goldfinch	Possibly Exists	In New Mexico, breeds widely throughout the state where seeds, particularly wild sunflowers (Helianthus spp.) are available.
Lewis' Woodpecker	Possibly Exists	Primary breeding habitats are open ponderosa pine, open riparian woodlands, and logged or burned pine; however, breeding birds are also found in piñon-juniper.
Loggerhead Shrike	Possibly Exists	Breeds in open country with short vegetation, often with fence rows (e.g., pastures).
Long-eared Owl	Possibly Exists	Breeds in dense vegetation close to grasslands or shrublands. Nests in large numbers in juniper adjacent to shrub-steppe in Idaho.
MacGillivray's Warbler	Limited to None	Breeds primarily in coniferous or mixed deciduous forests with dense undergrowth.
Mountain Bluebird	Possibly Exists	Typically breeds at prairie/forest ecotones. Uses piñon-juniper extensively during winter, but the absence of nest cavities probably precludes widespread breeding at the monument.
Mountain Chickadee	Possibly Exists	Typically breeds in montane coniferous forests, including piñon-juniper, but like with the mountain bluebird, the absence of nest cavities probably precludes widespread breeding at the monument.
Mountain Plover	Limited to None	Typically associated with shortgrass prairie. Where taller grasses dominate, they are limited to areas of heavy grazing and prairie dog towns.
Mourning Dove	Exists	Quite adaptable in its breeding habitat, but tends to occur in open woodlands and at the edge between forest and prairie biomes.
Northern Bobwhite	Limited to None	Breeds in early successional stages of a wide variety of habitats including agricultural fields and grasslands.
Northern Flicker	Exists	Typically breeds near forest edges and open woodlands, including piñon-juniper.
Northern Harrier	Limited to None	Breeds in open marsh areas and grasslands. Does not tend to breed in the Great Plains where woody cover is greater than 30%.
Northern Mockingbird	Exists	Typically breeds in open habitats with scattered shrubs or small trees.
Northern Rough-winged Swallow	Limited to None	Typically breeds in open areas with suitable nest sites that are predominantly vertical banks of sand, clay, or gravel (e.g., road or stream cuts), often near open water.
Pine Siskin	Limited to None	Primarily breeds in open coniferous forests.
Pinyon Jay	Exists	Breeds primarily piñon-juniper woodlands.
Plumbeous Vireo	Possibly Exists	Typically breeds in montane coniferous or mixed forests as well as cottonwood bottomlands. Does occur in Gambel Oak shrublands with scattered tall trees, and has been reported to breed in piñon-juniper.
Prairie Falcon	Limited to None	Typically breeds in arid grasslands and shrub-steppes, but requires cliffs or bluffs for nest sites.
Pygmy Nuthatch	Limited to None	Breeds almost exclusively in stands of long-needled pines, particularly Ponderosa and Jeffrey pine with sufficient number of snags for nesting.
Red Crossbill	Limited to None	Breeds in mature coniferous forests with abundant cone crops.
Red-breasted Nuthatch	Limited to None	Typically breeds in mature and diverse stands of coniferous forest, particularly spruce, fir, pine, hemlock, larch, and cedar.
Red-headed Woodpecker	Limited to None	Prefers xeric woodlands with tall trees with large circumferences, high basal area, and low density of stems in understory
Red-tailed Hawk	Possibly Exists	Typically breeds in open to semi-open habitats with elevated nest/perch sites.
Rock Wren	Possibly Exists	Breeds in arid or semiarid areas with exposed rock, such as talus slopes or scree.
Rufous-crowned Sparrow	Limited to None	Breeds in semiarid grassy shrublands and open woodlands on moderate to steep grassy and rocky hillsides. Prefers shrubs of short stature (<1m) to dense stands.
Sage Thrasher	Limited to None	Breeds in shrub-steppe generally dominated by big sagebrush.

Species	Breeding Habitat	Breeding Habitat Components Relevant to Capulin Volcano NM
Say's Phoebe	Limited to None	In the Great Plains, tends to breed in open arid areas, especially rocky habitats that provide open areas near buildings
Scaled Quail	Limited to None	In New Mexico reported to breed in desert grasslands, but prefers shrub-grass communities
Spotted Towhee	Exists	Occupies a wide range of habitats, but typically breeds in shrubby thickets, including piñon-juniper.
Stellar's Jay	Limited to None	Typically breeds in coniferous and mixed coniferous-deciduous forests. Has been reported to breed in piñon-juniper in Colorado, but probably not a typical breeding habitat.
Summer Tanager	Limited to None	Western populations of this species tend to breed in riparian woodlands dominated by willows and cottonwoods at lower elevations.
Swainson's Hawk	Limited to None	Typically breeds in areas of open grasslands and sparse shrublands,
Turkey Vulture	Limited to None	Typically breeds in forested or partly forested areas with rock outcrops or abandoned buildings for nest sites.
Vesper Sparrow	Exists	Occurs in a broad range of grassland habitat types, including native prairie and semidesert grasslands.
Violet-green Swallow	Limited to None	Typically breeds in open deciduous, coniferous, and mixed woodlands, including ponderosa pine and quaking aspen. The absence of nest cavities probably precludes breeding at the monument.
Virginia's Warbler	Exists	Typically breeds in piñon-juniper and oak woodlands.
Western Bluebird	Limited to None	Breeds in open coniferous and deciduous woodlands and grasslands with scattered trees and snags. The absence of nest cavities probably precludes widespread breeding at the monument.
Western Kingbird	Possibly Exists	Breeds in a variety of open habitats including grasslands and savannah habitats.
Western Meadowlark	Exists	Breeds in a wide range of grassland habitats, and are common in native grasslands.
Western Scrub-Jay	Exists	Most commonly breeds in oak and piñon-juniper habitats.
Western Tanager	Possibly Exists	Typically breeds in open coniferous and mixed coniferous-deciduous woodlands, particularly Douglas fir and Ponderosa pine. Has been reported to breed in piñon-juniper, but probably not commonly.
Western Wood-Pewee	Exists	Breeds in a variety of woodland and forest types. Reported to be common in piñon pine woodlands in New Mexico.
White-breasted Nuthatch	Limited to None	Typically associated with mature deciduous, or mixed deciduous/coniferous woodlands.
Wild Turkey	Exists	Occur in a variety of woodland habitats throughout their range, but are common in oak and piñon-juniper in New Mexico, particular where piñon-juniper adjoins with Ponderosa Pine.
Yellow-billed Cuckoo	Limited to None	Generally associated with riparian areas for breeding.
Yellow-headed Blackbird	Limited to None	Breeds primarily in prairie wetlands.
Yellow-rumped Warbler	Limited to None	Typically breeds in mature coniferous and mixed coniferous-deciduous habitats. Tends to prefer spruces and firs.

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