National Park Service
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Natural Resource Stewardship and Science

Natural Resource Conditions at Valles Caldera National Preserve

Findings & Management Considerations for Selected Resources

Natural Resource Report NPS/VALL/NRR—2022/2409





ON THIS PAGE
Full moon over Valle Grande.
Image Credit: ©Dan Williams.

ON THE COVER
Top: Rainbow over Valle Grande.
Middle: Felsenmeer slope on Redondo Peak (left), New Mexico meadow jumping mouse (center). Pygmy nuthatch (right).
Bottom: Jemez Mountains salamander (left), Fall colors with snow topped Redondito Peak (middle), Smoke from the Thompson Ridge Fire (right).
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Natural Resource Report NPS/VALL/NRR—2022/2409

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Fort Collins, Colorado

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Executive Summary

Valles Caldera National Preserve (VALL) encompasses 35,977 ha (88,900 ac) in the Jemez Mountains of north-central New Mexico and is surrounded by the Santa Fe National Forest, the Pueblo of Santa Clara, and Bandelier National Monument. VALL's explosive volcanic origin, about 1.23 million years ago, formed the Valles Caldera—a broad, 19- to 24-km (12- to 15-mi) wide circular depression. It is one of the world's best examples of a young caldera (in geologic time) and serves as the model for understanding caldera resurgence worldwide. A series of resurgent eruptions and magmatic intrusive events followed the original explosion, creating numerous volcanic domes in present day VALL—one of which is Redondo Peak at an elevation of 3,430 m (11,254 ft), which is the second highest peak in the Jemez Mountains. In fact, VALL in its entirety is a high-elevation preserve that hosts a rich assemblage of vegetation, wildlife, and volcanic resources.

The National Park Service (NPS) Natural Resource Condition Assessment (NRCA) Program selected VALL to pilot its new NRCA project series. VALL managers and the NRCA Program selected seven focal study resources for condition evaluation. To help us understand what is causing change in resource conditions, we selected a subset of drivers and stressors known or suspected of influencing the preserve's resources. Here are some highlights.

What is causing change in resource conditions?

- Mean temperatures during the spring and summer months are increasing, but warming is slower at VALL than for neighboring areas (e.g., Bandelier National Monument).
- The proportion of precipitation received as snow has declined.
- From 2000 to 2018, forest pests damaged or killed 75% of the preserve's forested areas.
- Only small, forested areas in VALL were affected by forest pests after the 2011 Las Conchas and the 2013 Thompson Ridge fires.
- The all-sky light pollution model and the sound pressure level model predict the lowest degree of impacts from light and sound to be in the western half of the preserve.

What are the resource conditions?

Of the seven focal study resources, adequate data were available to evaluate the current conditions and trends for four via condition assessments. A summary of the condition ratings by indicator is presented in Table ES-1, and some highlights from the four condition assessments follow.

Table ES-1. Summary of VALL's natural resource condition assessment indicators of condition ratings.

Focal Resource	Indicator of Condition	Condition Rating
Landscape Permeability (a.k.a. habitat connectivity)	Ecosystem permeability (upper montane)	Good
	Ecosystem permeability (lower montane)	Good/Fair
	Ecosystem permeability (shrublands)	Fair/Poor
	Ecosystem permeability (grasslands)	Fair/Poor
	Ecosystem permeability (riparian/valley bottoms)	Good/Fair
	Landscape permeability	Fair/Poor
Visual Resources	Visual resources (named by NPS Air Resources guidance)	Good
Restored Wetlands	Flow duration	Unknown
	Cover (of wetland plants)	Good
Songbirds	Community composition	Good

Landscape Permeability

- Permeability for all ecosystems inside the preserve is slightly higher than permeability beyond the preserve's boundary.
- Management actions in the preserve can address highly permeable areas for the upper montane ecosystem (e.g., Redondo Peak), contributing to areas outside of the preserve.

Visual Resources

- There are minimal impacts to the scenic views as seen from seven locations in the Valle Grande District.

Restored Wetlands

- The presence of water increased significantly in restored wetlands, but additional monitoring (currently underway) is needed to understand how much of the increase is attributable to restoration versus increased precipitation.
- Wetland plant cover increased in the restored sites that were evaluated.

Songbirds

- Nearly all expected songbirds are present in VALL.
- There are 53 confirmed bird species of concern in VALL.
- Between two and 10 indicator bird species were observed in the five habitats evaluated.

What is known about the resources with limited data?

For the remaining three focal study resources with limited condition-related data, gap analyses were developed, highlighting the status of knowledge and useful indicators, data, and studies for future investigation. Here are some highlights.

Redondo Peak Biodiversity

- Ninety-seven percent of the 101 plant species recorded on Redondo Peak are native.
- Four new moth species were identified, and at least 75 species of spiders were documented during recent inventory efforts.

New Mexico Meadow Jumping Mouse Habitat Availability

- Four patches of VALL's creek habitat meet the U.S. Fish & Wildlife Service's minimum size requirement for supporting jumping mouse populations.
- Additional suitable jumping mouse habitat within known foray distances may occur between some of the existing patches.

Jemez Mountains Salamander

The Jemez Mountains salamander has been observed several times over the past 20 years, but some areas with historic (20th century) sightings have not yielded 21st century observations.

How can we bridge NRCA findings with management actions?

To link the NRCA science to management activities, the NRCA Program held a meeting with VALL managers. Meeting participants reviewed the NRCA findings and discussed potential near-term and future actions to improve conditions and address data gaps for management consideration. Here's a subset of the discussion outcomes.

- Identify areas of high resource value by incorporating information from multiple taxa, including the 2021 locations of Mexican spotted owl, and biophysical data used in the landscape permeability analysis, along with the New Mexico meadow jumping mouse and the Jemez Mountains salamander habitat models.
- Prioritize the preservation and protection of Redondo Peak, which represents a significant contributor to potential regional climate adaptation. This is especially true for areas west of the preserve, which serve as a source for high-elevation species and potential areas into which lower-elevation species can expand should warming push life zones into higher elevations.
- Develop an integrative monitoring plan for preserving landscape-scale resources: dark night sky, scenic views, including the air quality visibility metric, and quiet soundscapes.
- Prioritize wetland restoration opportunities by combining findings from the other condition evaluations (e.g., New Mexico meadow jumping mouse, landscape permeability).
- Focus interpretation, education, and partnership efforts, including stream restoration activities, toward additional angler organizations to manage recreational use resource impacts, especially to New the Mexico meadow jumping mouse habitat.
- Enlist citizen scientists to assist with the monitoring of visual resources by establishing visitor camera spots for collecting standardized scenes of interest and with documenting birds by tying VALL's bird checklist to an easily submitted form.

- Develop partnerships to research and monitor surface activity time periods for the Jemez Mountains salamander to help inform VALL's forest thinning and fire management activities (using pre- and post-burn data) and to understand how ongoing restoration activities impact the salamander and its habitat.

Conclusion

VALL's NRCA summarizes and synthesizes information on selected resources in the preserve. The resource condition findings and status of knowledge summaries can be applied to augment the preserve's existing collaborative and integrated resource management efforts. The information can also be used for developing funding proposals and targeting critical data gaps identified throughout the condition evaluations.

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List of Acronyms

ALR:	All-sky Light Pollution Ratio
ARD:	Air Resources Division
BBS:	Breeding Bird Survey
Bd:	*Batrachochytrium dendrobatidis* (amphibian chytrid fungus)
CCRP:	Climate Change Response Program
CFLRP:	Collaborative Forest Landscape Restoration Program
CWP:	Colorado Parks & Wildlife
dBA:	A-weighted decibel
DPSSR:	Drivers, Pressures, Stressors, States, Responses
ENSO:	El Niño-Southern Oscillation
FCA:	Focused Condition Assessment
FHP:	Forest Health Monitoring Program
FRV:	Fundamental Resource and Value
GCM:	Global Circulation Model
IBA:	Important Bird Area
IDA:	International Dark-Sky Association
IMD:	Inventory & Monitoring Division
JMS:	Jemez Mountains Salamander
LANL:	Los Alamos National Laboratory
NAS:	National Audubon Society
NF:	National Forest
NHNM:	Natural Heritage New Mexico
NMDGF:	New Mexico Department of Game and Fish
NMSWAP:	New Mexico State Wildlife Action Plan

List of Acronyms (continued)

NPS:	National Park Service
NRCA:	Natural Resource Condition Assessment
NRSS:	Natural Resource Stewardship and Science Directorate (NPS Washington support office)
NSNSD:	Natural Sounds and Night Skies Division
OIRV:	Other Important Resource and Value
RCP:	Representative Concentration Pathway
SQM:	Sky Quality Meter
USDA:	United States Department of Agriculture
USEPA:	United States Environmental Protection Agency
USFS:	United States Forest Service
USFWS:	United States Fish and Wildlife Service
USGS:	United States Geological Survey
USU:	Utah State University
UTV:	Utility-terrain Vehicle
VALL:	Valles Caldera National Preserve
WRCC:	Western Regional Climate Center
WRD:	Water Resources Division

Glossary

Condition Assessment: A condition assessment reports on the *current condition* of one or more *indicators of condition* for a given resource. A resource topic is selected as a condition assessment when enough data are available to inform current condition of selected indicators, which are evaluated by using scientifically justifiable *condition rating statements*. What constitutes "enough" data is a professional judgement based on a review of all available data and discussion with park staff, subject matter experts, and researchers involved in collecting the applicable data. Condition is evaluated for each indicator using a 5-level rating system, ranging between good-fair-poor; if trend can be reported for an indicator, it is reported as improving, stable, deteriorating, or unknown/indeterminate.

Condition Rating Statements: These correspond to the five-level rating system developed for the indicators of condition. The five levels are good, good/fair, fair, fair/poor, and poor, with corresponding "stop light" colors. Condition ratings statements are developed at the indicator level for the combination of measures evaluated for each indicator. The statements must be logical and defensible based on the best available science.

Confidence Level: These correspond to a three-level rating system of low–medium–high described for the indicators of condition rating evaluation. These levels are based on the repeatability of evaluation findings and how confident the author is in the information used to evaluate condition.

Current Condition: This defines the status of condition for an indicator based on the accumulation of one or more measures. "Current" applies to the condition as it exists today, based on what has previously occurred, not on what is likely to occur. Something such as level of hazard or risk, which identifies the proposed or likelihood of what may occur due to the intrinsic characteristics of the resource, will not be used to report on current condition**.** In general, data collected within the last ten years can be used to determine current condition, although this will depend on the rate of change for a particular indicator and its corresponding measures.

Data Gap: A resource is listed as a data gap when information is lacking, or expertise is needed to adequately evaluate condition. One key difference between a data gap and a gap analysis is the level of information reported.

Driver: Ecosystem drivers are major (and most often) external influencers of change to natural systems, functioning across large areas or scales. Drivers are defined as "any relatively discrete events in space and time that disrupt ecosystem, community, or population structure and change resources, substrate, or the physical environment (White and Pickett 1985)." Drivers are most often beyond a manager's ability to influence or change.

Gap Analysis: A gap analysis is a summary of what is known about a given resource in addition to what information is lacking rather than reporting on an indicator of condition. These information gaps are summarized in a table of *proposed* indicators, measures, and reference criteria with the goal of providing a framework for a future study.

Indicator: An indicator is a descriptor of something useful to measure, but it is not the measure itself. Indicators should be specific, measurable, and sensitive to change. Status of current condition for a condition assessment is assigned at the indicator level. This is because resources are often more complex and nuanced than what is reflected in just a few measures. In a gap analysis, these are listed as *proposed* indicators with no condition assigned to them.

Measure: A measure is either qualitative or quantitative and provides specific information about the indicator. There can be one or more measure(s) for each indicator. Selected indicators and measures are often those that are commonly used by National Park Service staff in monitoring the status of a resource, as well as those that are well represented in the literature and can provide context when park-specific data are lacking. In a gap analysis, these will be listed as *proposed* measures.

Pressure: A pressure is a result of a driver that potentially affects a resource. An NRCA presents drivers and pressures as the fundamental forces that play important roles in regulating or altering ecological resource conditions in the park and does not differentiate between the two.

Reference Criteria: Reference criteria are pivot points, thresholds, or ranges based on peer-reviewed literature, state standards, known criteria, or some other justifiable source of information. Quantitative reference criteria are generally better than qualitative reference criteria, but when specific data are lacking, qualitative reference criteria are useful. Regardless of the type of reference criteria used, they must be justifiable. In a gap analysis, these will be listed as *proposed* reference criteria.

Response: Management implications and useful near-term actions/activities park managers can consider to protect, maintain, and/or restore important ecological resource conditions in parks.

State (Condition): The "health" or condition of the resource reported at the indicator level. Refer to the definition for Current Condition above.

Stressor: "Stressors can manifest as physical, chemical, or biological perturbations to a system that are either foreign to that system, or natural to the system, but occurring at an excessive or deficient level. Stressors cause significant changes in the ecological components, patterns, and processes in natural systems. They act together with drivers on ecosystem attributes (Barrett et al. 1976)." When possible, stressors are selected as measures with which to evaluate current condition of an indicator.

Natural Resource Condition Assessment – Introduction

The National Park Service's (NPS) Natural Resource Condition Assessment (NRCA) Program evaluates natural resource conditions in park units and delivers the results to park staff, scientists, strategic planners, and the general public through reports and associated products. All NRCA efforts strive to report resource condition information that informs multiple levels of park stewardship activities. Stewardship activities may include partnerships, resource stewardship plans, park management plans, and may inform on-the-ground actions that park management can implement.

As part of the NRCA program, Natural Resource Condition Assessments (NRCAs) are one-year projects designed to provide efficient, yet defensible, "status of knowledge" information on drivers and stressors, current conditions, and critical data gaps for a limited number of important park ecological resources. NRCAs are intended to use the best available scientific data for park-selected focal resources, drivers, stressors, and manager questions or needs. This body of scientific information is synthesized, analyzed, and interpreted using appropriate study methods and techniques. A manager-scientist team of experts considers the overall reasonableness and defensibility of study findings, management implications associated with those findings, and useful responses that park managers may consider to further understand, maintain, and/or improve natural resource conditions.

Standard products from NRCA projects include a detailed project report and associated products. These may include species checklists, geospatial maps and data, presentations, and others. All reports and associated products are available via the NPS Datastore (https://irma.nps.gov/DataStore/).

Conceptual Framework for Assessing Resource Conditions and Influences

NRCA projects employ a Drivers, Pressures, Stressors, States, and Responses (DPSSR) conceptual framework (Figure I-1) similar to that used and advocated by others (Office of National Marine Sanctuaries 2020; Harwell et al. 2019). The DPSSR framework structures the content in an NRCA report and guides discussions of the anthropogenic and/or natural factors that "drive" ecosystem change. The effects of a driver or pressure (hereafter referred to as driver) may affect the current condition (or state) of a natural resource indicator as a positive or negative stressor. For stressors that are within the park's "span of control", a park management response may maintain, improve, or restore the natural resource indicator of condition to a desired state. For stressors that the park can't directly manage or influence, it's still helpful to understand potential impacts, especially when identifying realistic resource management goals.

It's important to note that an NRCA project does not report on all natural resources for a park. Instead, the NRCA Program or park managers may use the DPSSR framework to guide the evaluation of new natural resource conditions or to re-evaluate conditions in future NRCAs, especially as drivers or stressors change or as new information becomes available.

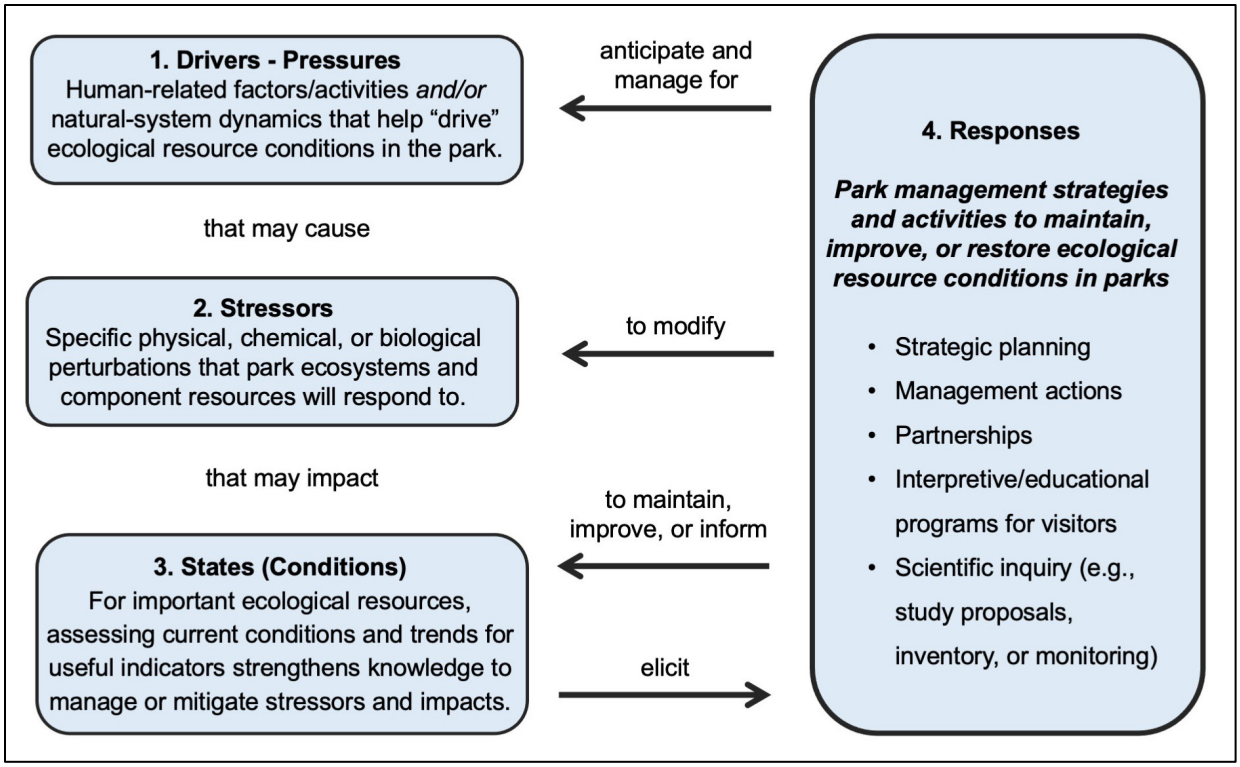


Figure I-1. The DPSSR conceptual framework is used to report drivers, stressors, states, and responses in NRCA studies (adapted from Harwell et al. (2019) and the Office of National Marine Sanctuaries (2020)).

NRCA Technical Report

Each NRCA projects are developed in five phases: project initiation, study plan scoping, study plan development, technical report development, and project finalization. During the initiation and study plan scoping phases, park managers select the subset of important focal natural resources that will be evaluated with respect to their conditions/states. Park managers also identify specific management questions and information needs they hope can be addressed in the NRCA study. During the study plan scoping and development phases, the focal resource drivers and stressors are identified and then reported in the technical report's Chapters 2 & 3. Management responses and considerations that help protect, maintain, and/or improve the focal natural resource conditions or to inform critical data gaps are reported in Chapter 4.

Focal Resources and Drivers & Stressors Summary for VALL's NRCA

Valles Caldera National Preserve (VALL) managers selected seven focal resources for the park's NRCA. The primary drivers and stressors influencing the conditions of those resources are listed in Table I-1, using the Conservation Measures Partnership (2016) *Classification of Conservation Actions and Threats* categories and terminology. The classification defines a common nomenclature to support collaboration among conservationists and consistency across NRCA reports.

Table I-1. The primary drivers-pressures and stressors influencing the conditions (states) of VALL's focal resources. The categories are from the Conservation Measures Partnership (2016) classification.

Drivers-Pressures ***Fundamental Forces to Consider***	**Stressors** ***Potential Influences to Consider***
Agriculture	Livestock ranching & associated developments
Residential & Commercial Development	Habitat fragmentation, population isolation, habitat loss, loss of species (e.g., beaver)
	Developments & associated features (power poles, fences)
	Noise & light pollution
Energy Production & Mining	Air-borne pollution
	Resource exploration & extraction (geothermal development)
Biological Resource Use	Resource harvesting (hunting, fishing)
Transportation	Roads and highways (Highway 24)
Human Intrusions & Disturbance	Noise & light pollution
	Recreational activities (visitor-wildlife conflicts, trampling)
Invasive & Problematic Species, Pathogens, & Genes	Problematic animals, insects, diseases, parasites, & plants
Natural Systems Modification	Altered surface hydrology (post-fire)
	Fire, fire suppression, fire effects
	Restoration activities
Climate Change	Changes in temperature & precipitation regimes

Chapter 1. Introduction to Park Setting and Resources

Valles Caldera National Preserve (VALL, preserve) is one of 19 national preserves included in a system of 423 national park units. Congressionally legislated in 2014, VALL's purpose is to "protect, preserve, and restore ecosystems and cultural landscapes within an outstanding example of a volcanic caldera for the purpose of education, scientific research, public enjoyment and use, and cultural continuity" (Public Law 113-291, Valles Caldera National Preserve Act (2014)). VALL is administered by the National Park Service (NPS), which is one of nine bureaus and offices of the Department of Interior that manages America's vast natural and cultural resources for the enjoyment and use of future generations.

1.1. Location

VALL is in the Jemez Mountains of north-central New Mexico, approximately 124 km (77 mi) northwest of Albuquerque, New Mexico, and 48 km (30 mi) west of Los Alamos, New Mexico (Figure 1.1-1). A primary access road, New Mexico State Route 4, leads you to the preserve's visitor center and the historic Cabin District, which served as headquarters and residences for sheep and cattle ranching operations beginning in the 1860s. The preserve encompasses 35,977 ha (88,900 ac) and is surrounded by the U.S. Forest Service's (USFS) Santa Fe National Forest (NF) along its northern and western boundaries and adjoins the Pueblo of Santa Clara along its northeastern boundary. Bandelier National Monument, another national park unit administered by the NPS, is located along the preserve's southeastern corner.



A scenic view across an expansive valle, which is Spanish for valley, in VALL. Image Credit: NPS.

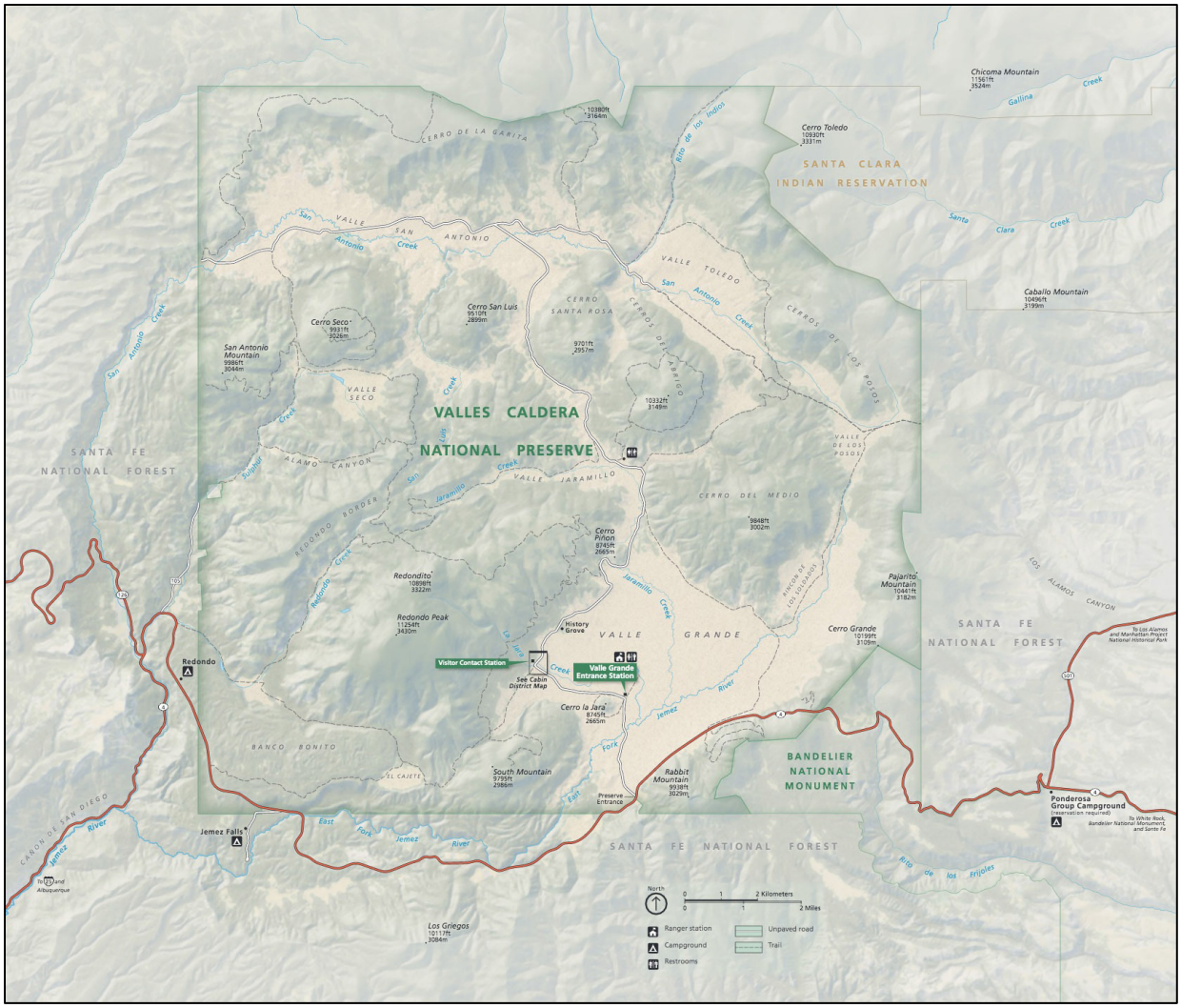


Figure 1.1-1. NPS map of VALL and surrounding region. Figure Credit: NPS/Harpers Ferry Center.

1.2. Setting and Resources

The Jemez Mountains region lies at the intersection of the Rio Grande rift and the Jemez lineament. The rift, a stretching and thinning area of the earth's crust, extends from central Colorado to the state of Chihuahua, Mexico, and the lineament, a chain of volcanic fields, spans from east-central Arizona to the Raton-Clayton volcanic field in northeastern New Mexico (Figure 1.2-1).

The Jemez volcanic field began its formation over 14 million years ago with a series of eruptions, including at least two especially explosive events. The most recent event (about 1.23 million years ago) formed the Valles Caldera—a broad, 19- to 24-km (12- to 15-mi) wide circular caldera depression that is almost entirely within VALL's legislated boundary.

From a geologic perspective, both the Valles Caldera and Yellowstone are two of the world's best examples of *young* calderas, and while Valles Caldera appears inactive, the rare and hot, acid-sulphate springs and fumaroles belie its appearance of extinction.

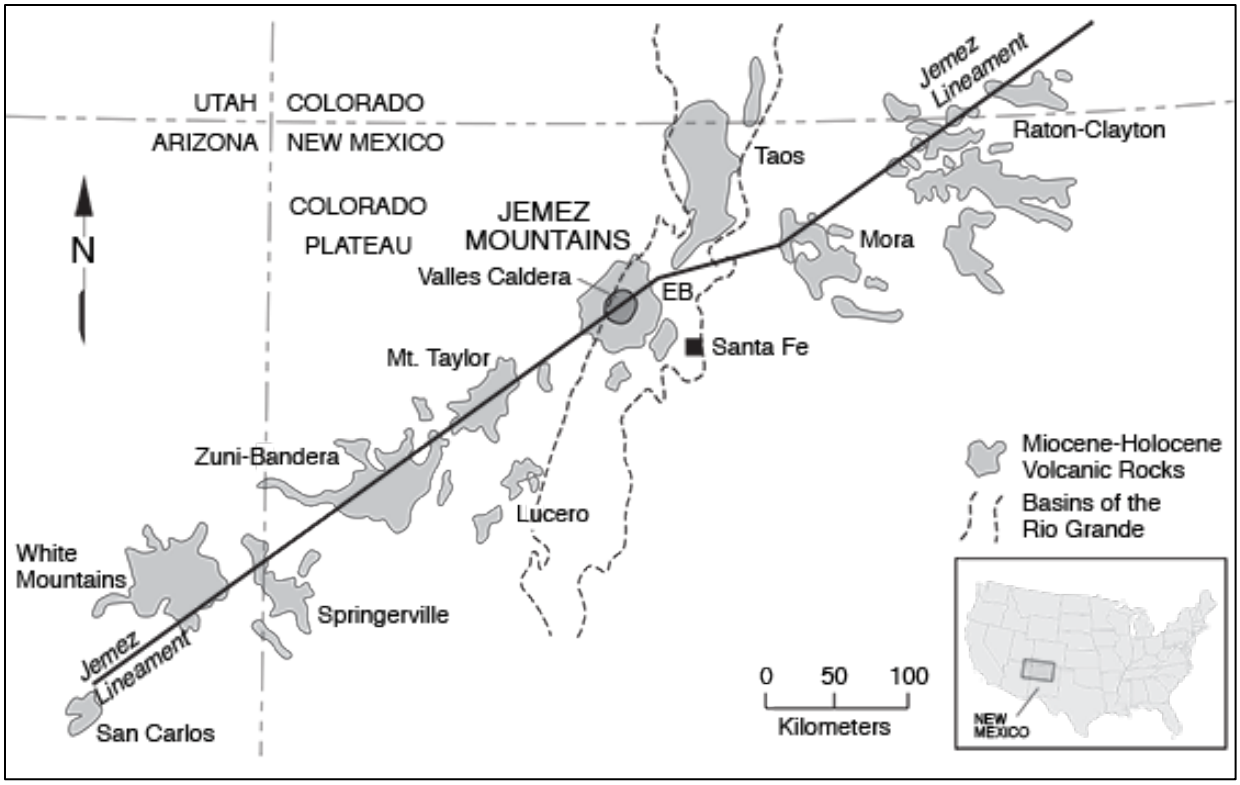


Figure 1.2-1. Map of the intersection of the Jemez lineament and the Rio Grande rift within VALL. Figure Credit: ©University of New Mexico EPSCoR (n.d.), adapted figure from Goff and Grigsby (1982).

1.2.1. Intra-continental Volcanic Origin of International Significance

After the initial intra-continental formation of the Valles Caldera, a series of resurgent eruptions and magmatic intrusive events followed, creating numerous volcanic domes and flows of obsidian and rhyolite (a silica-rich volcanic rock) (Figure 1.2.1-1). The highest dome in the preserve, Redondo Peak, is at an elevation of 3,430 m (11,254 ft) and is the second highest point in the Jemez Mountains. It is of international significance, serving as the type locality (or model) for understanding caldera resurgence worldwide.

1.2.2. High Elevation Ecosystem

VALL is at the top of the Southwest Jemez Mountains watershed, and its streams comprise the headwaters of the Jemez River—a tributary of the Rio Grande. With elevations ranging from 2,391 m (7,845 ft) to 3,430 m (11,254 ft), the preserve in its entirety is a high elevation ecosystem that includes wetlands and wet meadows, montane grasslands, woodlands, and coniferous forests, all of which contrast with the lower elevations and more arid regions of New Mexico.

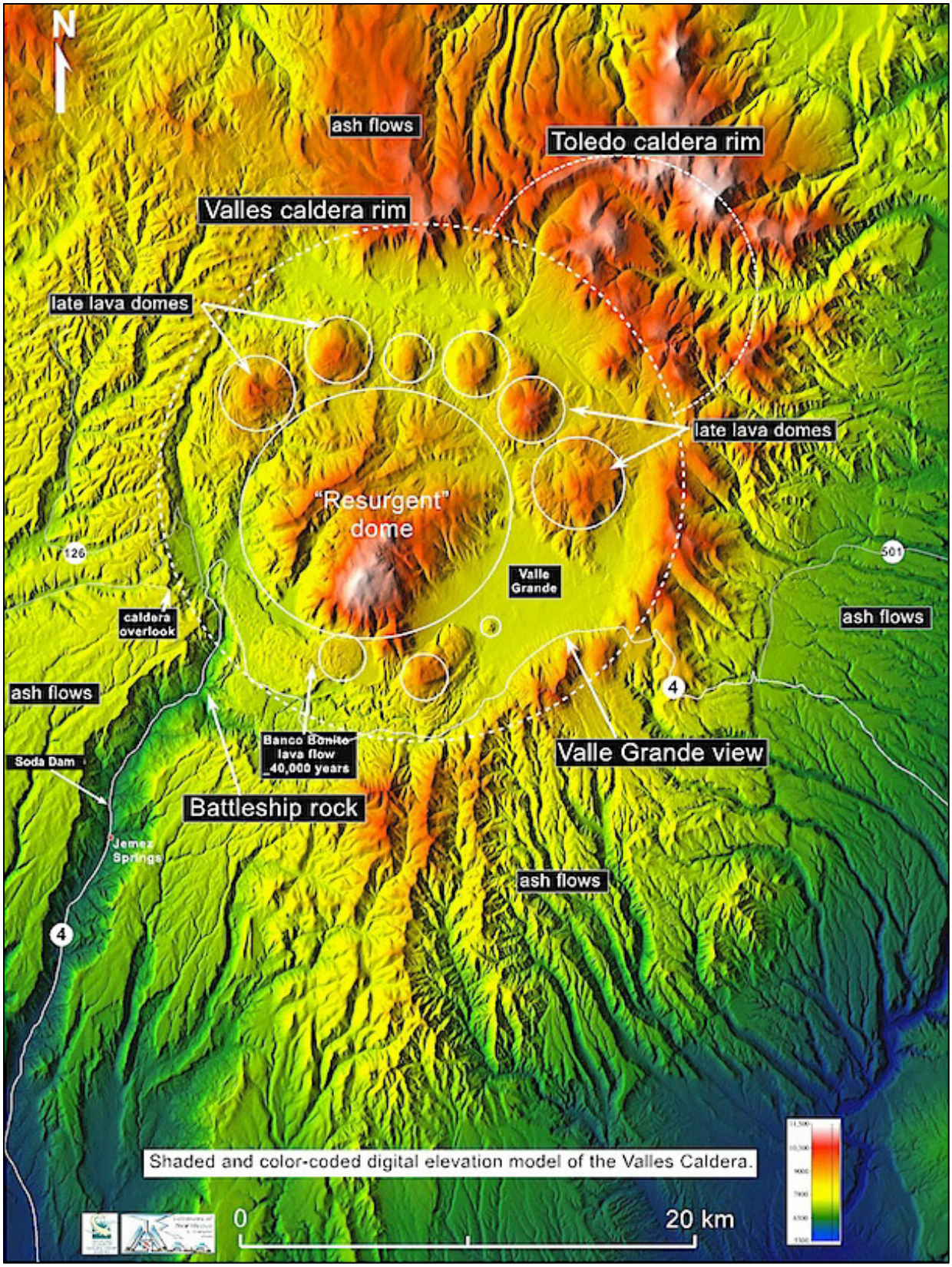


Figure 1.2.1-1. Volcanic rims, domes, and ash flows within and surrounding VALL. Figure Credit: ©New Mexico Museum of Natural History and Science.

VALL is characterized by warm summers, cold winters, and low humidity. Temperature and precipitation vary with elevation throughout the landscape. Redondo Peak receives around 96.5 cm (38 in) of mean annual precipitation, while Valle Grande receives around 25.4 cm (10 in) less (Western Regional Climate Center [WRCC] 2021 (data 2005–2020)). Although temperatures are typically cooler at higher elevations, at VALL, cold air drains into the valle bottoms, making these areas cooler than the surrounding peaks (Muldavin et al. 2006). Pacific fronts bring snow in winter and rain in spring and fall. Half or more of the amount of precipitation occurs in late summer and early fall as thunderstorms resulting from the North American monsoon. Interannual precipitation is strongly influenced by the El Niño-Southern Oscillation (ENSO). El Niño events tend to bring higher-than-average winter and early spring precipitation, while interspersed La Niña events bring below-average precipitation and drought (Touchan et al. 2011). Decadal-scale variations in sea surface temperatures in the Pacific Decadal Oscillation and the Atlantic Multidecadal Oscillation interact with the shorter-term variations of the ENSO to influence long-term variations in precipitation and cycles of drought (Chylek et al. 2014). This creates a precipitation pattern in VALL of 25–30 years of below-average precipitation and drought followed by 25–30 years of wetter-than-average precipitation, as evidenced by tree ring studies in central New Mexico going back about 600 years (Milne et al. 2003).

The precipitation that falls or flows into the caldera's big valleys are important recharge zones for the region's groundwater. When the rocks in the volcanically active subsurface heat groundwater, the water rises. As the heated water reaches the surface, hot springs, fumaroles, or mud pots occur, as observed at the preserve's recently acquired 16-ha (40-ac) Sulphur Springs property, underscoring the still active geothermal system and uniqueness of the area.



Fog and snow at VALL visitor center. Image Credit: NPS.

1.2.3. Flora & Fauna

The highest elevation ecosystems in the Jemez Mountains and on VALL's Redondo Peak include upper montane meadows, spruce-fir (*Picea engelmannii-Abies lasiocarpa*) forests, and exposed rock outcrops or scree fields known as felsenmeers, which are relatively rare, comprising only 434 ha (1,074 ac) in the preserve (Muldavin et al. 2006).

The mid-elevation mixed conifer forests occupy the largest area in the preserve and include dry and moist mesic forests and woodlands, as well as blue spruce (*Picea pungens*) stands that occur along the fringes on north aspects of mountain slopes (Muldavin et al. 2006). The ponderosa pine (*Pinus ponderosa*) forests, which are between the mixed conifer forests and upper montane grasslands, occupy the forest zone's lower elevations.

The preserve's grasslands include upper, lower, and forest. The lower elevation montane grasslands occupy the largest area in VALL. Upland bunch grasses dominate, but scattered stands of trees or shrubs are present where disturbances have occurred or where a low fire incidence exists (Muldavin et al. 2006).



View from the north rim of the Valles Caldera, with Valle Toledo on the left, Valle San Antonio on the right, and Cerros Santa Rosa, and Cerro Abrigo in the center. Redondo Peak is on the right, and the southeastern caldera rim is visible in the far distance. Image Credit: NPS.

The wetland resources in the preserve include palustrine emergent meadows, and to a much lesser extent, palustrine fens, bogs, vernal pools, springs, and seeps, and first- and second-order intermittent- or perennial-flow riverine channels. The palustrine emergent meadows are extensive and occur in the large, open, low-gradient landscape areas, primarily adjacent to the second-order perennial flow channels. A variety of sedges (*Carex* spp.), cinquefoil (*Potentilla* spp.), rushes (*Juncus and Eleocharis* spp.), and longleaf pondweed (*Potamogeton nodosis*) comprise VALL's wet meadows.

Almost all the primary streams in VALL's upper watersheds are intermittent (or ephemeral) and contribute to the physical and biological health of the secondary perennial streams. The riverine systems include the linear features and the area of the floodway between the banks that convey surface water. Typical geomorphic features include different bedload types, and the biological conditions vary depending on the hydrologic regime. According to Muldavin and Tonne (2003), the edges of the intermittent and perennial streams support a diverse herbaceous layer of over 40 grasses and forbs, most of which are aquatic plants. The most common ones are Canada reedgrass (*Calamagrostis canadensis*), Fendler's waterleaf (*Hydrophyllum fendleri*), seep monkeyflower (*Mimulus guttatus*), Columbian monkshood (*Aconitum columbianum*), and Fendler's cowbane (*Oxypolis fendleri*).

With over 121 km (75 mi) of perennial streams in VALL, wildlife is never too far from a water source. In addition, there exist a total of 182 legacy stock tanks (impoundments) across the preserve, many of which restrict normal hydrologic function in both ephemeral and perennial watersheds. However, many of these streams are spring fed by "flashy water" because of the broken piles of rhyolite. As a result, several of the streams are, and will likely continue to be, impacted as environmental conditions become drier. This may result in a stream's decreased ability to maintain water through a drought period, becoming more intermittent. Thus, a knowledge gap is understanding which streams are fed by surface precipitation, and more likely to be impacted by climate change, versus ones that are groundwater fed and less likely to go dry, even with changing climate.

With abundant water sources and diverse vegetation communities, VALL supports an equally diverse array of wildlife, including elk (*Cervus canadensis*), mule deer (*Odocoileus hemionus*), mountain lion (*Puma concolor*), and black bear (*Ursus americanus*), fish, and almost 200 species of birds, including vagrants, accidentals, and those with few observations, as well as other species, such as aquatic and terrestrial invertebrates and fungi. VALL is a designated National Audubon Society Important Bird Area (NAS 2008), providing habitat for 40 species of concern (NM-ACP 2016; NMDGF 2016; PIF 2017). Other special status species include the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*), the Jemez Mountains salamander (*Plethodon neomexicanus*), and the Mexican spotted owl (*Strix occidentalis lucida*). The area is known as one of the most unique trout fishing sites in the state, with the perennial East Fork of the Jemez River and San Antonio Creeks, forming the core of the cold water fishery in the preserve.

The rich assemblage of vegetation, wildlife, and volcanic resources of the Jemez Mountains has attracted diverse groups of people throughout human history, including present-day. Several Indigenous peoples continue to make annual pilgrimages to a sacred shrine located atop Redondo Peak and have done so for generations prior to the privatization of the land in the mid-1800s (Anschuetz and Merlan 2007). In addition, scientists from around the world come to VALL to study its varied and unique resources, underscoring the preserve's significance not only to the local and regional Indigenous peoples, but to the global scientific community as well.

Chapter 2. Drivers and Stressors

Chapter 2 summarizes select primary driving forces (drivers) and the physical, chemical, and biological disturbances (stressors) of the selected focal resources. For streamlining purposes, drivers and pressures are not differentiated throughout the report, and when stressor-related data are available (e.g., non-native invasives, water contaminants), they are used as indicators of condition and/or measures to evaluate the states of preserve-selected focal natural resources in Chapter 3.

2.1. Human History

People have been interacting with the resources of the caldera and surrounding region for thousands of years, creating a landscape of considerable change. American Indians sustainably hunted and fished the abundant wildlife and fish and gathered plants for ceremonial and medicinal uses. The caldera's high-quality obsidian was a significant resource to the Puebloans, the Navajo, and other Native American groups for ceremonies, toolmaking, and trading. It was also widely distributed across the Southern Rocky Mountains, Great Plains, and the Rio Grande Valley regions of the United States (Anschuetz and Merlan 2007).



VALL's Chief of Science & Resource Stewardship, Robert Parmenter, explains the formation of the caldera from the overlook along New Mexico State Route 4. Image Credit: NPS/Utah State University.

During the mid- to late-19th century, several changes of private land ownership of the caldera area occurred, and with the various owners came changes to the primary land uses. Sheep grazing began in 1860, with up to 100,000 animals per year. Cattle replaced sheep in the mid-20th century, with up to 12,000 head per year. Other land use practices included sulphur mining and geothermal exploration, logging of most of the old-growth forests, which occurred from 1930 to 1970, creating over 1,609 km (1,000 mi) of roads. Tourism and recreational activities, including elk hunting, fishing, and even movie-filming, were also actively promoted and are still in effect today.

In 2000, the U.S. government purchased the Valles Caldera from private land ownership and established the Valles Caldera Trust under the U.S. Department of Agriculture (USDA), which was an unprecedented experiment in decentralized public land management. During the Trust's 15-year tenure, a team of scientists developed a robust science-based and adaptive resource management program, and in 2010, formed the Southwest Jemez Mountains Collaborative Forest Landscape Restoration Program (CFLRP). The purpose of the CFLRP is to coordinate activities to restore natural fire regimes and improve ecosystem resilience at the watershed (landscape)



Mountain bikers on Rabbit Mountain, overlooking the Valle Grande. Image Credit: NPS.

In 2014, the U.S. Congress introduced legislation to designate the Valles Caldera Trust as a unit of the National Park System, and in 2015, it transferred management of the land to the NPS. As a national preserve, hunting, fishing, and livestock grazing are permitted—all land use practices that

occurred historically, with one significant difference; present-day activities are intensively monitored to inform adaptive management practices and innovative strategies in resource sustainability.

For example, VALL has been conducting an All-Taxa Biological Inventory of flora and fauna, drawing scientists from multiple disciplines. Since 2016, VALL has issued 175 scientific research permits, representing 37 disciplines (NPS RPRS, Bill Commins, program manager, emailed VALL permit summary to Kim Struthers, Utah State University, 10 August 2021).

2.2. Visitor Use

Under NPS management, VALL offers four seasons of recreation opportunities to visitors. Activities include wildlife viewing, cross-country skiing, hiking, biking, horseback-riding, stargazing, hunting, fishing, scenic-viewing, and more. In 2020, 30,434 recreation visitors came to the preserve, with 74% of the total number of visits occurring from July–October (NPS Visitor Use Statistics 2021). Those visitors spent an estimated $2.0 million, primarily on lodging, restaurants, gas, and retail, supporting 28 jobs in the region (Cullinane and Koontz 2021). Statewide, 1.5 million visitors to New Mexico's NPS units spent an estimated $85.2 million in 2020 throughout the local gateway communities, supporting 1,230 jobs (Cullinane and Koontz 2021).

As VALL's visitation increases, so do resource conflicts and concerns related to human-wildlife interactions, such as bear maulings. Other examples of visitor-induced stressors include the trampling of riparian vegetation along stream banks, the introduction of non-native invasive plant seeds, and noises related to human activities, such as engine noise, conversations, etc.

2.3. Pollution

Dark Night Sky (light pollution)

Natural dark skies are a valued resource within national parks, reflected in NPS management policies, which highlight the importance of a natural photic environment to aesthetics (NPS 2006). However, the value of night skies goes far beyond visitor experience and scenery. The photic environment affects a broad range of species, is integral to ecosystems, and is a natural physical process (Moore et al. 2013).

Natural light intensity varies during the day-night (diurnal) cycle, the lunar cycle, and seasonal cycles. Organisms, which include humans, have evolved to respond to these periodic changes in light levels in ways that control or influence movement, feeding, mating, emergence, breeding, migration, hibernation, and dormancy (Royal Commission on Environmental Pollution 2009). Given the effects of light on organisms, it is likely that introducing artificial light into the natural light/dark 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 NPS visitors.

To understand, improve, and maintain dark night skies in the preserve, staff completed a lighting inventory in 2020 and retrofitted 71% of the preserve's light fixtures to reduce or eliminate unnecessary light pollution (Woods et al. 2020). Staff also collected night sky data at 11 locations throughout the preserve (Figure 2.3-1). These efforts were to support the application to become a designated International Dark-Sky Park.

On 3 February 2021, the International Dark-Sky Association (IDA; 2021) awarded VALL a Dark-Sky Park certification, and while the designation does not carry any regulatory authority, it showcases the importance of dark night skies for both preserve recreationists and for the surrounding communities.

Prior to VALL's 2020 data collection effort (VALL 2020, M. Peyton, wildlife biologist, e-mailed file to Lisa Baril, Utah State University, 15 April 2021), scientists from the NPS Natural Sounds and Night Skies Division (NSNSD) surveyed the night sky at one location (Valle Grande) on the evening of 22–23 June 2017 (Figure 2.3-1). All locations that have been monitored for night sky metrics are summarized in Table 2.3-1, along with the corresponding condition ratings.

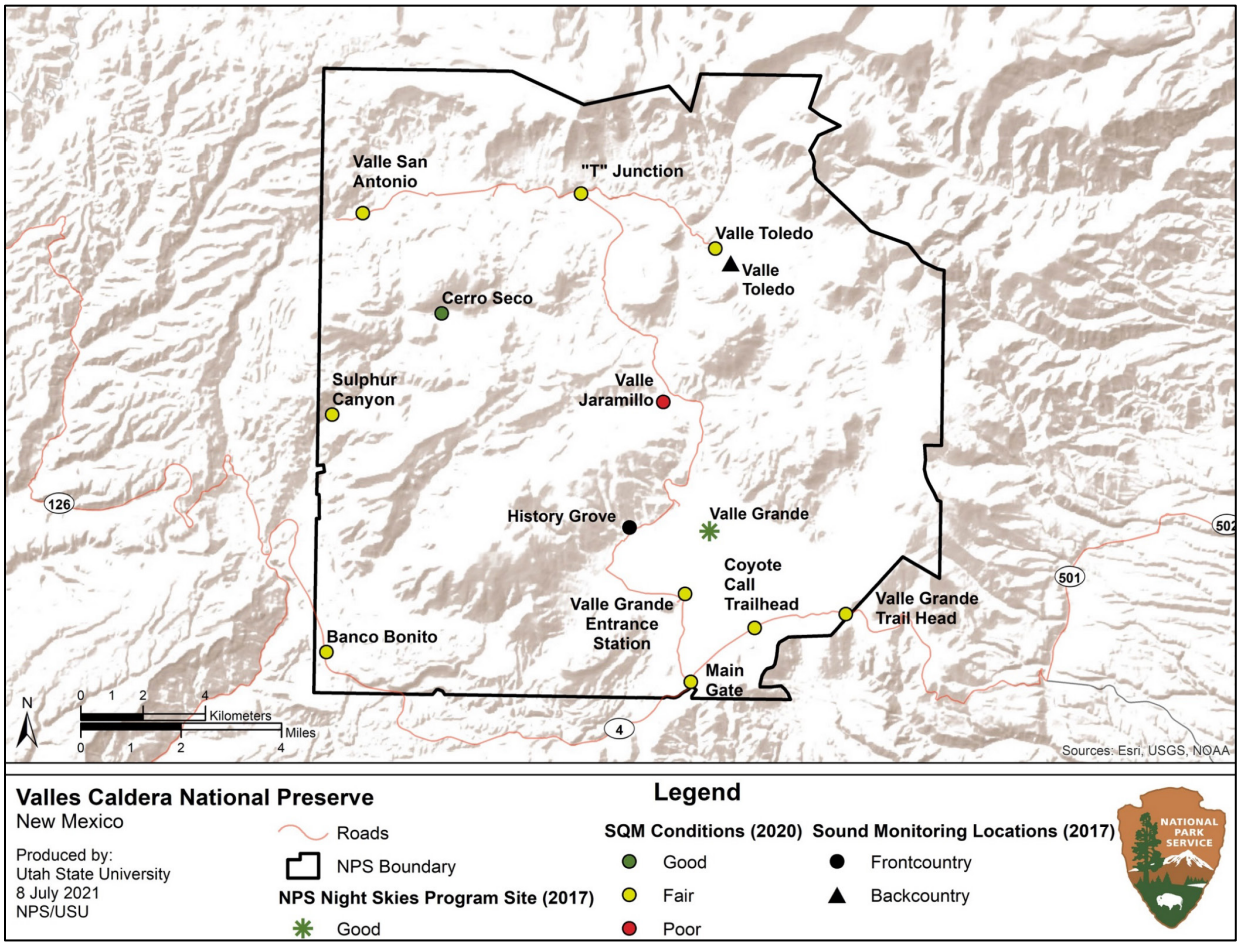


Figure 2.3-1. Locations and conditions of the sky quality meter (SQM) night sky monitoring results at VALL. Sound monitoring locations are also shown (black circle and triangle).

Table 2.3-1. Summary of Sky Quality Meter (SQM) readings collected at 12 locations in VALL (NPS NSNSD 2017; VALL 2020).

Location	Date	Mean SQM (mag/arcsec^2)	Condition
Valle Grande	22–23 June-2017	21.63	Good
"T" Junction	12-Aug-2020	21.47	Fair
Valle Toledo	12-Aug-2020	21.32	Fair
Valle San Antonio	12-Aug-2020	21.56	Fair
Valle Jaramillo	12-Aug-2020	21.17	Poor
Cerro Seco	12-Aug-2020	21.63	Good
Sulphur Canyon	12-Aug-2020	21.53	Fair
Banco Bonito	12-Aug-2020	21.46	Fair
Valle Grande Entrance Station	12-Aug-2020	21.26	Fair
Main Gate	20-Aug-2020	21.57	Fair
Coyote Call Trailhead	20-Aug-2020	21.56	Fair
Valle Grande Trail Head	20-Aug-2020	21.28	Fair

In 2017, the NPS NSNSD observers described the night sky from the Valle Grande location as a "rural" sky based on the Bortle Dark-Sky scale, which is a qualitative approach for classifying night sky conditions (Bortle 2001). A Bortle classification between 1 and 3 indicates a good condition for non-urban park night skies (Moore et al. 2013). However, the light domes of Espanola, Los Alamos, Santa Fe, and Albuquerque (all towns and cities in New Mexico) were visible from the Valle Grande site (Woods et al. 2020).

In addition to the Bortle metric, the NPS NSNSD used a hand-held Sky Quality Meter (SQM) to measure sky brightness towards the zenith (highest point in the sky). The hand-held SQM is an economical and convenient tool but does not reliably measure the sky brightness when the sky is darker than ~21.5 mag/arcsec^2 (i.e., >21.5 mag/arcsec^2). From the Valle Grande location, the 2017 SQM value was measured at 21.63 mag/arcsec^2, which indicates a good condition. The SQM readings collected at the 11 locations in VALL in mid-August 2020 are presented in Table 2.3-1. The readings indicate fair conditions at all locations, except one–Valle Jaramillo–which was rated as poor condition (Woods et al. 2020).

A more objective measure of the night sky environment is the all-sky light pollution ratio (ALR), which is the amount of light in the night sky that can be attributed to human sources (e.g., city lights, streetlights, vehicle headlights) (Duriscoe 2013). For the preserve, an ALR of 0.63 was modeled from satellite imagery, representing 63% brighter than average natural conditions (Figure 2.3-2), which warranted a fair condition rating. For comparison, a ratio of 0.0 indicates a pristine night sky, and a ratio of 1.0 indicates a night sky that is 100% brighter than average natural conditions (Moore et al. 2013).



Milky Way in 2018. Image Credit: ©Marc Bailey.

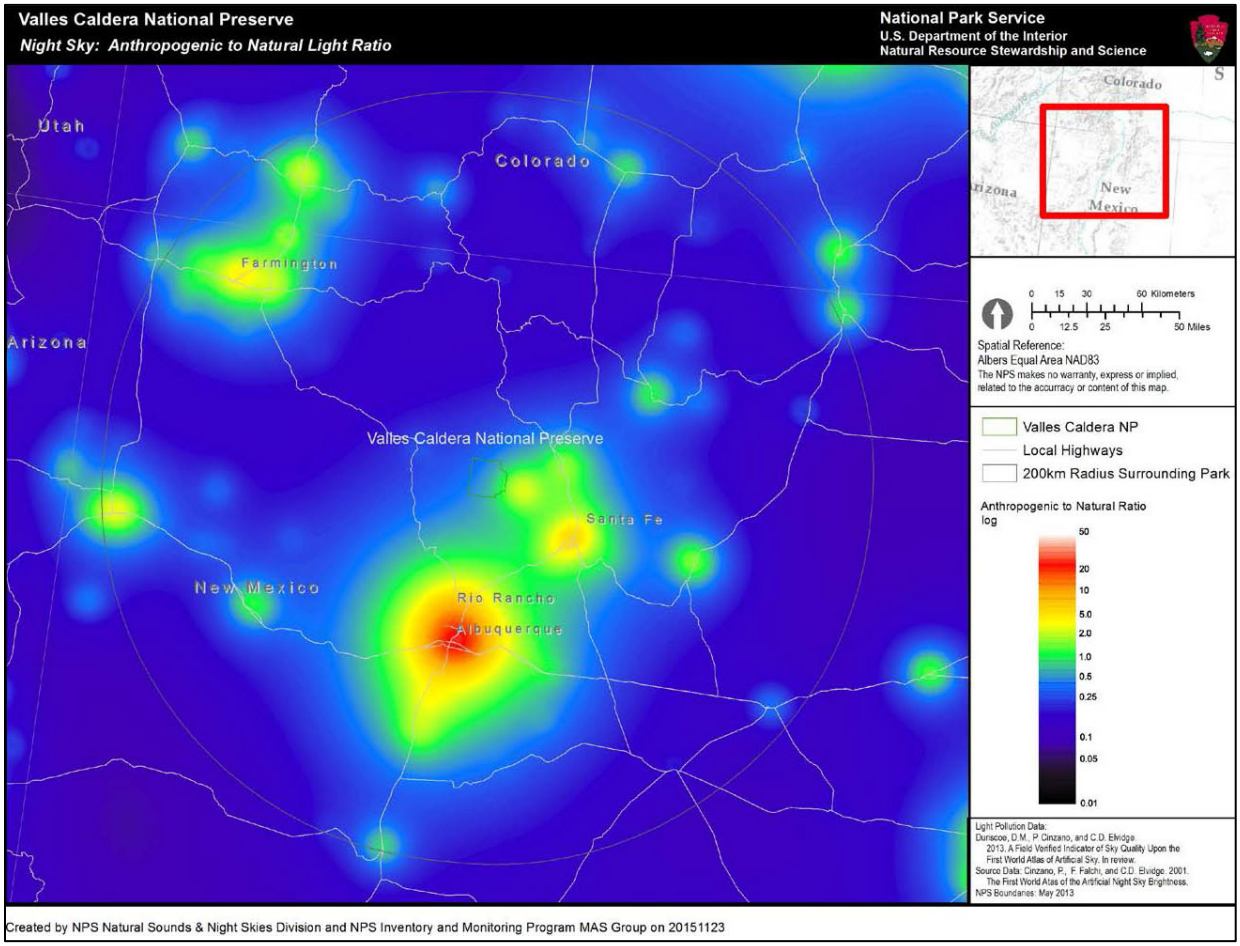


Figure 2.3-2. Modeled all-sky light pollution ratio in and around VALL. Figure Credit: NPS Natural Sounds and Night Skies Division.

Soundscape (noise pollution)

The acoustic environment plays an important, but often overlooked, role in how humans experience a landscape. For undeveloped parks like VALL, natural sounds are integral to enhancing the visitor experience. To assist parks with managing their acoustic environment, the NPS NSNSD estimates acoustic conditions across parks using a geospatial sound model, which predicts daytime sound levels during midsummer. The model includes explanatory variables (e.g., roads, airports, railroads, vegetation types) and field measurements of sound pressure levels.

At VALL, the average median existing sound level, including human-caused sounds, is predicted to be 0.6 decibels (dBA) above natural conditions (Figure 2.3-3). The modeled sound levels ranged from 0.0 dBA in the least impacted areas, to 4.8 dBA in the most impacted areas. The increase of 0.5 dBA above natural conditions reduces the listening area for wildlife and visitors by 13%.

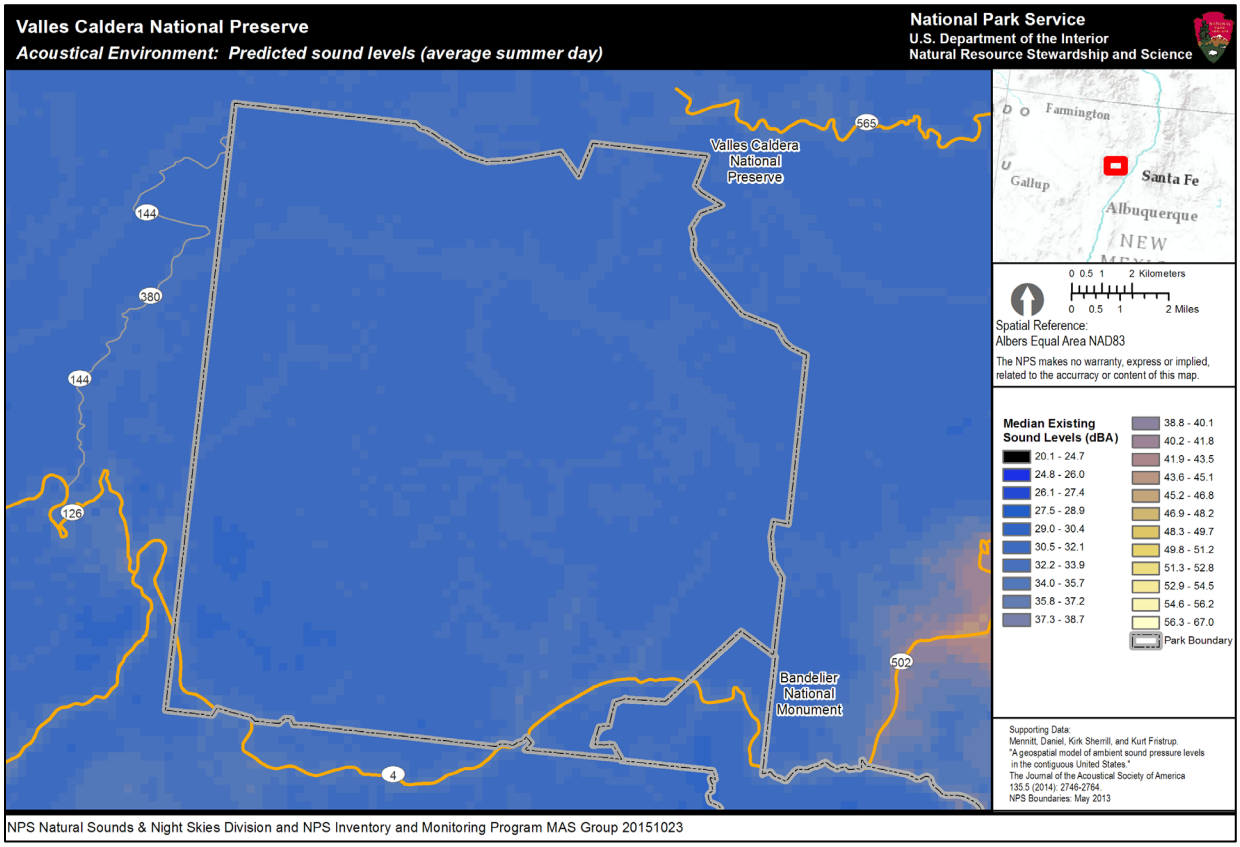


Figure 2.3-3. Predicted median existing sound levels (dBA) for VALL. Figure Credit: NPS Natural Sounds and Night Skies Division.

The NPS NSNSD also examines whether sound levels exceed certain thresholds related to human health and speech. In June and July 2017, sound monitoring equipment was deployed at two locations in the preserve to capture the differences in soundscape between a backcountry site and a front country site (refer to Figure 2.3-1 for locations). At both sites, sound levels rarely exceeded 45 decibels (dB), and most of the time, sound levels were below 35 dB (Figure 2.3-4). This is consistent

with the World Health Organization's recommendation for maximum noise levels inside bedrooms (less than 45 dB). Job (2020) further describes recommended sounds levels.

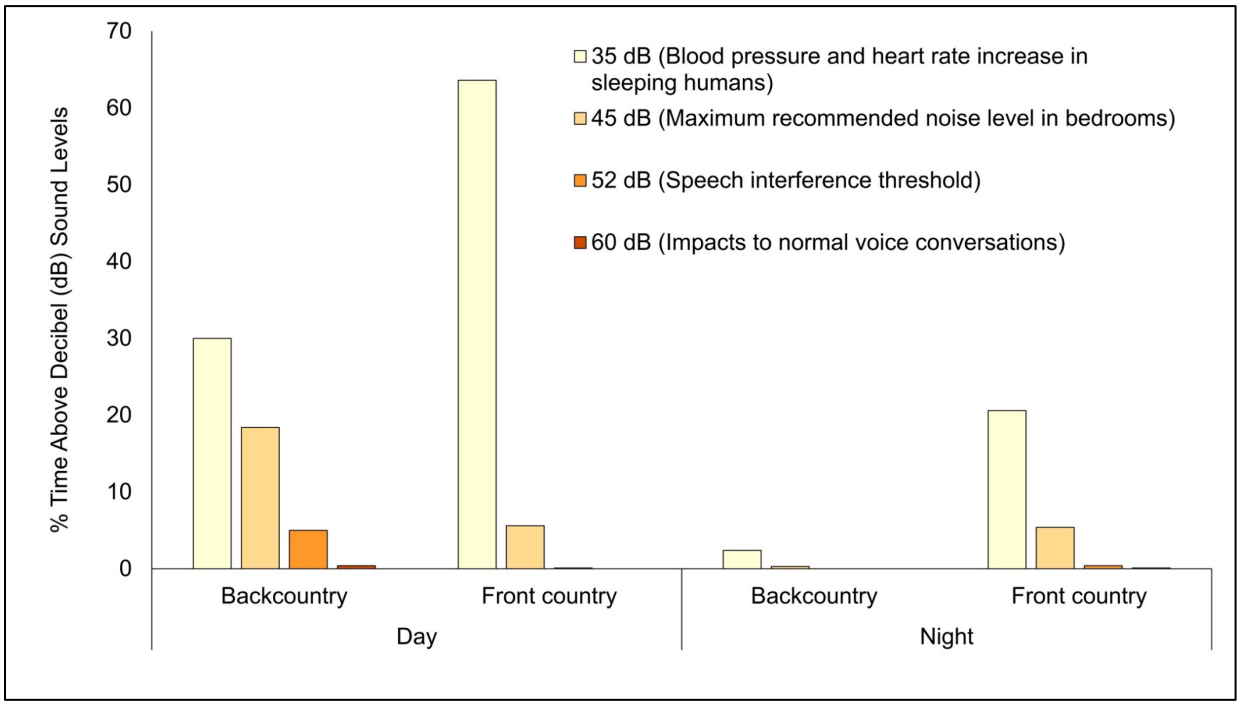


Figure 2.3-4. The percentage amount of time above metrics collected in 2017 for backcountry and front country sites in VALL.

The majority of sounds recorded at both acoustic monitoring sites were natural. The most common natural sound recorded was wind, but birds and insects also contributed significantly to the natural soundscape, in addition to coyotes (*Canis latrans*), elk, and Gunnison's prairie dogs (*Cynomys gunnisoni*).

Although these baseline data suggest that VALL's soundscape is relatively quiet, there were some anthropogenic noises detected. Aircraft sound was the most commonly heard noise at both sites, while vehicle noise was only recorded at the front country site (the backcountry site is behind a locked gate). All noise sources were audible for just 26.5% of the time at the backcountry site and for 29.7% of the time at the front country site.

In conclusion, based on NSNSD's night sky all-sky light pollution and the sound pressure level models, the area in the preserve predicted to have the lowest degree of impacts from light and sound is along the western half of VALL. This information, coupled with a preserve-wide visual resources condition assessment, could inform a landscape-scale monitoring plan to protect the darkest, quietest, and least visually trammeled areas in VALL. Managers could use this type of information in future zoning or wilderness planning efforts, as well as to inform the preserve's research permitting process to help maintain pristine conditions where it matters most.

Air Quality

Air pollutants can limit a visitor's ability to view the scenic landscapes throughout VALL and can have a variety of negative effects on ecosystem health. These include acidification, fertilization or eutrophication, and changing soil pH, which affects microorganisms, understory plants, and trees when excessive pollutants are deposited through rain and snow (wet deposition) or dust and gases (dry deposition) (NPS Air Resources Division [ARD] 2010).

Although air quality across the U.S. has improved over the last several decades, there are still major concerns regarding pollutants in the U.S. (USEPA 2020). According to the U.S. Environmental Protection Agency (USEPA) (2020), in the U.S., roughly two-thirds of all sulfur dioxide (SO_2) and one quarter of all NO_x originate 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 (USEPA 2020). The National Parks Conservation Association released a 2019 study based on NPS ARD data, revealing that 96% of 417 park units exhibited significant air quality issues in at least one category of unhealthy air, harm to nature, hazy skies, or climate change (NPCA 2019). Using the NPS ARD reference criteria for wet nitrogen and sulfur deposition levels over a 5-year average (2014–2018), the conditions at VALL were rated as poor and fair, respectively, with unknown trends (NPS ARD 2021a).

An additional airborne pollutant of concern at VALL is silica dust, which becomes a human-health hazard when aerosolized (Sing and Sing 2010). Silica is a naturally occurring compound and is found in the high-silica rhyolite lava domes and tephras (i.e., material ejected during a volcanic eruption) within the caldera (Wolff and Gardner 1995). When the preserve's soils and rocks are disturbed through activities, such as construction and maintenance, restoration, or the use of utility-terrain vehicles (UTVs), silica can become airborne. The aerosolized silica can damage a person's lungs and initiate a wound response that may lead to a serious condition known as silicosis—a respiratory disease caused by breathing in (inhaling) silica dust. Long-term exposure to aerosolized silica may also lead to pulmonary tuberculosis (Sing and Sing 2010).

A study at VALL occurred from 28 September to 4 October 2019 to gather data on respirable silica exposures during two separate activities: cement pouring and UTV use on dirt roads (Ryan-Miller 2019). Two samples collected during cement pouring yielded between 12 and 24 μ/m^3, while six samples collected during UTV use on dirt roads averaged 51 μ/m^3. In two UTV samples (76–78 μ/m^3), silica levels exceeded the Occupational Safety and Health Administration's permissible exposure limit of 50μ/m^3 (Ryan-Miller 2019). Ryan-Miller (2019) notes that these laboratory values may have been somewhat lower than what actually occurs in the environment because of an equipment issue. Based on these results, Ryan-Miller (2019) recommended re-evaluating airborne silica in VALL during cement-pouring activities lasting more than an hour and a more robust sampling of UTV driving.

Wildfire is another contributor to degraded air quality conditions. Declines in winter snowpack increase land surface aridity, which is associated with an increase in wildfire activity across the

western U.S. (Mote et al. 2005; Barnett et al. 2008). From 1979 to 2015, human-caused climate change accounted for an ~55% increase in forest fuel aridity, adding nine days of high fire potential between 2000 and 2015 in the western U.S. (Abatzoglou and Williams 2016).

Wildfire activity is projected to increase by a factor of four per degree of Celsius warming (Solomon et al. 2011), which is expected to increase summer atmospheric organic aerosol concentration by 40% by the 2050s (Spracklen et al. 2009). In high elevation areas in the intermountain west, Hallar et al. (2017) found that surface-level organic aerosol loading is dominated by summer wildfires. Particulate matter from wildfires and other sources not only affects human, wildlife, and plant health, but airborne particulates reduce visibility, which also affects the quality of dark night skies.



Milky Way above a stream in VALL. Image Credit: NPS/Jim Stein.

2.4. Forest Pests

In many western forests, including those in VALL, decades of fire suppression have led to unnaturally high tree densities (Hessburg et al. 2019), which is a major stressor that can increase the susceptibility of trees to forest pests. High tree densities can also lead to large, high-severity fires that are outside the natural fire regime (Hessburg et al. 2019). In recent years, drought conditions across the Southwest have exacerbated the stressors forests already face, and warmer temperatures have shortened the life cycle of some bark beetles (Bentz et al. 2010). In combination, these factors have led to damage or death across large swaths of forests in and around the preserve.

Every year, the USFS' Forest Health Monitoring Program (FHP) maps forest pest outbreaks across the U.S. (Johnson and Wittwer 2006). Most agents responsible for tree damage or death in the western U.S. are native, and include bark beetles, defoliating agents, and disease-causing pathogens (USFS 2013). Forest pests serve an important role in maintaining healthy forests by killing weaker trees and allowing for the subsequent growth of more resilient forests. Although forest pests are a natural and important disturbance agent, the scale of outbreaks (both spatially and temporally) is unprecedented in the last 200 years (Hessburg et al. 2019). Data downloaded from the USFS FHP Insect Detection Survey website (USFS 2018) showed that annually (2000–2018), <1% to 60% of the preserve's forested areas have been affected by forest pests (Figure 2.4-1).

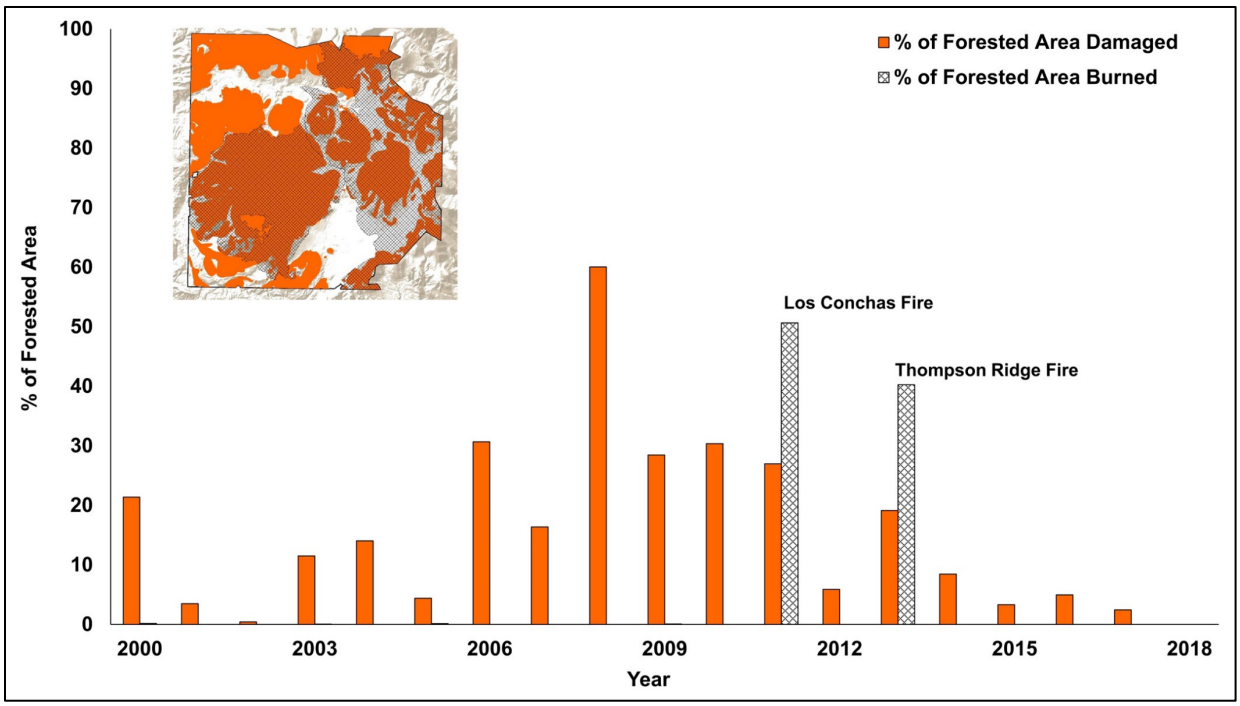


Figure 2.4-1. Percentage of forested area mapped as affected by forest pests from 2000 to 2018.

Cumulatively, 75% of the preserve and 92% of all forested areas were damaged or killed by forest pests during this period. The total forested area mapped as damaged varied annually but peaked in 2008 (60% of forested area), after which the forested area mapped as damaged remained relatively high for the next three years (26–30%), until declining in 2012, then again after 2013 (<10%) per year.

In 2011, just three years after the peak of forest pest damage, the Las Conchas Fire burned 34% of the preserve and 51% of all forested areas, and two years later in 2013, the Thompson Ridge Fire burned 27% of the preserve and 40% of the preserve's forested areas. Prior to either fire, the mapped damaged areas were largely within the perimeter of those two fires, but after the fires, only small areas were affected by forest pests.

Douglas-fir (*Pseudotsuga menziesii*) and quaking aspen (*Populus tremuloides*) were the most common forest pest host species in most years. Since 2013, ponderosa pine has been increasingly affected. Western spruce budworm (*Choristoneura freemani*) was the primary damage agent, accounting for >50% of all damage, but western tent caterpillar (*Malacosoma californicum*) and Douglas-fir beetle (*Dendroctonus pseudotsugae*) were also significant damage agents in some years (Figure 2.4-2).

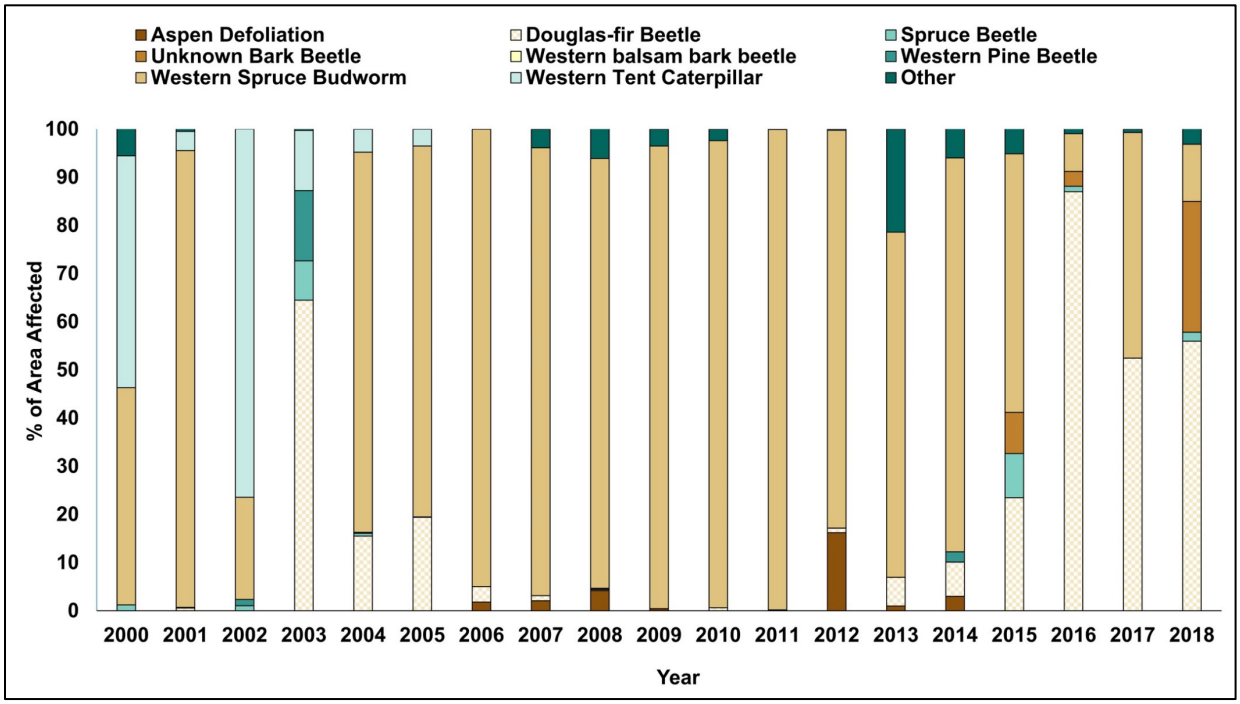


Figure 2.4-2. Percentage of forested area affected by damage agent from 2000 to 2018.

Since 2013, the USFS has classified a portion of damaged areas by level of severity. From 2013 to 2015, damage was mapped as either light (4–10%) or moderate (11–29%). In 2017, however, much of the infestation was mapped as severe (30–55%) or very severe (>50%). In 2018, severity levels were light or moderate. Of particular note is that Douglas-fir bark beetles have caused substantial mortality in Douglas-firs within the preserve's History Grove—a 51 ha (125-ac) old-growth forest, with 250 to 400-year-old ponderosa pine and Douglas-fir trees (NPS 2018a).

2.5. Climate Change

Historic Conditions & Trends

VALL has already experienced significant and rapid, human-caused climate change (USGCRP 2017, Gonzalez et al. 2018a). At VALL, mean temperatures have increased at a rate of 1.4°F per century from 1895 to 2018 (Figure 2.5-1, gray lines), with greater increases in minimum temperatures (1.5°F per century) than maximum temperatures (1.3°F per century; Carlson and Gross 2019). Mean temperatures from 1914 to 2020 at VALL headquarters in Jemez Springs (at 1,909 m/6,263 ft elevation, which is substantially lower elevation than the rest of the preserve) have increased at 1.8° F per century (NPS VALL, B. Parmenter, chief of science & resource stewardship, e-mailed file

to Dana Witwicki, NPS NRCA Program, 15 March 2021), showing that parts of the Jemez Mountains are closely following the Intergovernmental Panel on Climate Change prediction of global warming (IPCC 2014). This increase in mean temperature is caused by warming in the spring and summer months, but not during winter months (NPS VALL, B. Parmenter, chief of science & resource stewardship, e-mailed file to Dana Witwicki, NPS NRCA Program, 15 March 2021). The rate of historical warming has been slower for VALL than for neighboring Bandelier National Monument, which is mostly at lower elevations (1.4°F/century vs. 2.1–2.4°F/century, respectively, from 1895 to 2018; Carlson and Gross 2019).

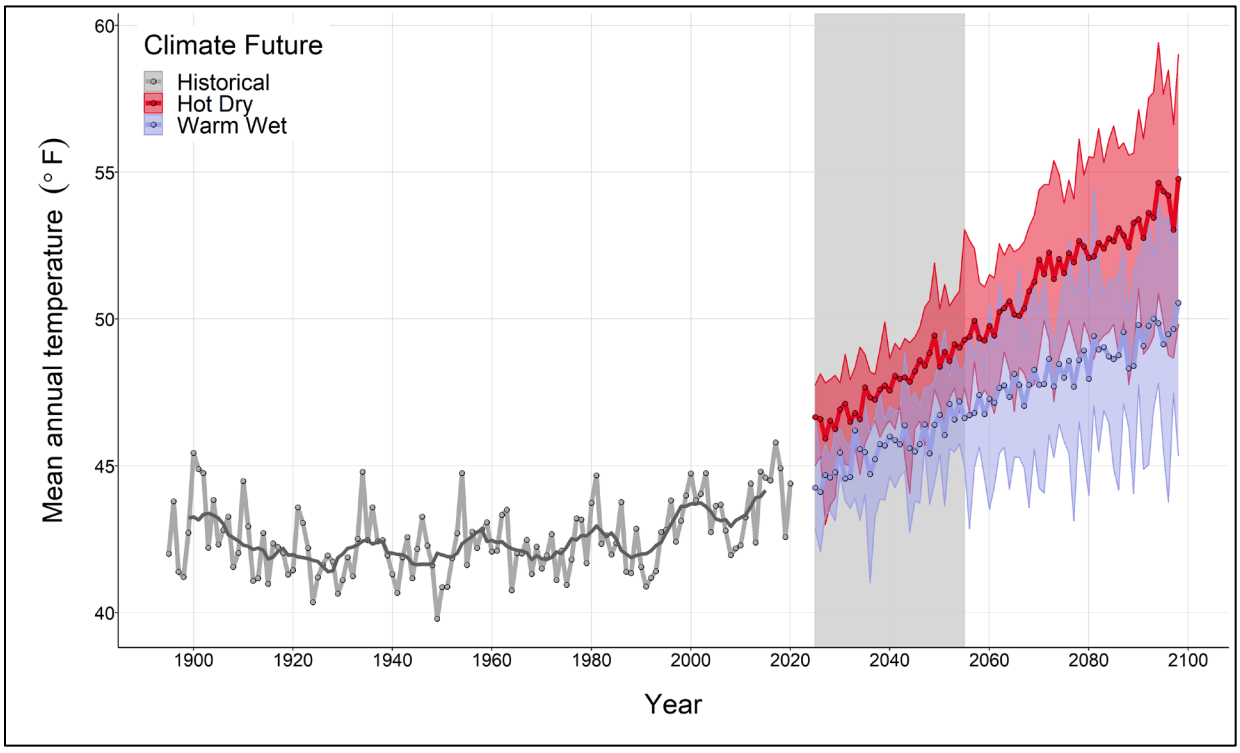


Figure 2.5-1. Historical climate observations (gray lines; PRISM records from 1895 to 2020; Daly et al. 2008) and future projections (red and blue lines; MACA-downscaled Global Climate Model projections from 2025–2099) for VALL's annual mean temperature. Figure Credit: NPS Climate Change Response Program.

The NPS Climate Change Response Program (CCRP) used a simple water balance model to evaluate the consequences of simultaneous changes in temperature and precipitation on soil moisture and water available for plant growth. Climatic water deficit can be interpreted as the additional amount of water that plants would use if it were available. The red and blue lines in Figures 2.5-1 and 2.5-2 represent the means of global circulation models (GCMs) grouped into Warm Wet and Hot Dry climate futures; red and blue shaded areas represent the minimum-maximum range of each climate future. The gray shaded area represents the future from 2025 to 2055 (referred to as ca. 2040) used to characterize changes from the historical baseline.

There have been no trends in annual precipitation during the period of analysis (Gonzalez et al. 2018a; Carlson and Gross 2019), however the proportion of precipitation received as snow has declined (Figure 2.5-2). At the lower elevation Jemez Springs station, annual snowfall has declined 2.0 cm (0.8 in)/year since 1980, including sharp declines or no snowfall in recent years (National Centers for Environmental Information 2019 as cited in Carlson and Gross (2019)). At the Quemazon SNOTEL station at 2,896 m (9,500 ft) on the eastern preserve boundary, snow water equivalent has declined strongly (-0.51 cm [-0.2 in]/year) since 1981 (Natural Resource Conservation Service 2019 as cited in Carlson and Gross (2019)). Snow depth or snowpack data are also collected at two higher elevation climate stations in the preserve (Redondo WRCC (3,231 m [10,601 ft]) and Garita Peak SNOTEL (3,206 m [10,157 ft]), but trends could not be evaluated due to the short data record (<7 years data in winter months).

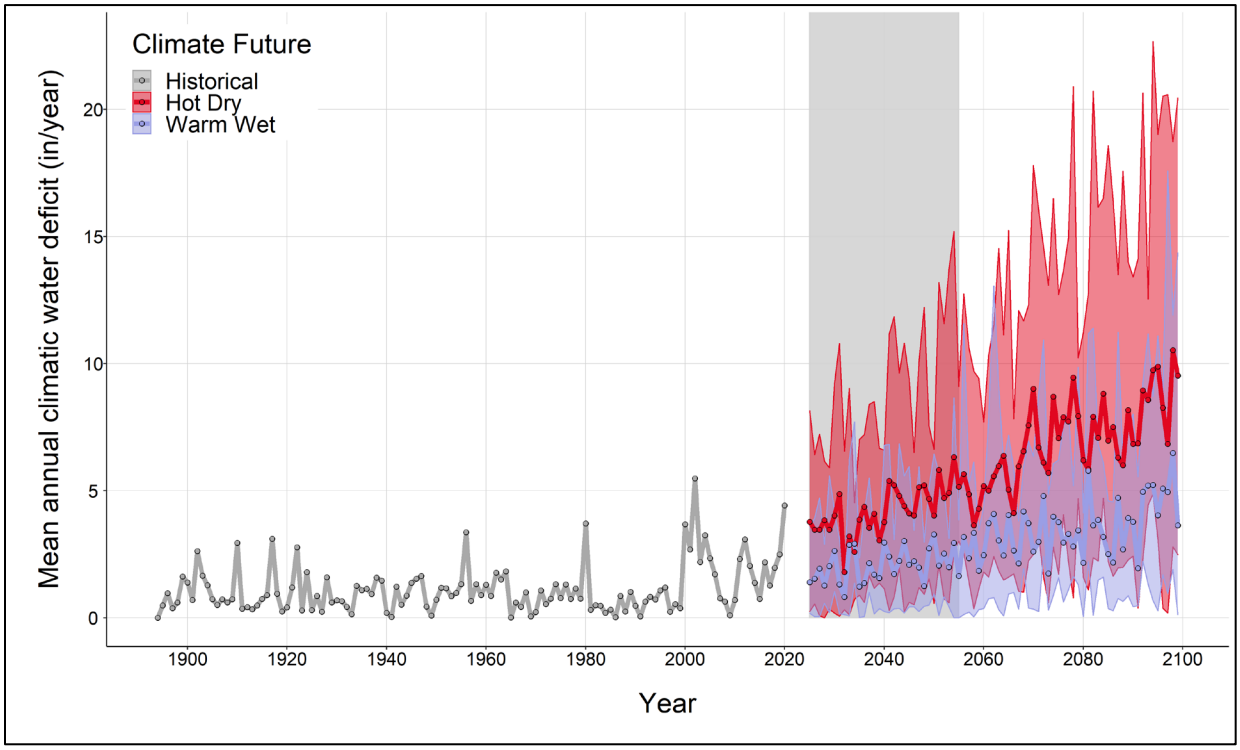


Figure 2.5-2. Historical climate observations (gray lines; PRISM records from 1895 to 2020; Daly et al. 2008) and future projections (red and blue lines; MACA-downscaled Global Climate Model projections from 2025 to 2099) for VALL's mean annual climatic water deficit. Figure Credit: NPS Climate Change Response Program.

Higher temperatures have increased evaporation, and without a comparable increase in precipitation this leaves less water in the ground for plants, groundwater recharge, and surface flows (Bradford et al. 2020). Annual water deficits at VALL shifted toward higher (drier) values around the year 2000 and have remained mostly above the historical average (Figure 2.5-2; Carlson and Gross 2019). Drought has been persistent in northern New Mexico for most of the 21st century, and most recently, the Four Corners region was affected by an extreme drought in 2018 (National Drought Mitigation Center U.S. Drought Monitor 2018 as cited in Carlson and Gross (2019)). Droughts and water

deficits frequently act as stress multipliers, exacerbating disturbances such as fires and facilitating invasion by non-native plants. In the Southwest, the number of wildfires per decade has nearly tripled, and the area burned has more than doubled since the 1970s (Westerling 2016). At VALL, large areas of the preserve have burned since 2011 in the Las Conchas and Thompson Ridge fires. Thus far, they have had a positive impact, stimulating the growth of grasses and removing some invasive trees in montane grasslands (Jacobs et al. 2015; Suazo et al. 2018).



Bark beetle damage to History Grove, which is a ponderosa pine and Douglas-fir old-growth forest in VALL. Image Credit: NPS.

Future Projections

The NPS CCRP evaluated historical climate conditions using PRISM data (Daly et al. 2008) from a montane grassland site in the Valle Grande area (elevation 2,660 m/8,727 ft) and future climate projections for VALL from global climate models (Abatzoglou and Brown 2012; Carlson and Gross 2019). Simulations included low (representative concentration pathway [RCP] 4.5) and high (RCP 8.5) emissions scenarios using an ensemble of MACA-downscaled GCMs (Abatzoglou and Brown 2012). Given the potential importance of severe drought in shaping the future climate of the Southwest, CCRP mainly considered the range of projected changes falling into Warm Wet and Hot Dry climate futures.

All climate models projected warming temperatures of >2.7 °F in all seasons by around 2040 (a 2025–2055 analysis period) relative to the 1950–2005 baseline (Figure 2.5-1). The greatest magnitude of warming was projected for the Hot Dry future, with summer maximum temperature potentially increasing by >7° F. Both futures predict an increase in extreme hot days and a decline in below-freezing days by more than three weeks per year (Table 2.5-1). Projections for precipitation

changes were more variable. The Warm Wet future projects increases in summer, fall, and winter precipitation, while the Hot Dry future projects decreases for spring and summer precipitation.

Table 2.5-1. Historical values of climate variables and projected changes from the historical baseline (1950–2005) to 2040 for Warm Wet and Hot Dry climate futures (NPS CCRP). Note: Historical values are means of GCM ensemble simulations for 1950–2005. Data are from Carlson and Gross (2019).

Climate Variable	Season	Historical	Warm Wet	Hot Dry
Seasonal maximum temperature (° F)	Winter	37	2.9	6.6
	Spring	53	3.6	7.0
	Summer	72	3.4	7.3
	Fall	55	3.8	7.2
Seasonal minimum temperature (°F)	Winter	13	3.4	5.6
	Spring	27	3.0	4.9
	Summer	44	2.8	6.4
	Fall	29	3.2	6.2
Seasonal precipitation (in.)	Winter	6.9	0.32	-0.05
	Spring	5.4	0.10	-0.58
	Summer	8.0	0.69	-0.80
	Fall	6.2	0.36	-0.07
Hot Days Per Year (>80 °F)	–	4	19.1	48.5
Cold Days Per Year (<32 °F)	–	209	-22.8	-40.7

The Fourth National Climate Assessment predicts that precipitation throughout the Southwest region is more likely to occur during higher-intensity one- or two-day events by the end of the 21st century (USGCRP 2017). These extreme events typically increase runoff, erosion, flooding, and other disturbances that can threaten preserve resources (USGCRP 2017). With increased runoff, a smaller portion of rainfall soaks into the ground and less water is available to plants. North American monsoon projections suggest that the overall amount of rainfall will remain similar to historic amounts, but the onset of the monsoon may be delayed by the end of the 21st century (Cook and Seager 2013). This means that precipitation may decline substantially in June and July while increasing in frequency and amount in September and October.

There is high confidence that a smaller proportion of precipitation will fall as snow in the future. Currently, about 25–35% of the snow water equivalent in VALL's snowpack goes back to the atmosphere as sublimation (Hedstrom and Pomeroy 1998; Hood et al. 1999; Essery et al. 2003; Elliot et al. 2010; Molotch et al. 2007). If more winter precipitation falls as rain, that sublimation loss will be reduced, and water will directly enter the soil for recharge and infiltration. But potential gains in soil water recharge may not be enough to balance projected evaporative losses (Bradford et al. 2020).

By 2050, snowfall in the Jemez Mountains is predicted to become rare in the shoulder months of November and March–April, and more precipitation will fall as rain at lower elevations in

December–February (Klos et al. 2014). In addition, climate projections for the western United States predict that up to 60% of annual snowpack may be lost by 2050 (Fyfe et al. 2017).

Warming temperatures will continue to increase atmospheric evaporative demand and that will increase landscape aridity even if precipitation remains constant or slightly increases (Bradford et al. 2020). Only under the most extreme wet projections is there a chance for annual water deficits to remain comparable to historical values (Carlson and Gross 2019). Higher climatic water deficits contribute to drier fuels and increased chance of fire ignition, increased drought stress on plants, reduced soil moisture, and reduced surface runoff (Westerling 2016; Thoma et al. 2020).

Multiple studies found that greenhouse gas emissions and the resulting warming will lead to increased frequency of >10-year drought events, or "megadroughts" (Cook et al. 2015; Gonzalez 2018b). These droughts are similar in severity to the worst droughts of the 20th century but are much longer in duration (Ault et al. 2016). A Southwest megadrought has a 70% or higher chance of occurring by the end of the 21st century according to climate projections using a high-emissions scenario, even with moderate increases in precipitation (Ault et al. 2016).

Lower snowpacks and earlier snowmelts will likely affect hydrology, shifting the timing and amount of spring runoff towards earlier peak runoff and less runoff overall (Gonzalez et al. 2018b). Hydrologic models for the Rio Grande basin predict declines in spring snow water equivalent of −20 to −60% by the 2050s, compared to 1990 values (Bureau of Reclamation 2016). The predicted changes in monsoonal and other seasonal precipitation varies between climate futures and makes it difficult to predict changes in high discharge events (Carlson and Gross 2019). Interannual variability of precipitation is likely to increase, leading to abundant water in some years followed by long periods of drought (USGCRP 2017).

2.6. Ranching & Livestock Management (Grazing)

The historic overgrazing of cattle and sheep within present-day VALL has contributed to the loss of riparian habitat and degraded streams and wetlands, altering the wetland plant species composition and distribution in palustrine wetlands. Cattle always congregate at water sources in the preserve and use wetland meadows intensively before moving upslope to feed on non-wetland grasses (particularly in the spring). The consequent trampling of vegetation and selective herbivory has resulted in channel degradation of the preserve's wetlands.

Muldavin and Tonne (2003) noted that bovine herbivory may contribute to the spread of non-native wetland grasses to a point where unique, non-natural assemblages of plants form, differing from the reference assemblages that occur in the same hydrology and soil chemistry environments. Wetland grazers, for example, may favor Baltic rush (*Juncus arcticus var. balticus*) over tufted hairgrass (*Deschampsia cespitosa*), and with overuse, wet meadows can shift to non-native Kentucky bluegrass (*Poa pratensis*) and a mixture of non-native and/or weedy forbs.



Typical cattle tank in line with a second-order riverine wetland channel at VALL; this is one of 182 cattle tanks on the preserve. Image Credit: NPS/Kevin Noon.

An additional stressor to the preserve's wetlands is the development of an extensive network of roads, resulting in hydrologic disruptions including at least six road crossings identified during a degraded wetland inventory desktop analysis that is summarized in Chapter 4. Another impact to wetlands is the creation of cattle tanks, which are ponds and earthen dams in line with intermittent drainage channels. There are 182 of these cattle tanks on the preserve, which interrupt spring runoff and water flow during summer rains from reaching further down the system, thus changing the hydrology of downstream channel reaches and floodplains. The cattle tank dams also slow the flow of energy, which allows suspended solids to drop out of the water column, disrupting the natural bedload and nutrient transport cycles. Once the tanks overflow during storm events, the waters erode

the downstream banks and increase the transport of suspended solids affecting important wildlife habitat.

And finally, the stressor of a declining water supply to wetlands via streamflow is attributed to a decline in precipitation. Miller et al. (2021) project streamflow in the southwestern U.S. to decrease by as much as 36–80% by the end of this century. It's expected that climate change will produce heavier or more intense downpours (that have, and will, replace the historical occurrence of many storm events of much lower precipitation concentrations). These heavier downpours will cause short, but concentrated, precipitation events, increasing the amount of water able to move over greater distances. This change in hydraulics will increase head cutting and incising in drainage ways (primarily through the common cobbly, sandy loams on 5 to 65 percent slopes in the preserve).



Angler fishing in VALL. Image Credit: ©Roger Blake.

Chapter 3. Focal Resource Evaluations

Chapter 3 reports on the conditions or states of VALL's selected focal natural resources. We evaluated these resources, either as a condition assessment or gap analysis, depending on data availability (Figure 3-1).

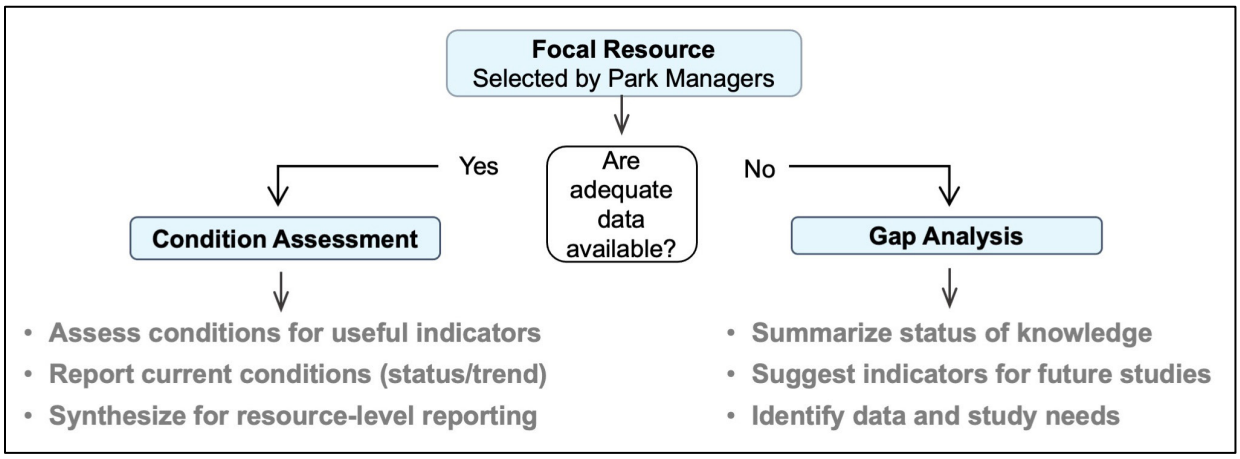


Figure 3-1. Two levels of evaluations are reported in NRCA studies depending on data availability: condition assessment and gap analysis.

For focal resources that lack adequate data for credible evaluations of their current conditions, we develop a gap analysis. A literature review, combined with expert input, produces a management-useful summary of the focal resource: its ecological importance, the general status of knowledge regarding factors influencing conditions, and useful data, indicators, and studies to consider in the future for improving managers' understanding of the resource.

For focal resources that have adequate data to assess current conditions for one or more indicators of condition, we develop a condition assessment. For each indicator, data for one or more measures are evaluated either qualitatively and/or quantitatively and combined to report a condition rating at the indicator level. Rating statements include the combined measures' qualitative characteristics, and, when available, quantitative values, for a range of good to poor conditions for each indicator (see Figure 3-2 for rating classes and colors). Sometimes, the indicator of condition is unknown and shown in gray. The rating statements need to include logical and defensible criteria for assigning a condition level. We do not report a condition rating for the focal resource itself because of the complexity of characterizing condition at that level adequately.

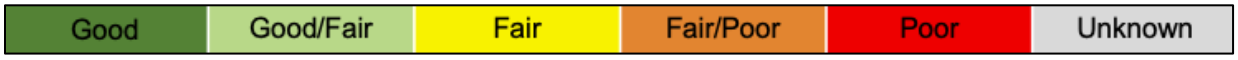


Figure 3-2. Indicators of condition rating classes and colors.

Each condition rating is assigned a confidence level, which is reported as high, medium, or low, depending on factors such as repeatability, age of data, and whether data were collected or modeled. If available, a condition rating trend is reported as improving, stable, deteriorating, or unknown.



A winter view into the Valles Caldera from Pajarito Mountain. Image Credit: ©Luke Mountz.

Natural resource condition assessments were completed for four focal resources: landscape permeability (connectivity), scenic views, songbirds, and wetlands. Gap analyses were completed for three focal resources: Jemez Mountains salamander, New Mexico meadow jumping mouse, and Redondo Peak biodiversity.

3.1. Landscape Permeability (Condition Assessment)

by David Theobald

3.1.1. Background & Importance

Ecological systems operate within landscapes and are typically understood in terms of composition, structure, and function (Noss 1990). A landscape with high ecological integrity supports and maintains a community of organisms and processes that are comparable to natural habitats within a region (Parrish et al. 2003). Central to landscapes with high ecological integrity is connectivity, which is commonly defined as the degree to which a landscape facilitates movement of species, populations, and genes among resource patches (Taylor et al. 1993). Managing for connectivity is the most common strategy recommended for ecological adaptation to climate change (Heller and Zaveleta 2009; Keeley et al. 2018).

This condition assessment of landscape permeability intends to 1) inform potential landscape planning and management for climate-wise adaptation by identifying protection, mitigation, and/or restoration action areas that maintain or improve habitat connectivity patterns and corridors, and 2) identify potential areas of opportunity for collaborating with adjacent landowners/managers. The landscape permeability results can be used to evaluate the adaptive capacity of species to climate change, especially with respect to movement as a climate adaptation response, which Thurman et al. (2020) classify as an attribute of adaptive capacity within the framework of climate variability analysis.



Fall colors on Rabbit Mountain, with a view across Valle Grande and Redondo Peak. Redondito is in the background. Cerro La Jara dome is in the center, with South Mountain on the left. Image Credit: NPS.

3.1.2. Study Framework

The conceptual model used to evaluate landscape permeability, in and surrounding VALL, builds on the triad of composition, structure, and function to understand ecosystem characteristics (Noss 1990). Modeling landscape permeability quantifies aspects of landscape structure (e.g., ecosystem patches) to inform an understanding of function (e.g., avoiding built-up areas or disconnected habitats). This is valuable in situations and landscape contexts where the distribution of organisms and the ecological and evolutionary processes that shape those distributions are heterogenous, as well as when having empirical data for specific species are limited (Spencer et al. 2010; Theobald et al. 2012).

Landscape permeability was calculated for two measures: 1) each of the five ecosystems ($p(e_k)$) (i.e., upper montane, lower montane, shrubland, grassland, and valley bottom/riparian), including those portions outside of the preserve, and 2) landscape permeability ($p(L)$), which is the average of permeability for the combined ecosystems (Table 3.1.2-1). The values for both measures ranged from 0.0 (not permeable, disconnected) to 1.0 (completely permeable, connected, natural) and are based on the probability of reaching a specific ecosystem (e.g., upper montane) or all ecosystems (i.e., landscape) within assumed dispersal distances. The condition rating statements reflect the degree to which landscape permeability has declined from a natural state and rely on percolation thresholds that are based on the average permeability values (natural/unnatural) at 10 km (6.2 mi) and 30 km (18.6 mi) distances.

Table 3.1.2-1. Study details for landscape permeability.

Indicator	Measure	Reference Criteria for Measure
Landscape Permeability (connectivity)	Ecosystem permeability, $p(e_k)$	Measures the permeability of an area of interest (e.g., park) as the probability of reaching a specific ecosystem (e_k) within the assumed dispersal distance. Results reflecting current land uses are compared to reference criteria that assume a "natural" landscape free of human modifications. Permeability values can range from 0.0 (unconnected) to 1.0 (connected) and from <0.4 (unconnected) to >0.6 (connected) for the percolation thresholds.
	Landscape permeability, $p(L)$ (study area)	Measures the permeability of an area of interest (e.g., park) as the probability of reaching all ecosystems (e_L) within the assumed dispersal distance. Results reflecting current land uses are compared to reference criteria that assume a "natural" landscape free of human modifications. Permeability values can range from 0.0 (unconnected) to 1.0 (connected) and from <0.4 (unconnected) to >0.6 (connected) for the percolation thresholds.

Percolation theory is mathematical and describes the formation of long-range connectivity in random systems. Below a certain threshold, connection does not exist. For example, the percolation thresholds in the five condition rating statements for this assessment range between <0.4 to >0.6, with the higher value reflecting that connection exists.

3.1.3. Data & Methods

Because ecological processes move through, into, and around VALL (about 360 km^2 (139 mi^2)), the entire study area encompassed about 10,000 km^2 (3,861 mi^2) in northern New Mexico and is roughly 50 km (31 mi) wide (Figures 3.1.3-1a and -1b show the study area extent). One hundred four ecological systems (USGS 2016; LANDFIRE v1.4), identified within the study area, were grouped by lifeform class into five ecosystems for analysis (refer to Appendix B, Table B-1 for a crosswalk of groupings). Permeability was evaluated to determine connectivity within the upper montane, lower montane, shrubland, grassland, and valley bottom/riparian ecosystems and throughout the entire landscape (i.e., combined ecosystems). Figure 3.1.3-1c shows the five ecosystems in the study area. Table 3.1.3-1 presents the proportion of ecosystems within the entire study area, VALL, and outside of VALL (i.e., entire study area minus VALL area) and the ecosystem elevations, listed primarily from high to low. In general, VALL is at a higher elevation relative to the surrounding study area.

The proportion of ecosystems shown in Table 3.1.3-1 reflects that the upper montane accounts for 1% of the entire study area, 3% of the area in VALL, and 1% of the area outside the preserve but still within the study area. Because the area in VALL accounts for only 3.6% of the entire study area, the proportion of the ecosystems in the entire study area and outside of the preserve is essentially the same. Note that the lower montane accounts for a high proportion of the preserve area (76%) and includes a variety of mixed conifer and woodland forests (Table B-1), and the shrubland ecosystem comprises 68% of the study area/area outside of the preserve.

To evaluate landscape permeability, locations that have high permeability values (e.g., patches) and a low degree of human modification for the areas that ought to be connected were identified. We used a "gradient-based" approach (McGarigal et al. 2009)—a general conceptual model of landscape structure that is based on continuous rather than discrete spatial heterogeneity—to identify numerous randomly selected locations from within each ecosystem. This approach better accounts for the natural variability and uncertainty in landscape analyses and is a more robust approach than arbitrarily creating "patches" of homogenous habitat.

Because wildlife movements through the landscape are assumed to be restricted by certain land uses and human activities, the degree of human modification, which primarily included built-up areas, roads, and croplands, and accessibility (using estimates of travel time factors) were mapped (Theobald 2013; Theobald et al. 2020, Figure 3.1.3-1d, with yellow and white colors depicting greater modification). The footprint and intensity of human modifications were quantified and combined into a resistance surface map of overall modification, *H,* that ranged from 0 to 1 (see Appendix B, Table B-2 for a full list of stressors, adapted from Table 1 in Theobald et al. (2020)). Note how the brighter areas in Figure 3.1.3-1d, especially from the northeast to the southeast of VALL, correspond to the surrounding cities and highways shown in the locator map (Figure 3.1.3-1a).

Table 3.1.3-1. Summary of the five ecosystem types by proportion of area and elevation for the entire study area, area within VALL, and area outside of VALL.

Ecosystem	Proportion			Mean elevation in meters (std. deviation)		
	Study area (~10,000km^2)	VALL (~360km^2)	Outside VALL (~9,640 km^2)	Study area	VALL	Outside VALL
Upper montane	0.01	0.03	0.01	3,115 (106)	3,234 (104)	3,106 (100)
Lower montane	0.16	0.76	0.16	2,717 (178)	2,790 (139)	2,703 (182)
Shrubland	0.68	0.12	0.68	2,147 (239)	2,603 (60)	2,144 (237)
Grassland	0.08	0.01	0.08	1,823 (148)	2,700 (184)	1,819 (136)
Valley bottom/riparian	0.07	0.07	0.07	2,101 (303)	2,621 (64)	2,083 (292)

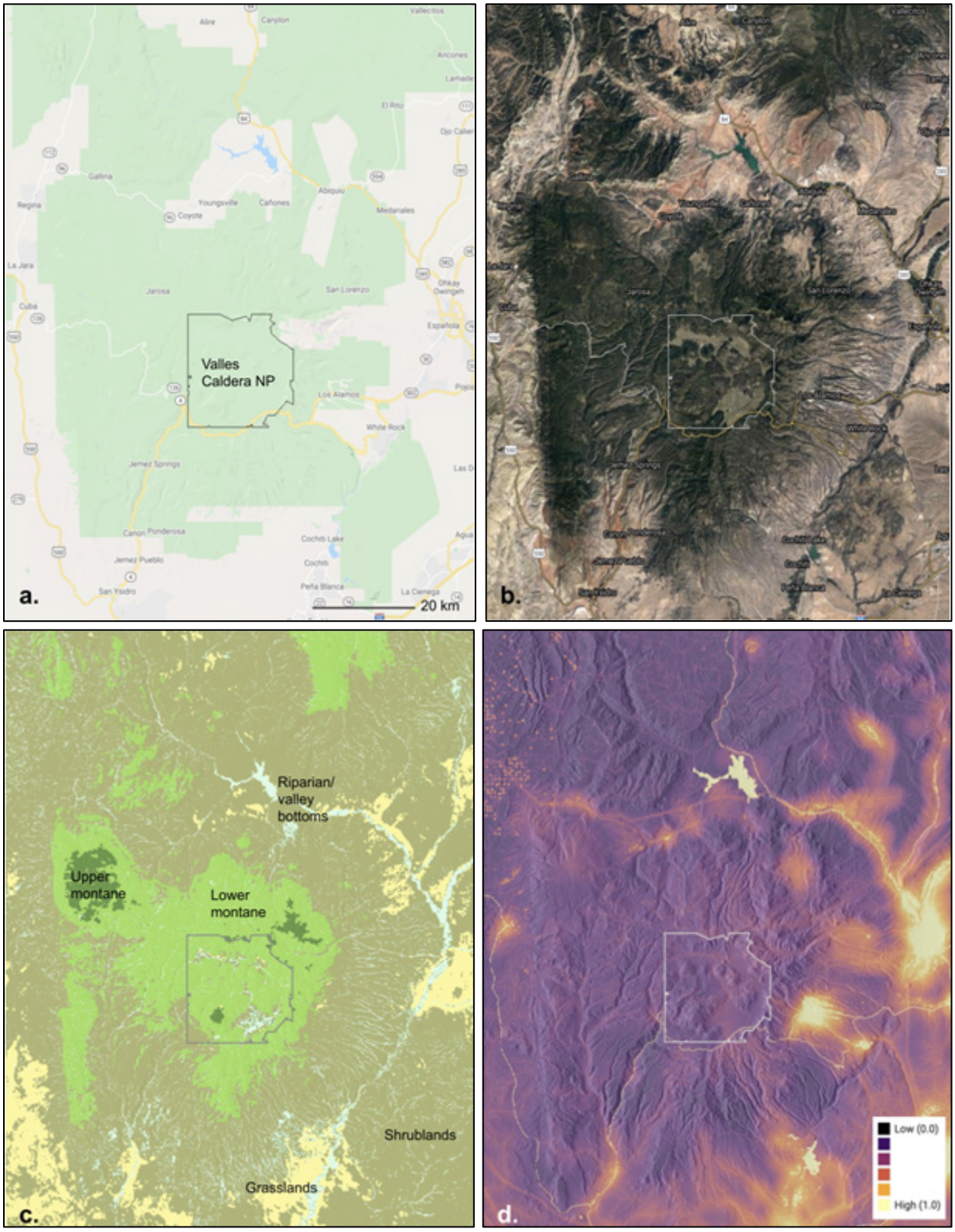


Figure 3.1.3-1. The landscape permeability study area around and including VALL shown (in the center of the study area): a. locator map; b. aerial imagery; c. five ecosystems of interest; and d. degree of human modification (low modification is darker and high modification is lighter).

To measure movement through the landscape, the least-cost distance was calculated from locations randomly found within each of the five ecosystems across the resistance surface. The least cost distance is the path between two locations that "costs the least to those travelling along it" to determine the most cost-effective route between a source and destination. The least-cost distance was then converted to a "dispersal" probability, *p*, value by calculating the mean and standard deviation for each pixel, assuming up to 10, 30, or 50 km (6.2, 18.6, 31.1 mi, respectively) movements. This approach is helpful because results are based on probabilities that are easily interpreted, robust, and provide a rigorous quantification of connectivity (Urban and Keitt 2001; Saura and Pascual-Hortal 2007; Theobald et al. 2012; Cushman et al. 2014; Saura et al. 2017).

Analyses were conducted to inform management activities, especially highlighting areas that may provide additional climate-wise adaptation benefits, by identifying:

1. locations that have both high in situ and permeability values; landscape permeability was calculated relative to the permeability values of the patches of existing ecosystem types within the preserve. This was accomplished by normalizing values (i.e., calculating a z-score) for the patches of each ecosystem type found within the preserve.
2. locations that would benefit from potential management activities to conserve or restore locations, providing benefits for potential future distribution of ecological systems beyond the distribution of ecosystem patches. This was accomplished by normalizing permeability values throughout the study area relative to the permeability found within the preserve and highlighting locations with high relative permeability z-scores.
3. locations throughout the study area, representing potential strategic partnering opportunities; permeability values outside of the preserve (essentially the perspective of neighboring land managers) were normalized, then locations were identified that had high permeability z-scores in both the from-preserve and from-outside preserve.

A series of maps are included to show the analyses results, reflecting the variability and patterns of the landscape permeability from the locations that are connected: the connectivity from specific ecosystem types, or connectivity through the "matrix" of land uses between areas of ecosystem interest across lands that are represented by other ecosystem classes. All input datasets were represented at a 30-m (98-ft) resolution, and permeability outputs were modeled at a 90-m (295-ft) resolution. For convenience, the mapped ecosystem permeability is denoted simply as *p(e)* and the landscape permeability as *p(L)*.

3.1.4. Results & Discussion

The overall landscape permeability *p(L),* which was calculated as the average permeability for the five ecosystems (Figure 3.1.4-1), shows the preserve centered within a highly permeable landscape (depicted by white in the figure). The landscape permeability gradually decreases away from VALL's boundary, with sharper declines in the eastern portion of the entire study area (depicted by blue and black in the figure). This coincides with the current areas of development, including the cities and highways surrounding VALL, and reflects the fact that permeability has been substantially reduced from "natural" conditions to 0.562 at the 30 km (18.6 mi) assumed dispersal distance (Table 3.1.4-1), which is between one-third to one-half less than a good reference value of 1.0.

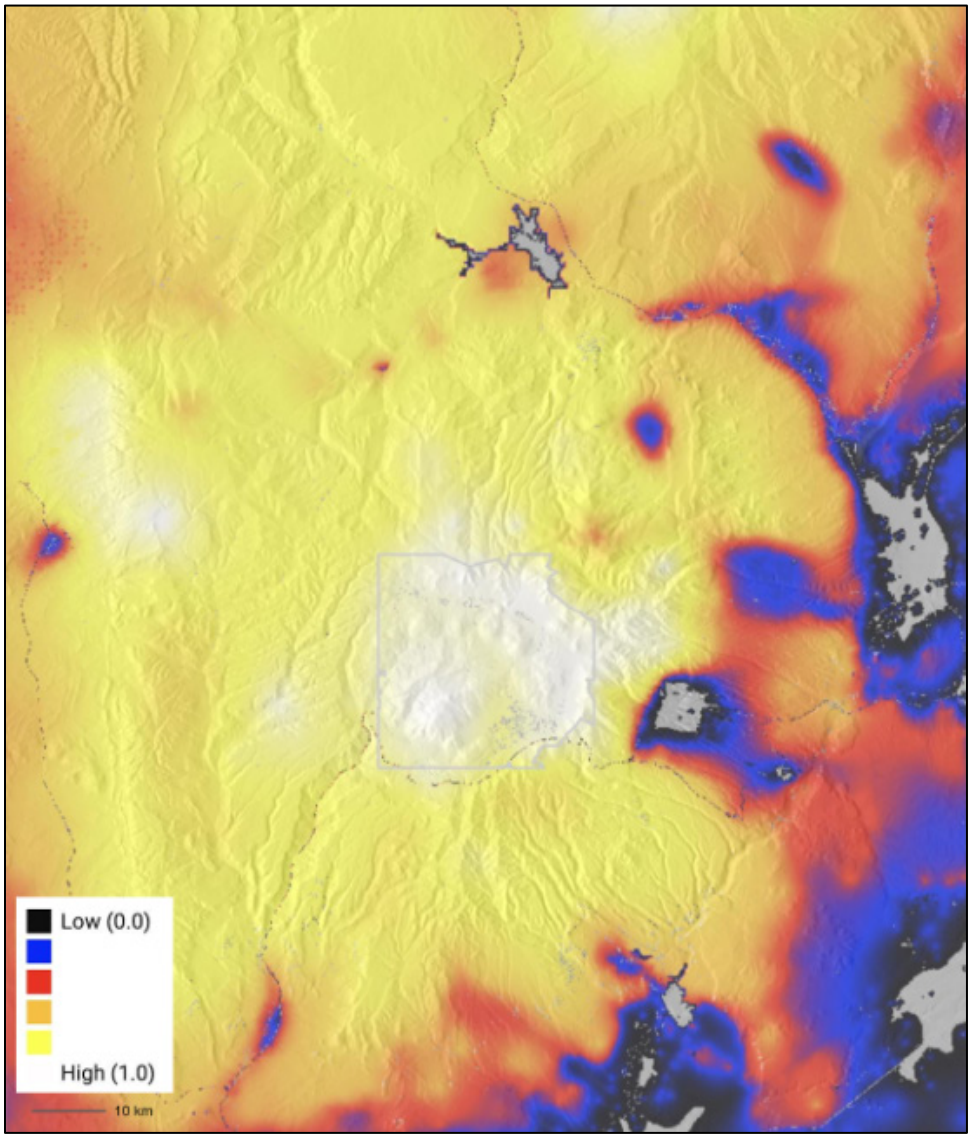


Figure 3.1.4-1. Landscape permeability, *p(L)*, assuming a 30 km (18.6 mi) movement distance for the study area around VALL. Generally, the landscape has higher permeability in the center (where VALL boundary outline is shown) and decreases rapidly towards the east and south. Landscape permeability was calculated as the average of permeability for five ecosystems (upper montane, lower montane, shrubland, grassland, and riparian/valley bottom).

Table 3.1.4-1. The results for the probability of ecosystem, *p(e),* and landscape, *p(L),* permeabilities for the study area around VALL. The "ecosystem" statistics are restricted to the locations within a given ecosystem, while the "matrix" values are calculated for locations outside an ecosystem, both within the full landscape including and surrounding the preserve. Results for the 10, 30, and 50 km assumptions of characteristic movement are provided to help understand the sensitivity of these assumptions. Note: Standard deviations are shown in parenthesis.

Ecosystem	Ecosystem (10 km)	Matrix (10 km)	Ecosystem (30 km)	Matrix (30 km)	Ecosystem (50 km)	Matrix (50 km)
Upper montane *p(e)*	0.547 (0.24)	0.037 (0.13)	0.990 (0.18)	0.190 (0.32)	0.999 (0.01)	0.340 (0.38)
Lower montane *p(e)*	0.402 (0.31)	0.227 (0.34)	0.981 (0.04)	0.558 (0.43)	0.999 (0.01)	0.711 (0.41)
Shrubland *p(e)*	0.202 (0.25)	0.423 (0.35)	0.758 (0.32)	0.858 (0.28)	0.896 (0.25)	0.926 (0.22)
Grassland *p(e)*	0.300 (0.33)	0.181 (0.27)	0.720 (0.36)	0.661 (0.34)	0.849 (0.29)	0.897 (0.23)
Riparian/Valley bottom *p(e)*	0.619 (0.38)	0.557 (0.36)	0.825 (0.35)	0.893 (0.26)	0.864 (0.32)	0.946 (0.20)
Landscape (study area) *p(L)*	0.274	0.376	0.562	0.645	0.698	0.780

The patterns of ecosystem permeability p(e) are much more variable, nuanced, and specific to each of the five ecosystems than the results for the landscape permeability (refer to Figures B-1 and B-2). At the 30 km (18.6 mi) assumed dispersal distance, the p(e) is moderately low for the shrubland (0.758) and grassland (0.720) ecosystems and higher for the lower montane (0.981) and riparian/valley bottom (0.825). Ecosystem permeability is the highest for upper montane (0.990), particularly at Redondo Peak, along VALL's northeastern boundary that is shared with the Santa Clara Pueblo (Cerro Toledo), and to the northwest in the Santa Fe NF around the Nacimiento Mountains, which is in the northwest portion of the Jemez Mountains. The patterns of ecosystem permeability at the 50 km (31 mi) dispersal distance are similar to the results reported at the 30 km (18.6 mi) dispersal distance. In contrast, the patterns of ecosystem permeability at the 10 km (6.2 mi) dispersal distance are much more localized and reflect lower permeability for all five ecosystems and the overall landscape. The "ecosystem" statistics in Table 3.1.4-1 are restricted to the locations within an ecosystem, while the "matrix" values are calculated for locations outside an ecosystem, including and surrounding VALL.

The departure of ecosystem permeability from a natural condition, reflecting no human modification/land use, highlights some patterns of impacts (Figure 3.1.4-2 and Table 3.1.4-2). Assuming a 30 km (18.6 mi) dispersal distance, Figure 3.1.4-2 shows that departure is lowest for all five ecosystems in VALL compared to areas outside the preserve (as shown in white in the series of figures), although the grasslands and upper montane ecosystems are limited in the preserve, representing 1% and 3% of VALL's area, respectively (refer to Table 3.1.3-1 for study area proportions). Also, a low departure from a natural condition relative to human modifications is consistently located to the west of VALL, whereas areas of high human modifications (e.g., cities, highways), are situated primarily to the east of VALL. The measures with the most permeability impacts include the overall landscape permeability, the shrubland ecosystem, and the grassland

ecosystem, by comparing values in Tables 3.1.4-1 and -2 at an assumed dispersal distance of 30 km (18.6 mi).

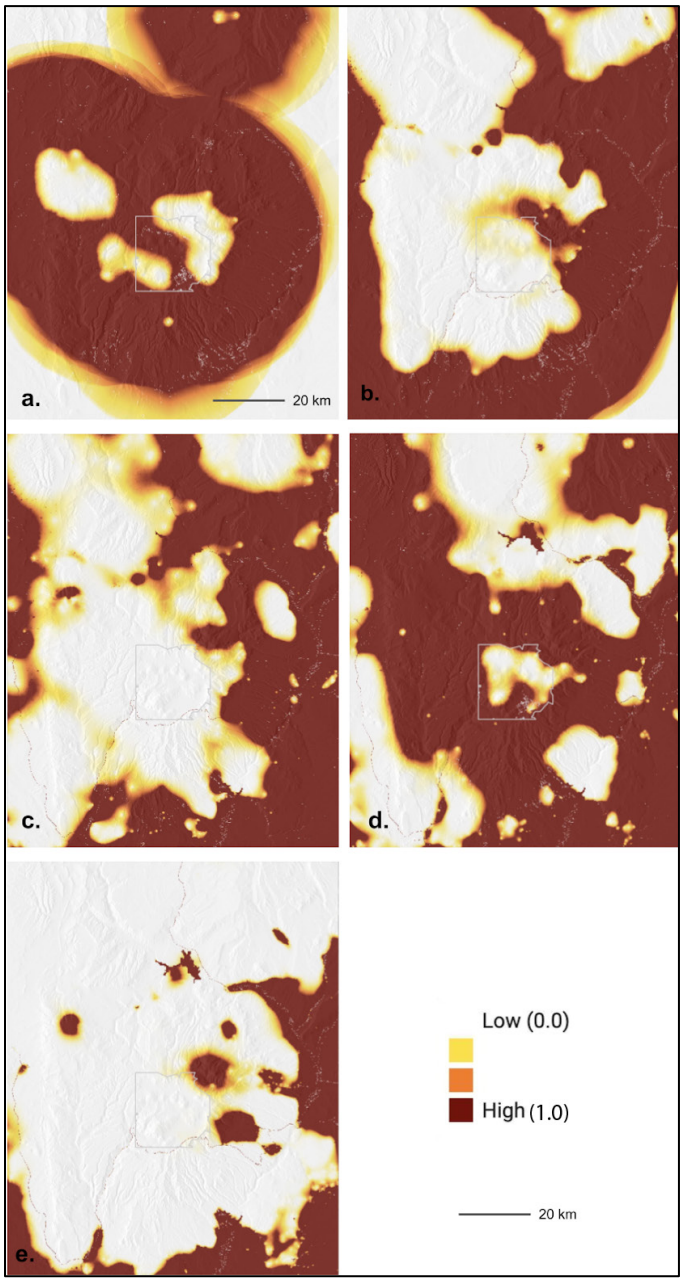


Figure 3.1.4-2. The departure of ecosystem permeability from the natural reference condition, assuming a 30 km (18.6 mi) movement distance for the study area centered around VALL: a. upper montane; b. lower montane; c. shrublands; d. grasslands; and e. riparian/valley bottom. Low departure is shown in white and higher is shown in red. Departure is calculated as natural minus current ecosystem permeability and can range from 0.0 to 1.0. For locations in or near a current ecosystem, low departure indicates no to minimal change from a natural state. Locations further than 30 km away from the upper and lower montane ecosystems (i.e., the edges/corners in a. and b.) indicate no departure simply because it is too far away from the current distribution of these ecosystems.

Table 3.1.4-2. Comparison of results to "natural" (no human land use) for the probability of ecosystem permeability, *p(e),* for the study area around VALL. The "ecosystem" statistics are restricted to the locations within a given ecosystem, while the "matrix" values are calculated for locations outside an ecosystem, both within the full landscape including and surrounding the preserve. Results for 10, 30, and 50 km assumptions of characteristic movement are provided to help understand the sensitivity of this assumption.

Ecosystem	Ecosystem (10 km)	Matrix (10 km)	Ecosystem (30 km)	Matrix (30 km)	Ecosystem (50 km)	Matrix (50 km)
Upper montane *p(e)*	0.934 (0.05)	0.103 (0.23)	0.999 (0.01)	0.441 (0.39)	0.999 (0.01)	0.793 (0.26)
Lower montane *p(e)*	0.824 (0.20)	0.412 (0.42)	0.999 (0.01)	0.874 (0.26)	0.999 (0.01)	0.985 (0.09)
Shrubland *p(e)*	0.605 (0.29)	0.863 (0.22)	0.995 (0.05)	0.988 (0.10)	0.998 (0.04)	0.988 (0.10)
Grassland *p(e)*	0.952 (0.09)	0.536 (0.38)	0.995 (0.07)	0.970 (0.11)	0.995 (0.07)	0.994 (0.07)
Riparian/Valley bottom *p(e)*	0.947 (0.17)	0.935 (0.16)	0.974 (0.15)	0.996 (0.06)	0.974 (0.15)	0.996 (0.06)
Landscape *p(L)*	0.523	0.561	0.833	0.862	0.907	0.884

To apply the landscape permeability results, locations were identified that would 1) best benefit from management activities to maximize potential future distribution of ecological systems beyond the distribution of ecosystem patches, and 2) inform the identification of places throughout the study area, and therefore potential strategic partnering opportunities (Figure 3.1.4-3 and Figures B-3, B-4, and B-5). The transparency of the colors shown in Figure 3.1.4-3 was determined by the permeability specific to: a. upper montane; b. lower montane; c. shrubland; d. grassland; and e. riparian/valley bottom. Higher ecosystem permeability for a given ecosystem is shown, draped on all *in situ* ecosystems, to highlight and illustrate potential types of management action locations shown in Figure 3.1.4-3f, numbers 1-7, which are described below.

Actions to maintain the upper montane ecosystem (Figures 3.1.4-3a & f-1) will also contribute to the potential adaptation of lower montane-associated species, albeit within a small and isolated patch atop Redondo Peak. The results also suggest that there is a relatively large patch of upper montane in the Nacimiento Mountains (Figures 3.1.4-3a & f-6), surrounded by a highly permeable lower montane landscape in the Santa Fe NF, west of VALL (Figures 3.1.4-3b & f-3 and B-6). This is an important area to focus partnership efforts to protect and maintain montane species movements, particularly those species/processes where the permeability of shrubland and grasslands is important (e.g., mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis*)). In addition, just outside VALL's southern boundary is a location of high shrubland permeability intersected by Highway 4 (Figures 3.1.4-3c & f-7), but permeability to the upper montane ecosystem is likely low (more localized patterns for the shrubland ecosystem are shown in Figure B-2c).

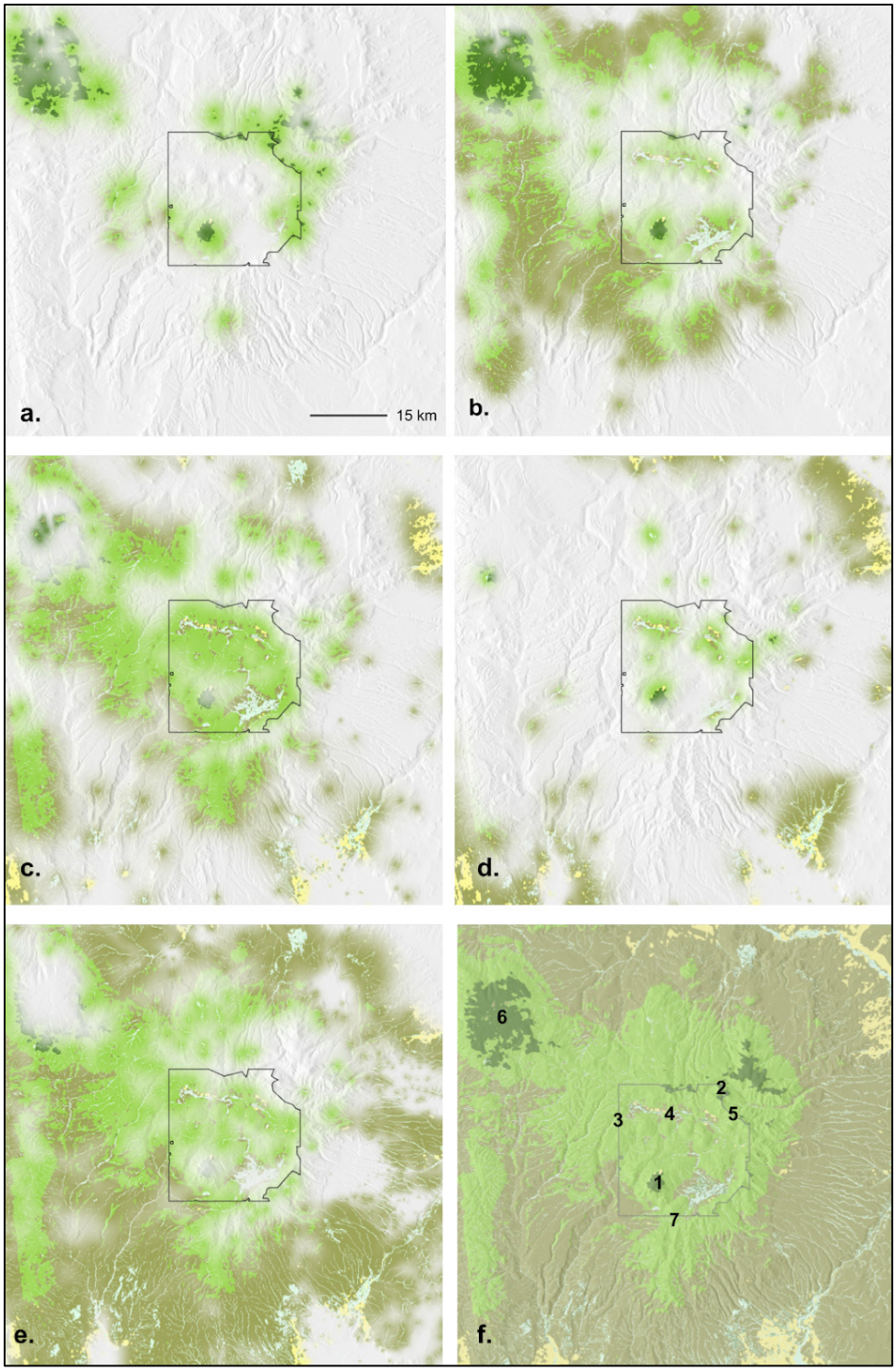


Figure 3.1.4-3. The permeability of each ecosystem: a. upper montane; b. lower montane; c. shrubland; d. grassland; e. riparian/valley bottom; and f. landscape. Lower ecosystem permeability is symbolized with higher transparency of the colors, and locations for potential management actions are depicted by numbers 1–7 on map f. Darker colors (green) represent higher permeability, while lighter colors (yellow/white) represent lower permeability.

The patterns of upper montane permeability support partnering efforts along the northeast boundary of the preserve in Cerro Toldeo (Figures 3.1.4-3a & f-2), although there is more limited permeability in that area for other ecosystems compared to the upper montane in the western portion of the study area. For example, the permeabilities shown in Figures 3.1.4-3b, c, d, e, & f-5 are relatively low, suggesting that there are low climate-change adaptation opportunities. However, targeted restoration activities may be appropriate here. High permeability, particularly for species associated with shrubland and riparian/valley bottom, is shown in Figures 3.1.4-3c, e, & f-4, and adds to other resource values present in this very important area of the preserve.

In conclusion, based on the condition rating criteria described in the Study Framework section and in the condition rating statements (Appendix C, Table C-1), permeability for the upper montane ecosystem was rated as good, followed by the lower montane and riparian/valley bottom ecosystems, which were rated as good/fair. The permeability conditions for the shrubland and grassland ecosystems and the overall landscape were rated as fair/poor (Table 3.1.4-3).

Table 3.1.4-3. Landscape permeability condition ratings summary.

Indicator	Condition Rating [1]	Trend	Condition Evaluation
Ecosystem Permeability (upper montane)	Good	Unknown	Permeability for current conditions decreased by <¼ of the natural state and is greater than the upper percolation threshold (0.6) on average at 10–30 km (6.2–18.4 mi). Confidence level is medium due to variability in age/condition of vegetation in the ecosystem.
Ecosystem Permeability (lower montane)	Good/Fair	Unknown	Permeability for current conditions decreased ¼–⅓ of the natural state and is greater than the upper percolation threshold (0.6) on average at 10–30 km (6.2–18.4 mi). Confidence level is medium due to variability in age/condition of vegetation in the ecosystem.
Ecosystem Permeability (shrublands)	Fair/Poor	Unknown	Permeability for current conditions decreased by ⅓ to ½ of the natural state and is between 0.4–0.6 percolation thresholds on average at 10–30 km (6.2–18.4 mi). Confidence level is low due to sparse data on understory conditions in the ecosystem.
Ecosystem Permeability (grasslands)	Fair/Poor	Unknown	Permeability for current conditions decreased by ⅓ to ½ of the natural state and is between 0.4–0.6 percolation thresholds on average at 10–30 km (6.2–18.4 mi). Confidence level is low due to sparse data on understory conditions in the ecosystem.
Ecosystem Permeability – (riparian/valley bottom)	Good/Fair	Unknown	Permeability for current conditions decreased ¼–⅓ of the natural state and is greater than the upper percolation threshold (0.6) on average at 10–30 km (6.2–18.4 mi). Confidence level is low due to restrictions on mapping narrow riparian/valley bottom areas.

[1] See Appendix C, Table C-1, for the 5-level condition rating statements for each indicator.

Table 3.1.4-3. Landscape permeability condition ratings summary.

Indicator	Condition Rating [1]	Trend	Condition Evaluation
Landscape Permeability	Fair/Poor	Unknown	Permeability for current conditions decreased by ⅓ to ½ of the natural state and is between 0.4–0.6 percolation thresholds on average at 10–30 km (6.2–18.4 mi). Confidence level is low due to limited mapping of localized human activities.

[1] See Appendix C, Table C-1, for the 5-level condition rating statements for each indicator.

The levels of confidence in the condition ratings would be higher if data about small, but important, human structures and activities were included in the analyses, particularly wildlife-proof fencing, under-/over-passes, and road-grade analyses. Also, more detailed information on vegetation composition and structure, in particular the type and timing of vegetation management (trimming, mowing, clearing, fuel treatments, etc.), wildlife management (e.g., hunting, trapping, etc.), and the extent of invasive species, particularly those that significantly alter ecological processes (e.g., cheatgrass (*Bromus tectorum*) and wildfire regimes).

A key parameter for the indicator of condition is the assumption of the dominant processes that are operating across the landscape to determine a reasonable scale to model permeability (e.g., dispersal distance). This caveat, associated with resolution, is germane to the riparian/valley bottom ecosystem, so caution is particularly warranted when interpreting those results. Also, the inclusion of spatially explicit estimates of climate change, such as climate velocity (the speed at which an organism would need to move to remain within a similar climate), would be potentially useful information. Pursuing multiple strategies in the face of much uncertainty, particularly with respect to downscaled climate models in mountainous regions, is necessary to identify and achieve management goals, especially at the landscape-scale.

3.2. Visual Resources (Condition Assessment)

3.2.1. Background & Importance

The conservation of scenery was established in the NPS Organic Act of 1919 ("…to conserve the scenery and wildlife therein…"), reaffirmed by the General Authorities Act, as amended, and addressed generally in the NPS (2006) Management Policies sections 1.4.6 and 4.0 (Johnson et al. 2008). Although no management policy currently exists exclusively for scenic or viewshed management and preservation, parks are still required to protect scenic quality as one of their most fundamental resources. According to Wondrak-Biel (2005), aesthetic conservation, interchangeably used with scenic preservation, has been practiced in the NPS since the early twentieth century. Aesthetic conservation strives to protect scenic beauty for NPS visitors to better experience the values of each park unit. The need for scenic preservation is as relevant today as ever, particularly with the pervasive development pressures that challenge NPS managers.

VALL offers opportunities for visitors to immerse themselves in wilderness, where experiences become more removed from anthropogenic sights and sounds, offering an opportunity to literally "visualize" their connection to nature. These views represent much more than just scenery; they represent a way to better understand the connection between self and nature. According to the preserve's foundation document "Valles Caldera's distinct topographic mosaic of expansive valley meadows, lush forested volcanic domes, meandering valley streams, and old growth ponderosa pine groves are in striking contrast to the arid New Mexico landscapes at lower elevations" (NPS 2018a). Wildlife watching, hiking, viewing dark night skies, winter skiing, and hunting and fishing opportunities provide visitors with a multitude of year-round activities by which to enjoy the scenic settings of the preserve (NPS 2018a).



Scenic vista with fall colors. Image Credit: NPS.

3.2.2. Study Framework

The NPS ARD's rapid assessment guidelines for evaluating visual resources in NRCAs (NPS 2018b) were used to determine the condition of the scenic views at seven locations in the preserve. The rapid assessment approach relies on the professional judgement of those evaluating the views to evaluate two measures: scenic quality and view importance (Table 3.2.2-1). Each measure is rated separately according to the descriptive statements provided in Appendix C, Table C-2. A matrix that combines these two measures is then used to rate the visual resource condition at each selected location (Appendix C, Table C-3).

Table 3.2.2-1. Study details for visual resources (NPS 2018b).

Indicator	Measure	Reference Criteria for Measure
Visual Resources	Scenic quality	Most views include landscapes in good condition with very few, or minor, features that detract from the desirable visual characteristics. Most views are also aesthetically pleasing and memorable because of bold forms and colors.
	View importance	Views are key to the purpose of the preserve and a primary reason that visitors come to VALL. Views are highly publicized and extensive effort goes into facilitating the visitor experience for scenery.

3.2.3. Data & Methods

VALL staff chose seven visual resource inventory points from which to assess the condition of visual resources (Figure 3.2.3-1). The locations were chosen based on fundamental resources and values (FRV) and other important resources and values (OIRV) as described in the preserve's foundation document (NPS 2018a). FRVs are "those features, systems, processes, experiences, stories, scenes, smells, or other attributes determined to warrant primary consideration during planning and management processes because they are essential to achieving the purpose of the preserve and maintaining its significance" (NPS 2018a). OIRVs are resources and values "not fundamental to the purpose of the park and may be unrelated to its significance but are important to consider in planning processes" (NPS 2018a). Staff took photos at each of the seven inventory points in either a 180° or 360° view using a Canon PowerShot SX60 HS digital camera on 9 April 2021. Staff then stitched the individual photos into panoramas using Adobe Photoshop software.

3.2.4. Results & Discussion

The view importance was rated as high at all seven locations (Table 3.2.4-1), which was why VALL staff chose those viewpoints for the initial condition assessment. Eventually, a full inventory of visual resources in the preserve will be conducted, particularly in the Valle Grande District, before any development occurs because of changes to zoning and public access during VALL's zoning and wilderness management plan development process. The scenic quality at the seven locations was rated as either moderate, moderate to high, or high (Table 3.2.4-1).

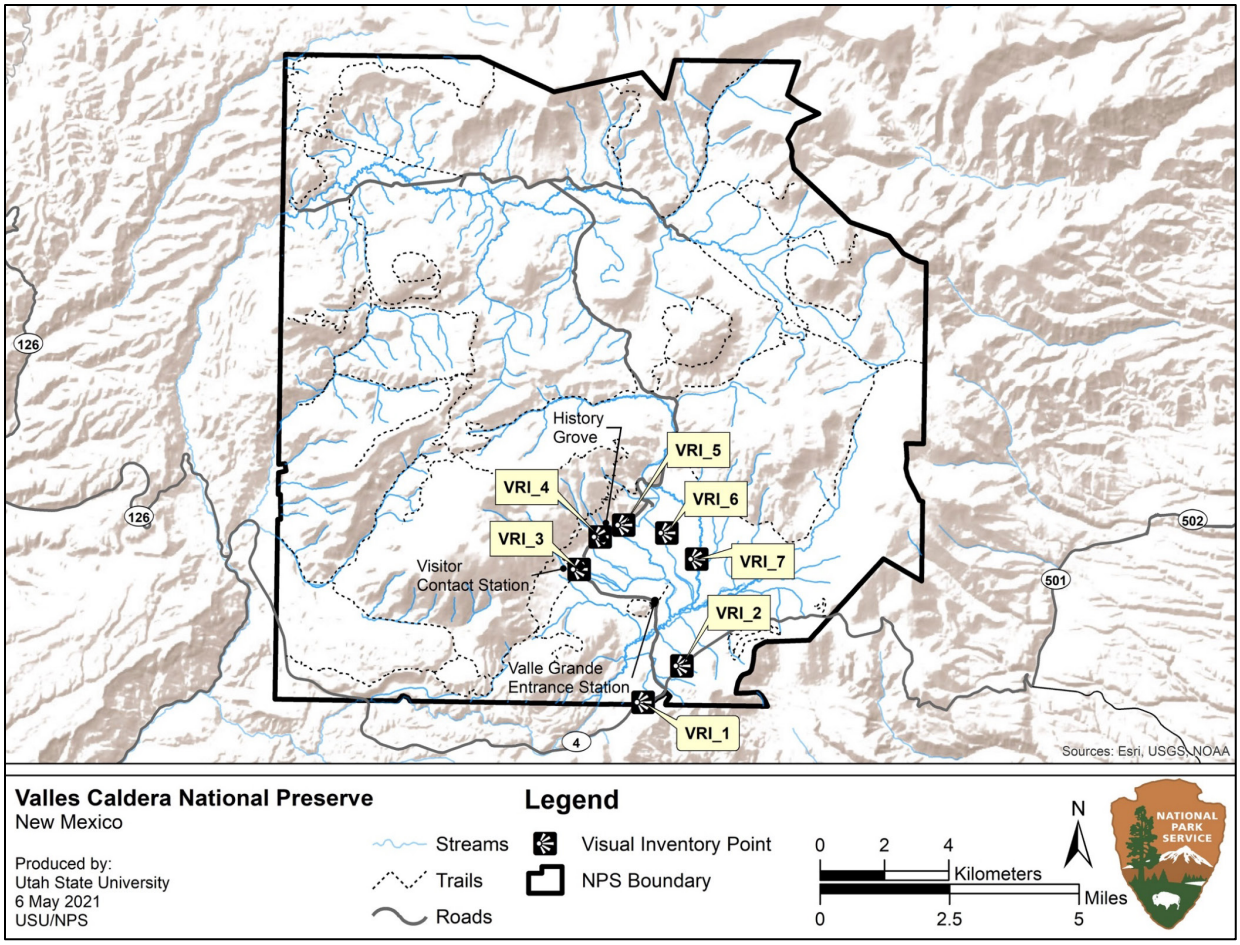


Figure 3.2.3-1. Locations of the seven visual resource inventory points.

Table 3.2.4-1. Results of the scenic quality and view importance evaluation.

Inventory Point (view)	Scenic Quality	View Importance	Overall Condition
VRI_1 (180°)	Moderate	High	Good
VRI_2 (180°)	Moderate to High	High	Very Good
VRI_3 (360°)	Moderate to High	High	Very Good
VRI_4 (360°)	Moderate	High	Good
VRI_5 (360°)	High	High	Very Good
VRI_6 (360°)	Moderate to High	High	Very Good
VRI_7 (360°)	High	High	Very Good

At VRI_1, fencing, several signs, posts, and roads present minor detractions from the scenic quality (Figure 3.2.4-1). In particular, the fencing creates a sense of being cut-off from the scenic view. VRI_2 was rated as moderate to high because the view contains minimal impacts from a barbed wire

fence and posts (Figure 3.2.4-1). In addition, the main entrance road and entrance station are visible. The Cabin District is also visible, but distance minimizes the impact to the wilderness setting.



Figure 3.2.4-1. Panoramic images of 180° views for VRI_1 (top) and VRI_2 (bottom).

The scenic quality at VRI_3 was rated as moderate to high. Water and trees contribute significantly to the scenic view at this location (Figure 3.2.4-2). Visual impacts include the main entrance road, and the administrative and public buildings and activities surrounding the main Cabin District. VRI_4 was rated as moderate for scenic quality. The forest appears unhealthy with dead and dying trees, windthrow trees, and felled hazard trees (Figure 3.2.4-3). Also, broken power lines are visible and detract from the scenic view. However, several large living ponderosa pines contribute to the aesthetic appeal at this location.



Figure 3.2.4-2. Panoramic images of 360° view of VRI_3.



Figure 3.2.4-3. Panoramic images of 360° view of VRI_4.

VRI_5 was rated as high in scenic quality. The view of History Grove, Valle Grande, and the caldera rim provide excellent views (Figure 3.2.4-4). There are minimal impacts to the scenic view from the horse barn, paddocks, "skinning shed," and entrance station, but sometimes vehicles are parked at the horse barn. Remnant fences in Valle Grande are also minor visual detractions. At VRI_6, there are views of Valle Grande, showcasing the vastness of the region (Figure 3.2.4-4). The horse barn and paddocks are the primary visual impairments. Logging roads on Abrigo Mountain and the entrance station road also detract slightly from the visual scenery. There are also towers visible on Cerro Pelado, which may detract from VALL's dark night sky.

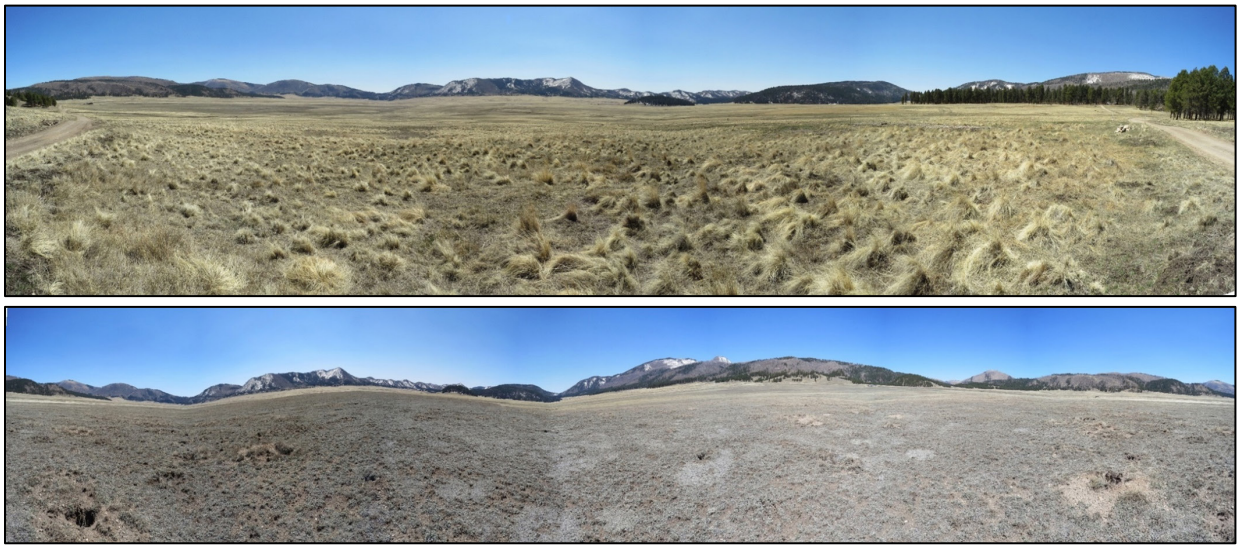


Figure 3.2.4-4. Panoramic images of 360° views of VRI_5 (top) and VRI_6 (bottom).

Lastly, VRI_7 was rated as high in scenic quality. The presence of water, mountains, and the expansive valle contributes to the diversity of the scenery. Most signs of people are distant, with Highway State Route 4, the main entrance road, and the entrance station being the primary visible human-created features (Figure 3.2.4-5).



Figure 3.2.4-5. Panoramic image of 360° view of VRI_7.

Using the condition rating matrix in Appendix C, Table C-3, the conditions at each of the seven visual inventory locations were rated as either good or very good (Table 3.2.4-1). With respect to these seven locations, the overall condition of the visual resources indicator is good (Table 3.2.4-2).

Table 3.2.4-2. Visual resources condition rating summary.

Indicator	Condition Rating [1]	Trend	Condition Evaluation
Visual Resources	Good	Unknown	Views include landscapes that are key to the preserve's purpose and serve as a primary reason for visitation. In addition, minimal visual impairments exist. Confidence in the condition rating is high, but condition is limited to only seven locations in the preserve.

[1] See Appendix C, Tables C-2 and C-3, for the 5-level condition rating statements for indicator.

The primary obstructions across the preserve, as cited in VALL's foundation document (NPS 2018a) are roads, logging roads on the volcanic domes, and sheep and cattle grazing infrastructure (e.g., corrals, fences, stock tanks, earthen dams, large ground water well pumps). Other factors that may detract from the scenic views, depending on location, include burned forests, invasive grasses, domestic livestock, increased visitation (e.g., dust from traffic, headlights at night), military overflights, and other human-caused changes to the landscape. However, the removal of some fences, wetland restoration efforts, and fewer livestock have improved, and will likely continue to improve, the scenery throughout the preserve (NPS 2018a).

Extrinsic stressors also affect VALL's scenic views. These include adjacent land use, including geothermal development and oil and gas production, and nighttime light pollution from nearby and more distant communities. Although this evaluation assesses daytime visual resources, a dark night sky is an important aspect of maintaining high quality views. The IDA designated VALL a Dark-Sky Park in February 2021 (refer to Chapter 2 for information). Although much of the preserve retains a

dark night sky, particularly in the western half, the light domes of Espanola, Los Alamos, Santa Fe, and Albuquerque (all towns and cities in New Mexico) are visible from inside the preserve (Woods et al. 2020). While VALL staff retrofitted the preserve's light fixtures to meet IDA guidelines, staff are currently engaged in drafting a zoning plan that could change the number of lights and the amount of light pollution originating from within the preserve (NPS, A. Steffen, cultural resources coordinator, manager-scientist web meeting, 3 June 2021). Even an increase in visitation or more roads, where visitors travel at night, could disrupt the night sky environment.

On a more regional scale, haze caused by pollution (e.g., coal fired power plants and agriculture) and forest fires are also factors that affect visual resources (NPS 2018a). Smoke from an increase in the length of the fire season, size of fires, and fire intensity may obscure views in the preserve more often than in the past (Ford et al. 2018). In high elevation areas in the intermountain West, Hallar et al. (2017) found that surface-level organic aerosol loading is dominated by summer wildfires. While overall visibility is likely to improve with reduced emissions, this will be partially offset by a longer, more intense fire season (Ford et al. 2018). Also, as conditions in the Southwest become drier, atmospheric particulate matter (e.g., dust) has and will continue to increase (Achakulwisut et al. 2017; Achakulwisut et al. 2018).

Using a five-year (2014–2018) index of haze, the NPS ARD rated VALL's visibility to be of fair condition (NPS ARD 2021a) and estimated a visual range between 151 km and 309 km (94 and 192 mi) in 2018. Without the effects of pollution, the estimated visual range would be between 201 km and 330 km (125 and 205 mi) (NPS ARD 2021a). There are no representative data for identifying the sources of particulate matter in VALL (NPS ARD 2021b).

Because only seven locations were evaluated for VALL's visual resources condition assessment, and most of the locations were along roads or in the front country, these results serve as a baseline, with condition ratings limited to those locations. Additional sampling is required to inform zoning and wilderness planning, to serve as a guide for the preserve's research permitting process, and to obtain additional baseline condition information.

As VALL staff collect addition visual resource data in the future, they will be able to determine the areas where the most pristine, untrammeled views are located. They can use this information to compare to the NPS NSNSD sound and night sky models to determine the areas throughout the preserve that are theoretically the darkest and quietest and of high scenic quality. Of high priority is a visual resource condition assessment of the preserve's proposed Rim Trail and Redondo Peak, in addition to a more thorough baseline assessment for the entire preserve (NPS, M. Peyton, wildlife biologist, manager-scientist web meeting, 3 June 2021).

3.3. Redondo Peak Biodiversity (Gap Analysis)

3.3.1. Background & Importance

VALL in its entirety is a high elevation ecosystem, and Redondo Peak is the highest point in the preserve and the second highest in the Jemez Mountains. The high elevation ecosystems in the Jemez Mountains and on Redondo Peak include upper montane meadows, spruce-fir forests, and exposed rock or scree fields known as felsenmeers (Muldavin et al. 2006). Combined, these community types comprise 15% of the preserve's total area (Figure 3.3.1-1). While Redondo Peak is both a biologically and culturally important area in the preserve, the 2013 Thompson Ridge Fire threatened those resources. The fire created a mosaic of severity on the peak, damaging habitat for the federally endangered Jemez Mountains salamander (NPS 2018a). The fire also increased the erosion risk for historic structures in the preserve's Cabin District and resulted in the loss of culturally important aspen carvings and other historic wood resources (NPS 2018a). As the effects of the Thompson Ridge Fire continue to manifest on the landscape, the sacred outline of a golden eagle (*Aquila chrysaetos*), visible along Redondo Peak's grass-covered south-facing slope, may vanish because of falling trees and the regrowth of vegetation (Anschuetz 2014).



VALL staff emptying a light trap during insect collecting on Redondo Peak. Image Credit: ©Valles Caldera Trust.

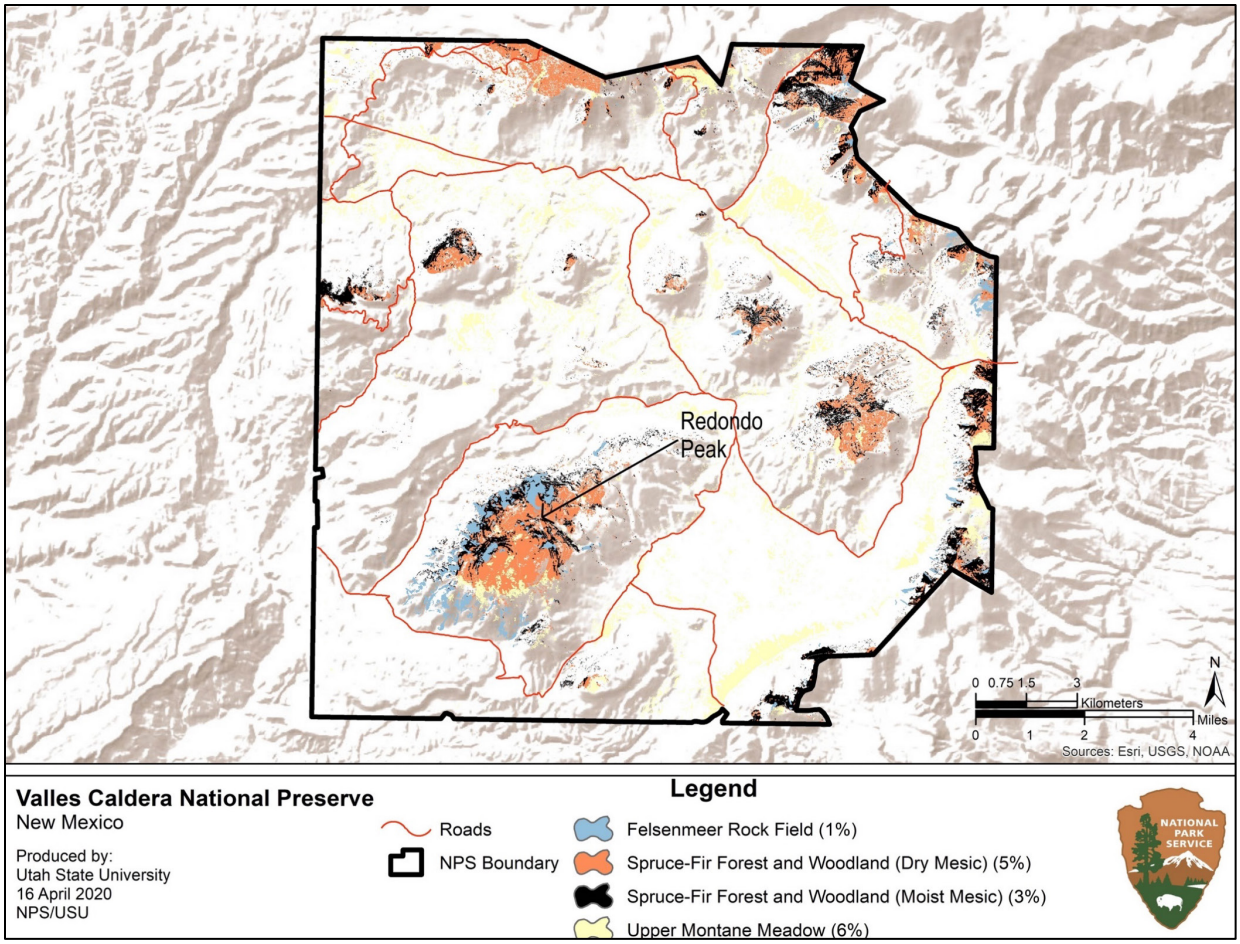


Figure 3.3.1-1. Distribution of three high elevation community types in VALL, primarily on Redondo Peak.

3.3.2. Status of Knowledge

In 2014, VALL staff conducted a comprehensive inventory of flora and fauna on Redondo Peak (NPS VALL, M. Suazo, plant ecologist, e-mailed file to Lisa Baril, Utah State University, 13 August 2020). Information on vascular plants, birds, bryophytes, invertebrates, and other taxa were collected, and for this gap analysis, we summarized the data for plants and some invertebrate groups (e.g., arachnids). Data on bryophytes, which are nonvascular plants comprised primarily of liverworts, hornworts, and mosses, were surveyed preserve-wide, including on Redondo Peak, and summarized (Romig 2012).

Although there are no similar surveys of spruce-fir, montane meadow, and felsenmeer communities in other areas of VALL, it is reasonable to infer that the species found on Redondo Peak are likely to occur in those other locations. In addition, biodiversity studies in similar habitats in the Southwest Rocky Mountain region are lacking to serve as a comparison to Redondo Peak's biodiversity. However, comparing species richness from one place to another may be less informative than monitoring key indicator and climate-sensitive species within each of the three habitat types on the peak over time.

For Redondo Peak's plant species richness, we summarized the data by the three habitat types and compared these data to their respective NatureServe Terrestrial Ecological System descriptions (Sayre et al. 2009). Our objective was to look for anomalies or departures from expected species composition, using the NatureServe descriptions as a baseline.

The spruce-fir forest was the most species rich of the three habitat types (76 plots), while mountain meadow (57 plots) and felsenmeer plots (36 plots) exhibited much lower species richness (Figure 3.3.2-1). Forbs and graminoids were the most species-rich groups, while trees, shrubs, and ferns were the least species-rich. Forbs outnumbered graminoids in the spruce-fir and mountain meadow plots, whereas the felsenmeer rock field community had similar forb and graminoid species richness. It also included the only fern species documented during the survey.

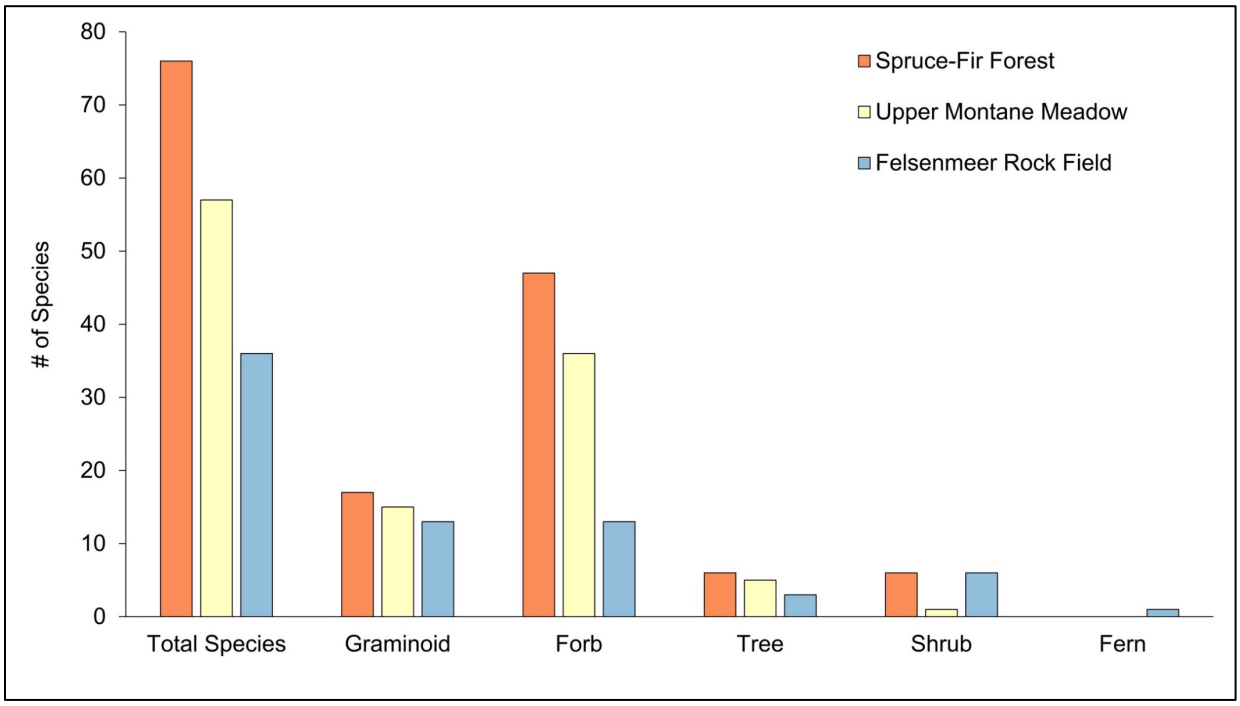


Figure 3.3.2-1. Redondo Peak's plant species richness by community type and lifeform.

Spruce-fir forests in the preserve belong to the NatureServe's Subalpine Fir-Engelmann Spruce (*Abies lasiocarpa-Picea engelmannii*) Southern Rocky Mountain moist (NatureServe 2020a) and dry (NatureServe 2020b) forest alliances. Both types occur in the preserve, with the dry forest dominant on Redondo Peak (see Figure 3.3.1-1). Spruce-fir forests comprise roughly 10% of the Southern Rocky Mountain region (Rondeau 2001), and the largest spruce-fir forests occur in the San Francisco Peaks of northern Arizona, the White Mountains of east-central Arizona, and in the Jemez Mountains (NPS 2016), occurring at the highest elevations in all the Southwest.

Aside from subalpine fir and Engelmann spruce comprising the dominant canopy cover, co-dominant species vary from one region to another (NatureServe 2020a). On Redondo Peak, co-dominants include white fir (*Abies concolor*), Douglas-fir, and blue spruce. Forest understories are highly

variable across the range of southwestern spruce-fir and are usually dominated by a diverse combination of grasses, dry sedges, mesic forbs, and shrubs (NatureServe 2020a). For example, Dye and Moir (1977) found large differences in the number of species and little similarity in species composition across spruce-fir forests. The only non-native species observed in spruce-fir forests on Redondo Peak were common dandelion (*Taraxacum officinale*) and Kentucky bluegrass.



Spruce forest on Redondo Peak. Image Credit: NPS/Robert Parmenter.

The New Mexico State Wildlife Action Plan (NMSWAP) lists climate vulnerability of this habitat type as moderate (NMDGF 2016). Warmer and drier conditions have increased forest pest activity in western forests over the last several decades (Bentz et al. 2010). Forest pests, including bark beetles and pathogens, have caused major damage to trees in the preserve. According to the U.S. Forest Service's Insect Detection Survey database, forests pests damaged 92% of all forested areas in VALL from 2000 to 2018, including spruce-fir forests on Redondo Peak (USFS 2018). Spruce-fir forests are a climax community, and no other species will replace spruce-fir as the dominant tree unless there is a major disturbance, such as fire or a bark beetle invasion.

Montane meadows occupy less than 3% of the Southern Rocky Mountain region (Rondeau 2001). NatureServe classifies this habitat type as Southern Rocky Mountain Montane-Subalpine Grassland (NatureServe 2020c). Deterioration of this community type is indicated by an increase in forbs or secondary small grasses, which is usually accompanied by a decline in primary grasses (e.g., Thurber's fescue (*Festuca thurberi*) and Parry's oatgrass (*Danthonia parryi*)). Continued degradation

leads to bare soils, lower soil stability, and reduced plant vigor. Cattle (*Bos taurus*) grazing may lead to degradation in montane meadows. The absence of invasive grasses and forbs in this habitat on Redondo Peak, such as smooth brome (*Bromus inermis*) and spear thistle (*Cirsium vulgare*), indicates that it is not over-grazed; however, Kentucky bluegrass was present.



Montane meadow on Redondo Peak. Image Credit: NPS/Robert Parmenter.

NatureServe reports that graminoid species richness in Southern Rocky Mountain Montane-Subalpine Grasslands is typically between 11 and 20 species, with a mix of warm- and cool-season grasses (NatureServe 2020c). On Redondo Peak, observers recorded 15 native grasses. Only one non-native forb (common dandelion) was present. Trees should be absent or rare in montane grasslands, but there were five tree species, two of which occurred on the edge of the meadow. This indicates at least some encroachment by trees into the peak's meadow habitat.

Montane meadows across their range are vulnerable to encroachment of trees due to the absence of low-severity and frequent fires, historic grazing practices, and changes in climatic factors (Coop and Givnish 2007). From 1935 to 1981, upper and lower montane grasslands in the Southwest Jemez Mountains declined by 55% (Allen 1989 as cited by Coop and Givnish 2007), and between 1935 and 1996, grasslands (both upper and lower montane) in the preserve declined by nearly 18%. Forest encroachment, however, was most severe at higher elevations on steep slopes. Above 2,800 m (9,186 ft), grassland area declined by 63% (Coop and Givnish 2007). However, there are no recent data on grassland change for the region. NatureServe reports that montane grasslands are likely to increase

given current climate change scenarios (NatureServe 2020c). This increase will likely be at the expense of adjacent forests and woodlands. NatureServe indicates that the resilience or adaptive capacity of montane grasslands to climate change is low, and the ecosystem's overall climate vulnerability is moderate (NatureServe 2020c). The NMSWAP lists climate vulnerability of this habitat type as low to moderate (NMDGF 2016).



Felsenmeer rock slope on Redondo Peak. Image Credit: NPS/Robert Parmenter.

Felsenmeer rock fields are a unique environment characterized more by rock than by plants. NatureServe classifies this environment as Rocky Mountain Alpine Bedrock and Scree (NatureServe 2020d). In VALL, felsenmeer rock fields are volcanic outcrops composed of rhyolite or andesite (Muldavin et al. 2006). Water retention is very low, and soils are poorly developed, making for harsh growing conditions (Valles Caldera Trust 2010a). Non-native species were uncommon in the rock fields and included common dandelion, Kentucky bluegrass, and leafy goosefoot (*Chenopodum foliosum*). Often, this community type is composed of non-vascular lichen-dominated communities, with less than 10% cover of vascular plants. The NMSWAP lists climate vulnerability of this habitat type as moderate to high (NMDGF 2016).

In summary, across the three habitat types surveyed for plant richness on Redondo Peak, observers reported 101 species, one of which, horned dandelion (*Taraxacum ceratophorum*), does not appear in NPSpecies (2020)). Of the 101 species, only three were non-native. Excluding the non-native

species, the 98 native species on Redondo Peak represent nearly 20% of all plant species in the preserve (NPSpecies 2020).

For Redondo Peak's arthropod species richness, we summarized the data by the number of specimens collected and by the richness, organized by Order, for each of the three habitat types. The following invertebrate data were provided by Mark Ward, an ecological consultant and NRCA reviewer. Two light traps were deployed on four nights in 2014 (May 27–28, June 23–24, July 23–24, and August 25–26) in the spruce-fir forest at the summit of Redondo Peak. Two additional light traps were deployed at mountain meadow sites just below the summit on the same June, July, and August dates. All Lepidoptera specimens were sorted into taxonomic families and pinned.

A total of 3,606 moths, belonging to 60 species in seven families (Erebidae, Geometridae, Hepialidae, Lasiocampidae, Noctuidae, Notodondidae, and Sphingidae), were identified by Michael G. Pogue, a retired lepidopterist from the Systematic Entomology Laboratory of the Agricultural Research Service of the USDA (affiliated with the Smithsonian National Museum of Natural History). Of the families identified, the Noctuidae were the most abundant and species-rich, with 3,398 individuals belonging to 48 species. Most Geometrids, some Noctuids from August 2014, and all Pyraloid and micromoth specimens have not yet been identified, so their numbers were not included in this summary.

Four new moth species were added to the preserve's species list: *Pseudohemihyalea labecula* (Erebidae), *Cucullia similaris*, *Euxoa septentrionalis*, and *Euxoa tessellata* (Noctuidae). Thirty Coleoptera specimens from light traps, belonging to 18 species in 12 families, were identified by Richard J. Buss (retired), now a volunteer with the Arthropod Division of the Museum of Southwestern Biology at the University of New Mexico.

Six free standing Malaise traps were deployed at Redondo Peak in 2014 (three in the spruce-fir habitat and three in the mountain meadow habitat) from late May to late September. One canopy malaise trap was deployed in the spruce-fir habitat from July 1 to late September. Samples were hand-picked for macro Coleoptera specimens that were subsequently identified by R. Buss.

A total of 3,124 specimens, belonging to 152 species in 34 families, was identified. Noteworthy specimens that may be new records for New Mexico included: *Pectotoma hoppingi* (Scraptiidae), *Selvadius cf. maderi* (Coccinelidae), *Euscaphurus* sp. (Eucentidae), and *Hoppingiana* sp. (Melyridae). There are pitfall trap data, but the results haven't been summarized (M. Ward, ecological consultant, comments to draft assessment submitted to T. Cook, 26 March 2021).

Additional arthropod data collected in 2014 at VALL were downloaded from the Symbiota Collections of Arthropods Network (SCAN 2020). Three hundred and eighty-eight specimens in five orders were identified across the three habitat types, using light traps, pitfall traps, litter samples, and malaise traps, but most specimens have not yet been identified to species, except for spiders and harvestmen, which are shown in Figure 3.3.2-2. Although the highest number of specimens were collected in the spruce-fir forest habitat type, slightly more species were found in the upper montane

meadows (Figure 3.3.2-3). In all, at least 75 species of spider and five species of harvestmen were identified across the three habitat types.

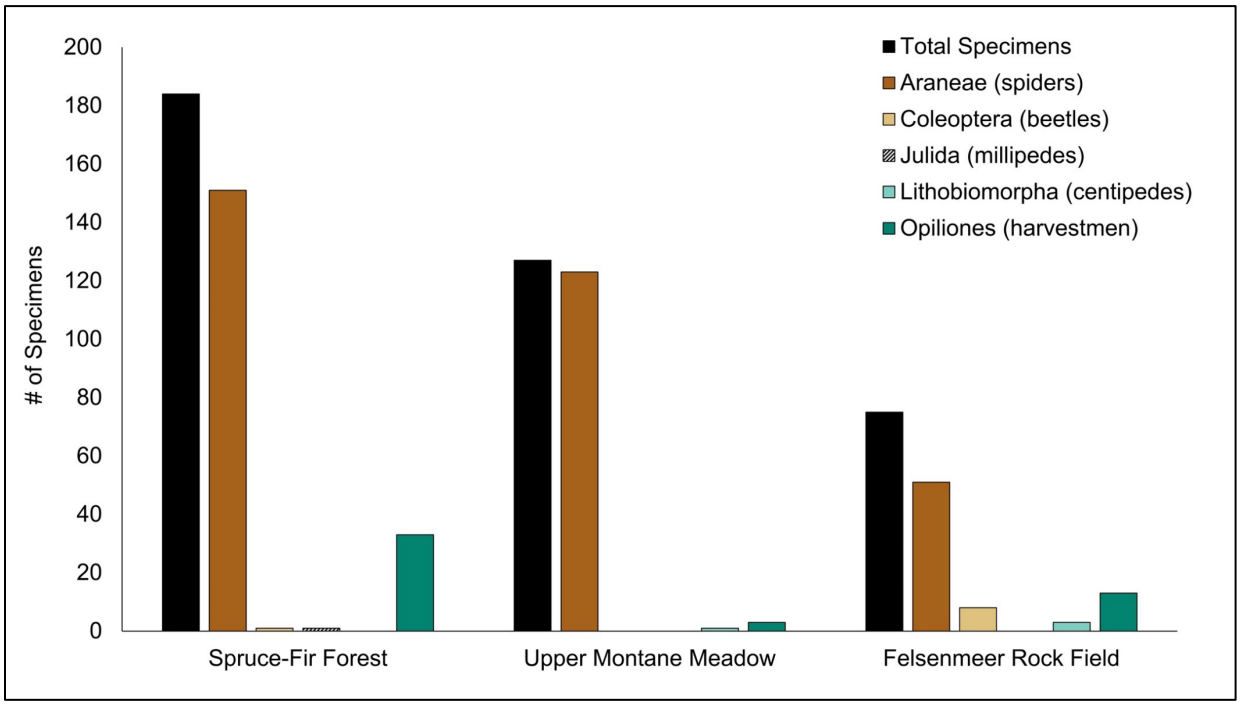


Figure 3.3.2-2. Abundance of spiders and harvestmen by community type on Redondo Peak.

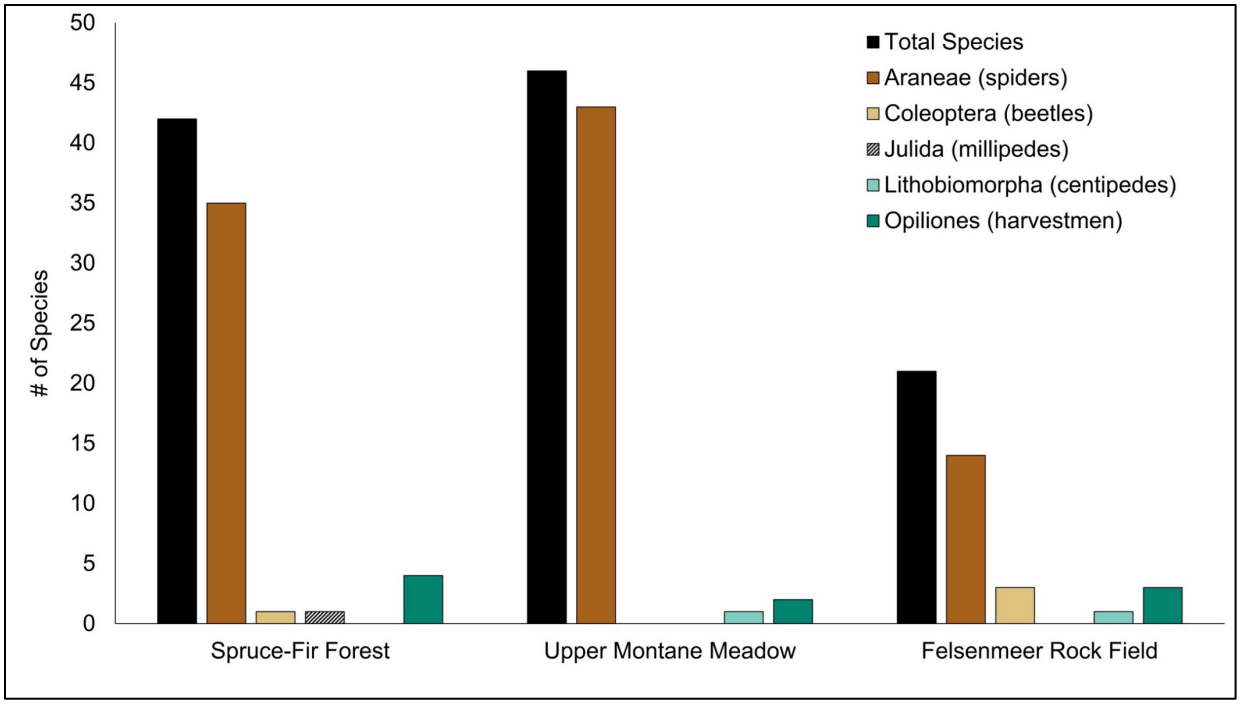


Figure 3.3.2-3. Richness of spiders and harvestmen by community type on Redondo Peak.

For Redondo Peak's bryophyte species richness, we summarized the data collected in multiple locations, including Redondo Peak, at elevations ranging from 2,650 m (8,694 ft) to 3,450 m (11,319 ft) (Romig 2012) during a 2009–2010 preserve-wide inventory. Five hundred and fifty-six samples, representing 113 species, were identified (Romig 2012). During the inventory, 98 species of moss, including nine species new to New Mexico, and 15 species of liverwort, were found in the preserve (Romig 2012). No hornworts were identified.

3.3.3. Discussion

The high elevation, rugged terrain of Redondo Peak limits anthropogenic impacts. There are few non-native species and the three ecosystems, at least in terms of plant composition, appear to be within the natural range of variation. However, this high elevation area is vulnerable to a changing climate, and certain species adapted to the high elevation environment may not persist in the preserve as temperature continues to rise and precipitation declines. Thus, monitoring a subset of climate-sensitive species in each of the three community types on Redondo Peak would provide an index to the health of this high elevation system over time (Table 3.3.3-1).

Table 3.3.3-1. Proposed study details for Redondo Peak biodiversity.

Community Type	Indicator	Measure	Reference Criteria for Measure
Spruce-Fir Forest	Boreal Owl	Abundance/population size	No declines in abundance/population size.
	Climate-sensitive Plants	Cover of: *Aquilegia coerulea* var. *coerulea*, *Artemisia franserioides*, *Carex bella*, *Draba helleriana* var. *helleriana*, *Mertensia franciscana*, *Penstemon whippleanus*	No declines in cover for any single species or no declines in overall cover when combined.
Upper Montane Meadow	Climate-sensitive Plants	Cover of *Draba helleriana* var. *helleriana*	No declines in cover.
Felsenmeer Rock Field	American Pika	Abundance/population size	Historically occupied sites remain occupied.
	Climate-sensitive Plants	Cover of: *Aquilegia coerulea* var. *coerulea, Draba helleriana* var. *helleriana, Erigeron acris* ssp. *debilis, Penstemon whippleanus, Senecio atratus*	No declines in cover for any single species or no declines in overall cover when combined.

The climate-sensitive species in Redondo Peak's upper montane meadow includes one perennial forb, *Draba helleriana var. helleriana*, which VALL staff identified during the 2014 bioinventory, whereas the climate-sensitive species in the spruce-fir forest include six potentially climate-sensitive plants that VALL staff identified in 2014 and the boreal owl (*Aegolius funereus*). The boreal owl is dependent on spruce-fir forests (Enquist and Gori 2008), and the NMSWAP considers the owl to be

of high priority, owing to a declining population, limited habitat, and disjunct habitat (NMDGF 2016).

Boreal owl surveys occurred in VALL during September 2012. Over the two nights of surveys, observers recorded up to six individuals. Although owls were surveyed in spring 2020, surveyors were unable to access the high elevation spruce-fir habitat until mid-May due to Covid-19 restrictions, which may explain why no boreal owls were detected during these surveys (Hawks Aloft Inc., T. Fetz, lead avian biologist, comments to draft songbirds assessment, received by Tammy Cook, NPS NRCA Program, 20 March 2021).

The climate-sensitive species in Redondo Peak's felsenmeer rock fields include five plant species and the American pika (*Ochotona princeps*). The talus slopes of Redondo Peak provide some of the best habitat for American pika in VALL (Valles Caldera Trust 2010b), but this NMSWAP species of concern also occurs in several other locations in the preserve. In 2015–2016, the New Mexico Department of Game and Fish (NMDGF), in cooperation with Natural Heritage New Mexico (NHNM), found pika at 21 of the 28 locations surveyed in VALL (Hayes 2016). The locations ranged in elevation from 2,676 m (8,780 ft) to 3,305 m (10,843 ft). The population of pika at VALL is unusual in that it occurs at a low latitude and is somewhat isolated from other populations (Hayes 2016).

Pikas are sensitive to extreme heat and extreme cold, but the temperature thresholds for heat and cold stress depend on the elevation and the aridity of a given location (Jeffress et al. 2013). However, in general, pika experience heat stress above 28°C (82°F) (Hayes 2016). Conversely, pika may experience cold stress beginning anywhere from 0°C (32°F) to −10°C (14°F) (Hayes 2016). During VALL's pika study, temperature, as recorded by dataloggers placed at the surface and below the talus slopes, revealed that heat thresholds were not exceeded at any of the sites, and the cold temperature threshold of 0°C (32°F) was not reached until 31 October (Hayes 2016). The preserve may also support the Goat Peak pika (*O. p. incana*), a subspecies of the American pika, but more information is needed for this subspecies (Valles Caldera Trust 2010b).

In addition, a yellow-bellied marmot (*Marmota flaviventris*) was observed in a talus patch on the eastern side of Redondo Peak at an elevation of 3,234 m (10,610 ft) on 7 July 2015 (Frey et al. 2019). Four additional observations have occurred in the Jemez Mountains since 2015 (Frey et al. 2019), which represent the first observations of the yellow-bellied marmot in this mountain range. The nearest known populations are in the Sangre de Cristo Mountains, 45 km (28 mi) northeast (Frey et al. 2019). The recent sightings in the Jemez Mountains suggest that a relictual population has persisted there (Frey et al. 2019).

A climate change vulnerability assessment that evaluated 248 conservation areas in six ecoregions of New Mexico ranked the Jemez Mountains highest for climate exposure (Enquist and Gori 2008). The ranking was based on significantly warmer and more highly variable temperatures since 1970 and significantly less precipitation since 1991. Between 1991 and 2005, precipitation declined by an average of 3%, but from 2000 to 2005, it declined by 17% (Enquist and Gori 2008). The species that are dependent on the cool, moist conditions typically found at higher elevations may be extirpated

from the preserve given future climate change scenarios. Thus, repeat inventories, especially for a suite of climate-sensitive species, may help managers develop strategies for climate adaptation and mitigation. In addition, processing the data that have already been collected for beetles, moths, butterflies, birds, and mammals from Redondo Peak will serve as a valuable baseline.

3.4. Restored Wetlands (Condition Assessment)

3.4.1. Background & Importance

Wetlands and wet meadows are one of the most biologically diverse habitat types in VALL (NPS 2018a), representing only approximately 7.7% of VALL's total area when mapped in 2001 (Muldavin et al. 2006). The wetlands and wet meadows occur in valley bottoms and swales, and along streams throughout the preserve (Figure 3.4.1-1). The federally endangered New Mexico meadow jumping mouse (USFWS 2014a) is dependent on wetland habitat, along with other sensitive species, such as the long-billed curlew (*Numenius americanus*) (Fellows and Jones 2009). A variety of facultative or obligate wetland grasses, rushes, and sedges are widespread in VALL's wetlands, while trees and shrubs are rare, but an important component of riparian structure and function.

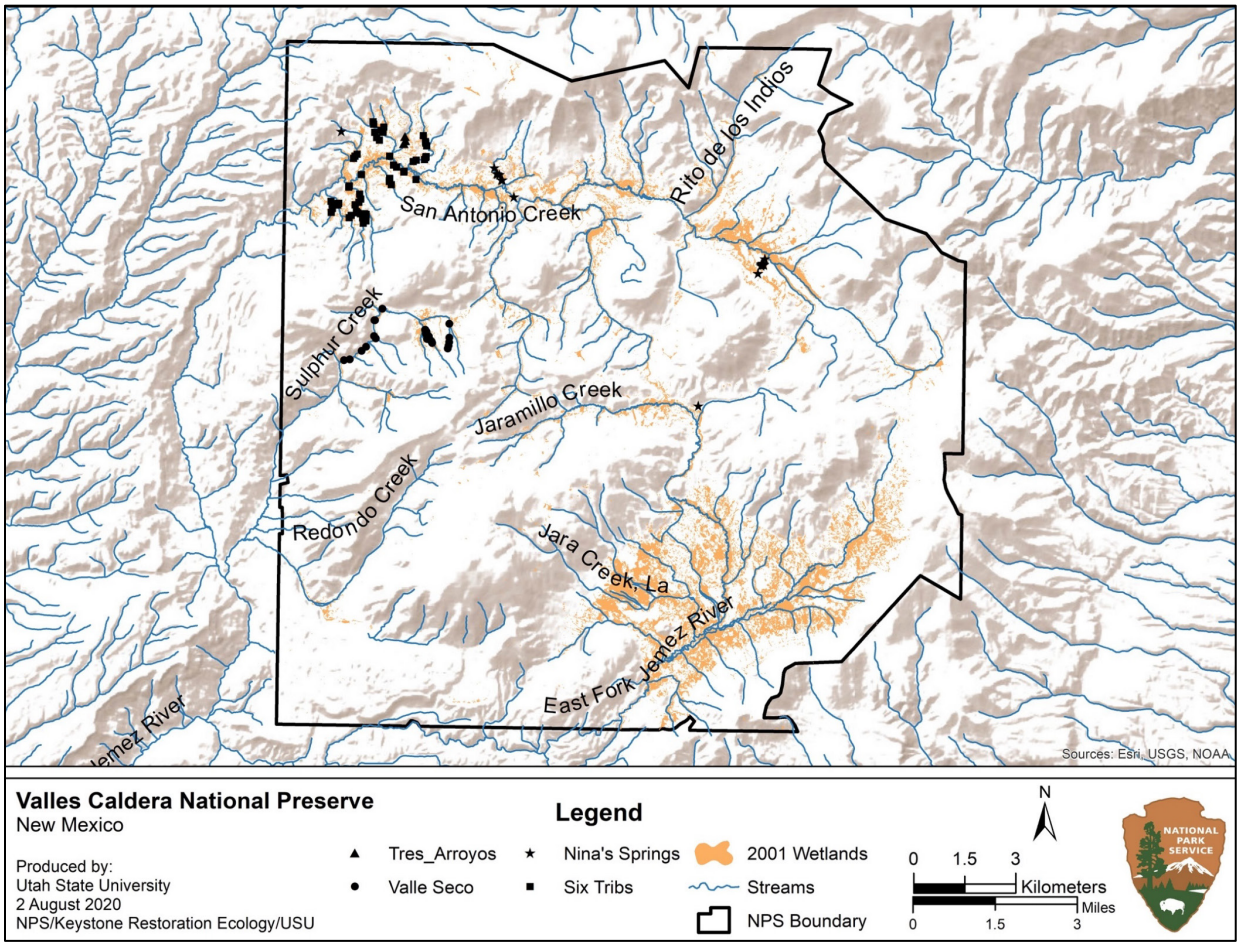


Figure 3.4.1-1. VALL's extent of wetlands mapped in 2001 by Muldavin et al. (2006). The restored wetland areas (2012–2019) are also shown.

Historically, wetlands were more common in the preserve than they are today, and wet meadows in the preserve were probably fens (NPS 2018a). Fens are permanently saturated wetlands fed primarily by mineral-enriched groundwater (USFS 2020). Rather than water flowing in a single stream channel, fens produce multiple shallow channels over a much larger area, which serve to reduce the rate of runoff, mitigate flooding, and filter pollutants.

Nearly 150 years of livestock grazing, road construction, and logging in present-day VALL led to wetland degradation and loss (Anschuetz and Merlan 2007). Since 2011, however, VALL's restoration efforts have improved wetland quality and extent throughout the preserve (NPS 2018a). Restoration has occurred along La Jara Creek, at several areas in the San Antonio Creek drainage (Rito de los Indios, Six Tribs, Nina's Springs, and Tres Arroyos), Jaramillo Creek, Redondo Creek, East Fork Jemez River, and Valle Seco, which drains into Sulphur Creek (see Figure 3.4.1-1).

3.4.2. Study Framework

Two indicators, flow duration and cover (of wetland plants), with one measure each, were used to evaluate the restored wetlands in the preserve (hereafter wetlands; Table 3.4.2-1). Reference criteria were derived from expectations of the effects of restoration activities identified in Vrooman (2015), Wells (2019), and Zeedyk and Vrooman (2017). Based on the wetland restoration efforts, flow duration data were available for two areas along San Antonio Creek (Six Tribs and Tres Arroyos) and for one area along Sulphur Creek (Valle Seco). Cover of wetland plants data, pre- and post-restoration efforts, were available for areas along La Jara Creek, Sulphur Creek, and tributaries of San Antonio Creek. Because the sample sizes are small, the level of inference for condition ratings is restricted to the areas listed above.

Table 3.4.2-1. Study details for the restored wetlands condition assessment (Vrooman (2015), Wells (2019), and Zeedyk and Vrooman (2017)).

Indicator	Measure	Reference Criteria for Measure
Flow Duration	# of days wetted during monitoring season	Significantly more wetted days post-treatment vs. pre-treatment ($\alpha = 0.05$).
Cover	% cover of wetland plants	Cover of species classified as obligate wetland, facultative wetland, or facultative plants increased post-treatment.

3.4.3. Data & Methods

To evaluate flow duration, which directly influences wetland plant cover, we conducted an analysis of variance (ANOVA) for the total number of wetted days pre- vs. post-treatment for three sites: Six Tribs ($n = 4$), Tres Arroyos ($n = 2$), and Valle Seco ($n = 3$) (Vrooman 2015; Vrooman et al. 2017). The number of wetted days was obtained using thermologgers located in the stream channel or in the soil near the stream channel. The number of wetted days by site were reported for one summer season pre-treatment and for one summer season post-treatment. The restoration projects did not include flow duration control plots, so treatment results are confounded by year (NPS, R. Parmenter, chief of science and resource stewardship, comments to draft evaluation received by K. Struthers, 7 April 2021). To attempt to address this issue, we conducted a t-test between pre-treatment (2014) precipitation and post-treatment (2015 and 2017) precipitation for the months of April, May, and June, which correspond to the months sampled for water presence (i.e., flow duration). The San Antonio and Valle Toledo weather stations (WRCC 2021) are located within the drainage area for

Six Tribs and Tres Arroyos restoration sites; however, there is no weather station located within the Sulphur Creek drainage.

For the measure of wetland plant cover, we summarized data from two transects at La Jara Creek (NPS VALL, M. Suazo, plant ecologist, e-mailed file to Lisa Baril, Utah State University, 2020). Pre-treatment data were collected in 2018 and post-treatment data were collected in 2019, along three 100-m (328-ft) transects. Cover by wetland plant status was calculated by determining the number of "hits" for each species along a line transect, then dividing that number by the total length of the transect. These averages were then summed by wetland indicator status, as defined by the USDA Natural Resources Conservation Service (USDA 2014). Additionally, we summarized wetland plant cover change pre- vs. post-treatment at Valle Seco and Six Tribs (Vrooman et al. 2017).

Lastly, we summarized wetland change in the restored sites (although this was not reported as a measure to evaluate conditions for the restored wetland areas). All or portions of La Jara Creek, Six Tribs, Valle Seco, Rito los Indios, and Nina's Springs restored wetlands were delineated using a handheld geographic positioning system (GPS) and walking the perimeter of the wetted area before and after treatments and/or by comparing satellite imagery and vegetation maps. However, it's important to note that not all restoration areas were mapped (Vrooman et al. 2017; Zeedyk and Vrooman 2017; Wells 2016, 2019).

3.4.4. Results & Discussion

For the flow duration measure, the number of wetted days increased significantly post-treatment across the three restoration sites (F (1,16) = 43.7, $p < 0.001$). Prior to the wetland restoration efforts, thermologgers generally indicated saturation only during the period following snowmelt in late April and early May (Vrooman 2015; Vrooman et al. 2017). After treatment, most sites remained saturated for the duration of sampling. At Sulphur Creek, three treatment sites averaged 20.3 days (range: 4–33) pre-restoration (2014) to 148.7 days (range: 140–153) post-restoration (2017) during 15 April to 15 September. At Six Tribs, the number of wetted days averaged 34.3 (range: 25–47) pre-restoration (2014) to 89.3 (range: 64–132) post-restoration (2015) during a 91-day period from 1 April to 30 June. And at Tres Arroyos, the two sites were wetted for just 30 days pre-treatment (April 1–30 to June 2014). Post-treatment, the two sites were wetted for the entire duration (91 days) of sampling (1 April to 30 June 2015). However, at both the San Antonio (t (145) = −2.8, p = 0.01) and Valle Toledo (t (113) = −3.0, p = 0.003) weather stations, precipitation was significantly higher post-treatment (2015) than pre-treatment (2014). At least for the Six Tribs and Tres Arroyos restoration sites, the significant increase in wetted days is at least partially attributed to an increase in precipitation. Because precipitation also increased significantly for two of the restoration sites for which there were weather data, we could not definitively tie the restoration efforts to improved flow. Therefore, the condition and trend for the flow duration indicator is unknown.

La Jara Creek's wetland plant cover data for two plots indicate that the cover of facultative, facultative wetland, and obligate wetland plants increased post-treatment (Figures 3.4.4-1 and -2). Obligate wetland plants were the dominant plant cover before and after restoration. La Jara Creek's non-wetland vegetation cover increased post-treatment for facultative upland plants, while upland plants declined slightly for an overall increase in non-wetland cover. We did not conduct t-tests for

differences in mean cover of upland and wetland plants pre- versus post-treatment because only two transects were monitored for one year pre- and post-treatment.

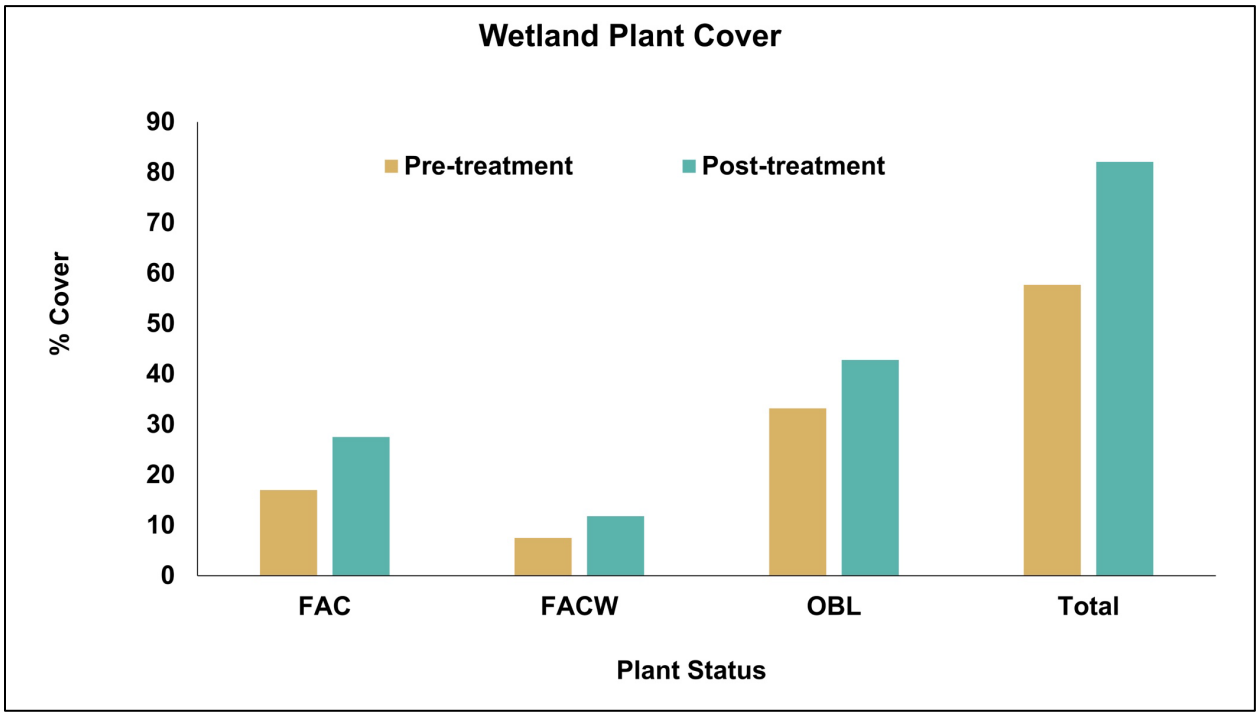


Figure 3.4.4-1. Wetland plant cover pre-treatment (2018) vs. post-treatment (2019) at La Jara Creek in VALL. FAC = facultative plants occur in both wetlands and non-wetlands; FACW = facultative wetland plants usually occur in wetlands, but sometimes occur in non-wetlands; and OBL = obligate wetland plants almost always occur in wetlands.

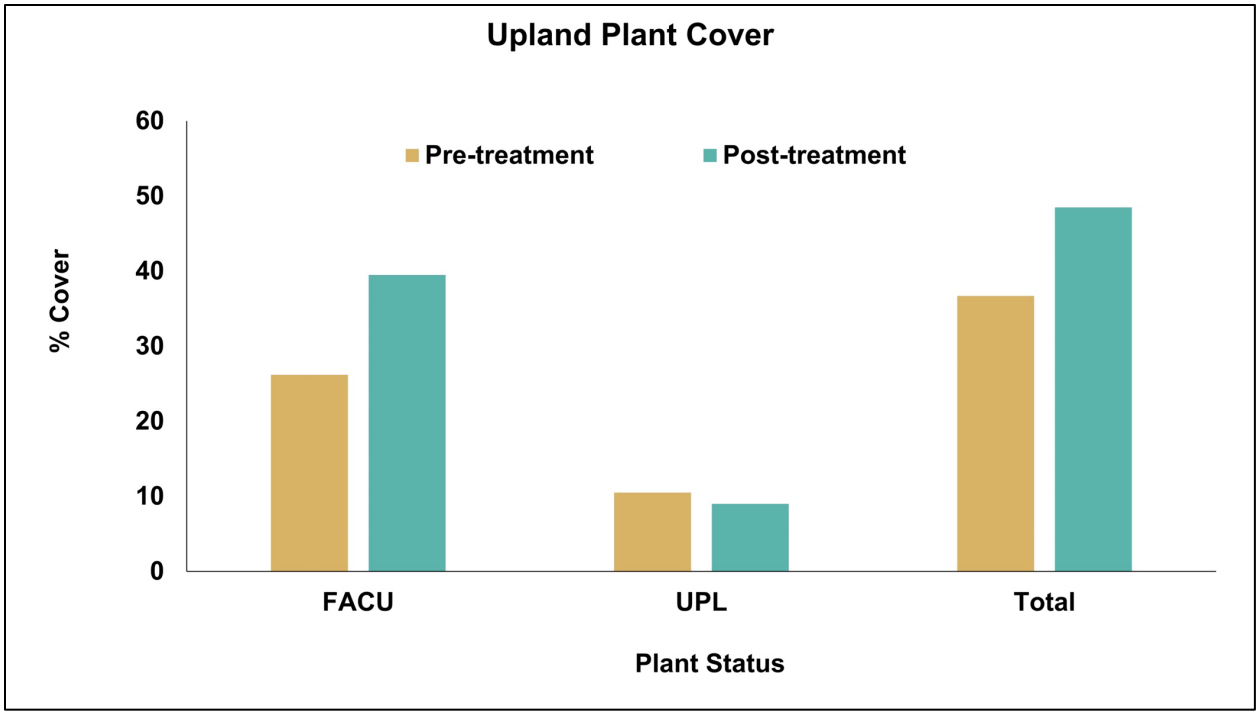


Figure 3.4.4-2. Upland plant cover pre-treatment (2018) vs. post-treatment (2019) at La Jara Creek in VALL. FACU = facultative upland plants usually occur in non-wetlands but are occasionally found in wetlands; UPL = obligate upland plants almost always occur in non-wetlands.

Similarly, wetland plant cover at Valle Seco increased in the five treatment plots post-restoration (2013 vs. 2017) (Vrooman et al. 2017). Interestingly, wetland plant cover in the two control sites declined slightly pre- vs. post-treatment ($p = 0.02$), which indicates that treatment sites are increasing in wetland plant cover, even when the control sites are declining in wetland plant cover (Vrooman et al. 2017). Although restoration efforts appear to be effective at Valle Seco, the exclusion of cattle grazing along this area occurred in late 2015 and likely contributed to an increase in wetland plant cover (Vrooman et al. 2017).

At the Six Tribs of San Antonio Creek restoration site, wetland plant cover increased significantly in both the control and treatment plots. Increases were greater in the treatment plots ($p = 0.02$) than in the control plots (Vrooman et al. 2017).

The restored wetland extent change analysis revealed that the pre-treatment wetland area was over 36.5 ha (90.3 ac), and the post-treatment area was 43.5 ha (107.4 ac), representing a 19.2% increase (Vrooman et al. 2017; Zeedyk and Vrooman 2017; Wells 2016, 2019). The increase likely represents the minimum change in wetland extent since not all restoration mapping data were available and only portions of restored areas were mapped due to time constraints. In addition, reaching full wetland extent may take three to five years post-treatment, and there may be some short-term negative effects from the restoration activities on wetlands and the surrounding areas. This is due to the use of heavy equipment and materials used to reconstruct and restore the wetlands.

The conditions for the two indicators are unknown and good and are summarized in Table 3.4.4-1. While the data suggest that the extent of VALL's restored wetlands has increased and that the cover of wetland plants and the flow durations improved, stream discharge is driven primarily by snowmelt in spring and monsoon rains in late summer (NPS 2018a) and the post-restoration years were wet, making it difficult to identify cause of improved conditions and trends. With significantly warmer and more highly variable temperatures since 1970 and significantly less precipitation since 1991 (Enquist and Gori 2008), continued wetland restoration efforts and beaver recolonization (discussed below) will help mitigate the effects of water loss from reduced winter snowpack and the absence of or limited monsoon rains. The confidence level in the condition evaluation for restored wetlands will improve as pre- and post-restoration data are obtained for evaluation. That information is vital to understanding wetland change in the preserve and for evaluating the effectiveness of restoration efforts.

Table 3.4.4-1. Restored wetlands condition ratings summary.

Indicator	Condition Rating [1]	Trend	Condition Evaluation
Flow Duration	Unknown	Unknown	Flow duration improved significantly in the three restored wetland sites, but this was at least partially attributed to a significant increase in precipitation at Six Tribs and Tres Arroyos; however, no weather station is near the Sulphur Creek site. Currently, the condition and trend are unknown.
Cover	Good	Improving	Cover of wetland indicator species is at least 80%, with obligate and facultative wetland species comprising greater cover than facultative species. Trend is improving because cover of wetland plants increased in all sites post-treatment. Confidence is high but only applies to treatment sites.

[1] See Appendix C, Table C-4, for the 5-level condition rating statements for each indicator.

Paradoxically, two unusually large and severe fires in the preserve may have helped restore wet meadows and incised streams to their original fen state (NPS 2018a) (although note that fires can also cause stream incision (Leonard et al. 2017)). Between the 2011 Las Conchas and the 2013 Thompson Ridge fires, 60% of the preserve burned. Both fires were the result of long-term fire suppression and subsequent fuels build-up of forested areas. Historically, fires were frequent, but of low intensity.

This historic fire regime may have maintained fens by frequent but modest soil erosion events into wetland areas, particularly in the Valle Grande's East Fork Jemez River (Miltenberger et al. 2017). In this case, post-Las Conchas Fire floods in 2011–2012 filled in ~2 km (1.2 mi) of stream channel with sediments, forcing stream water out of the original channel and re-establishing a large fen in the Valle Grande. This area was quickly colonized by sedges and emergent macrophytes, resulting in a currently stable wetland that has resisted channel down cutting during spring snowmelt and summer

thunderstorm events (NPS, R. Parmenter, chief of science and resource stewardship, comments to draft evaluation received by K. Struthers, 7 April 2021).

Beavers (*Castor canadensis*) were present historically along Sulphur and Rito de los Indios creeks (Valles Caldera Trust 2010b), but there are currently no known beaver colonies in the preserve (NPS 2018a). The lack of aspen, willows (*Salix* spp.), and thinleaf alder (*Alnus incana tenufolia*) along streams has apparently prevented widespread colonization in VALL, although beavers occur around the preserve and occasionally pass through (Valles Caldera Trust 2010b). There are, however, two sites which individual beavers have occupied (probably for several years). Both sites are in the San Antonio Creek area, with one at the far western boundary of the preserve and the other at the confluence of San Luis and San Antonio creeks (NPS, R. Parmenter, chief of science and resource stewardship, comments to draft evaluation received by K. Struthers, 7 April 2021). While beavers in these two locations have not been successful at building dams, they have been able to survive in bank burrows (NPS, R. Parmenter, chief of science and resource stewardship, comments to draft evaluation received by K. Struthers, 7 April 2021).



Wetlands provide habitat for beavers, which, in turn, create habitat for a wider variety of species. Image Credit: ©Robert Shantz.

There have been some efforts to plant narrowleaf cottonwood (*Populus angustifolia*) and willows along certain stretches of Redondo, Rito de los Indios, San Antonio (Vrooman 2014), Jaramillo, and Sulphur creeks (NPS, R. Parmenter, chief of science and resource stewardship, comments to draft

evaluation received by K. Struthers, 7 April 2021), but these plants do not appear to be thriving in all locations (NPS, M. Peyton, wildlife biologist, 7 November 2019, NRCA study plan scoping call). Willows are now well established in the upper Jaramillo Creek and upper Rito de los Indios Creek, but plantings are struggling in lower Jaramillo, Redondo, Sulphur, and San Antonio creeks (NPS, R. Parmenter, chief of science and resource stewardship, comments to draft evaluation received by K. Struthers, 7 April 2021). Notably, plantings outside of ungulate exclosures have experienced near complete mortality within a few years of planting (Rio Grande Return, R. Whittlesey, restoration director, comments to draft evaluation received by T. Cook, 14 March 2021). Just how much woody vegetation historically grew along streams in the preserve is unknown, but in 2002, a team of riparian specialists evaluated streams in the preserve and concluded that woody riparian vegetation was likely historically present but rare (National Riparian Service Team 2002), whereas herbaceous plants were and still are the dominant cover type in mesic areas (National Riparian Service Team 2002).



Restoration by Vrooman using the pond and plug technique. Image Credit: ©Steve Vrooman.

Browsing has been identified as a potential threat to wetland recovery, especially as it relates to the growth and survival of woody riparian vegetation in the preserve. There are between 2,500 and 3,000 elk that reside in the preserve (NPS 2021). During summer months, elk primarily graze grassland vegetation and spend little time in wetland areas (Roberts et al. 2017). In winter, however, elk shift

their diet to include more woody plants, such as cottonwoods and willows, as deep snow prevents access to ground cover (though elk preferentially select grasses when available) (Christiansen and Creel 2007). In general, grasses comprise 66% of their winter diet, browse species represent about 29%, and forbs comprise the remaining 5% across the western U.S. (Christiansen and Creel 2007).

Although some level of browsing is beneficial to willow growth by stimulating branching, excessive browsing can inhibit plant growth. However, water availability ultimately mediates the rate of willow height growth and determines whether willows grow tall enough to escape the height of browsing ungulates (Bilyeu et al. 2008). To what extent woody riparian vegetation is impacted by browsing in the preserve depends not only on the number of elk but also on their behavior and spatial distribution. Other factors, such as hydrology and soils, also influence willow and cottonwood recovery (Tercek et al. 2010).

Historic overgrazing and browsing by cattle and sheep (*Ovis aries*) are also partly responsible for VALL's wetland and riparian degradation. Continued grazing of cattle in the preserve contributes to continued wetland degradation, but the number and location of cattle allowed into the preserve is intensively managed and varies annually depending on predicted forage production (NPS 2018a).

During the 2019 NRCA study plan scoping meeting, NPS staff expressed interest in using the wetlands map to identify invasive plants in the preserve, with the most common species including Kentucky bluegrass, timothy grass (*Phleum pretense*), and dandelion. Note that these are facultative or facultative upland plant species, indicating somewhat drier conditions. If patches of non-native invasive plants are at least the scale of Landsat imagery and have a distinct spectral signature from other vegetation, it may be possible to map non-native invasive plants remotely. However, because of the difficulty in mapping wetlands in general, multi-date imagery from a single season and/or hyperspectral imagery would be useful in parsing species (Guo et al. 2017; Mahdavi et al. 2018). Ultimately, field data collection would provide the most accurate assessment of non-native invasive plant distribution in the preserve, but it is also the most time-consuming method of gathering data.

3.5. New Mexico Meadow Jumping Mouse Habitat Availability (Gap Analysis)

3.5.1. Background & Importance

The New Mexico meadow jumping mouse (*Zapus hudsonius luteus*) (hereafter jumping mouse) is a federally endangered riparian obligate subspecies endemic to the southern Rocky Mountains (USFWS 2014b). Past observations indicate that the subspecies inhabited "riparian areas and wetlands along the Sangre de Cristo and San Juan Mountains from southern Colorado to central New Mexico, including the Jemez and Sacramento Mountains and the Rio Grande Valley from Espanola to Bosque del Apache National Wildlife Refuge, and into parts of the White Mountains of eastern Arizona" (USFWS 2014c). Primary habitat occurs along perennial streams with dense herbaceous vegetation (USFWS 2014c). Declines throughout their range has been attributed to loss or damage of riparian plants due to cattle grazing, stream diversions, off-road vehicles, camping, and human social trails (USFWS 2014c). Flooding (and other factors) in the aftermath of fires has also damaged jumping mouse habitat (USFWS 2020a).



New Mexico meadow jumping mouse. Image Credit: ©Jennifer Frey.

In the 2014 United States Fish and Wildlife Service (USFWS) species status assessment, only 29 extant populations of jumping mouse were reported from 2005 to 2013 (two in Colorado, 15 in New Mexico, and 12 in Arizona) (USFWS 2014c). Since the 2014 assessment, the number of known populations has risen to 77 (18 in Colorado, 22 in New Mexico, and 37 in Arizona) (USFWS 2020a). Ten of the 77 populations occur in the Jemez Mountains, including one in VALL (USFWS 2020a). The rise in known populations is largely due to increased surveys in areas that had not been previously surveyed or surveys of areas where jumping mice had not been previously detected, adding 39 new populations to the 2014 estimate (USFWS 2020a). Additionally, there have been changes in how a population is defined. The USFWS (2020a) defines a jumping mouse population as

"detections that are located along functionally connected streams, are within dispersal distance from one another (1 km [3,281 ft]), do not have barriers between detection sites, and were detected from 2005 to 2018."

3.5.2. Status of Knowledge

Nine of the 10 current (i.e., since 2005) jumping mouse populations in the Jemez Mountains are in three designated critical habitat subunits. Primary habitat meets the USFWS minimum patch size and connectivity requirements for viable and healthy populations. Secondary habitat patches are those that do not meet the USFWS minimum criteria but may support jumping mice (Figure 3.5.2-1).

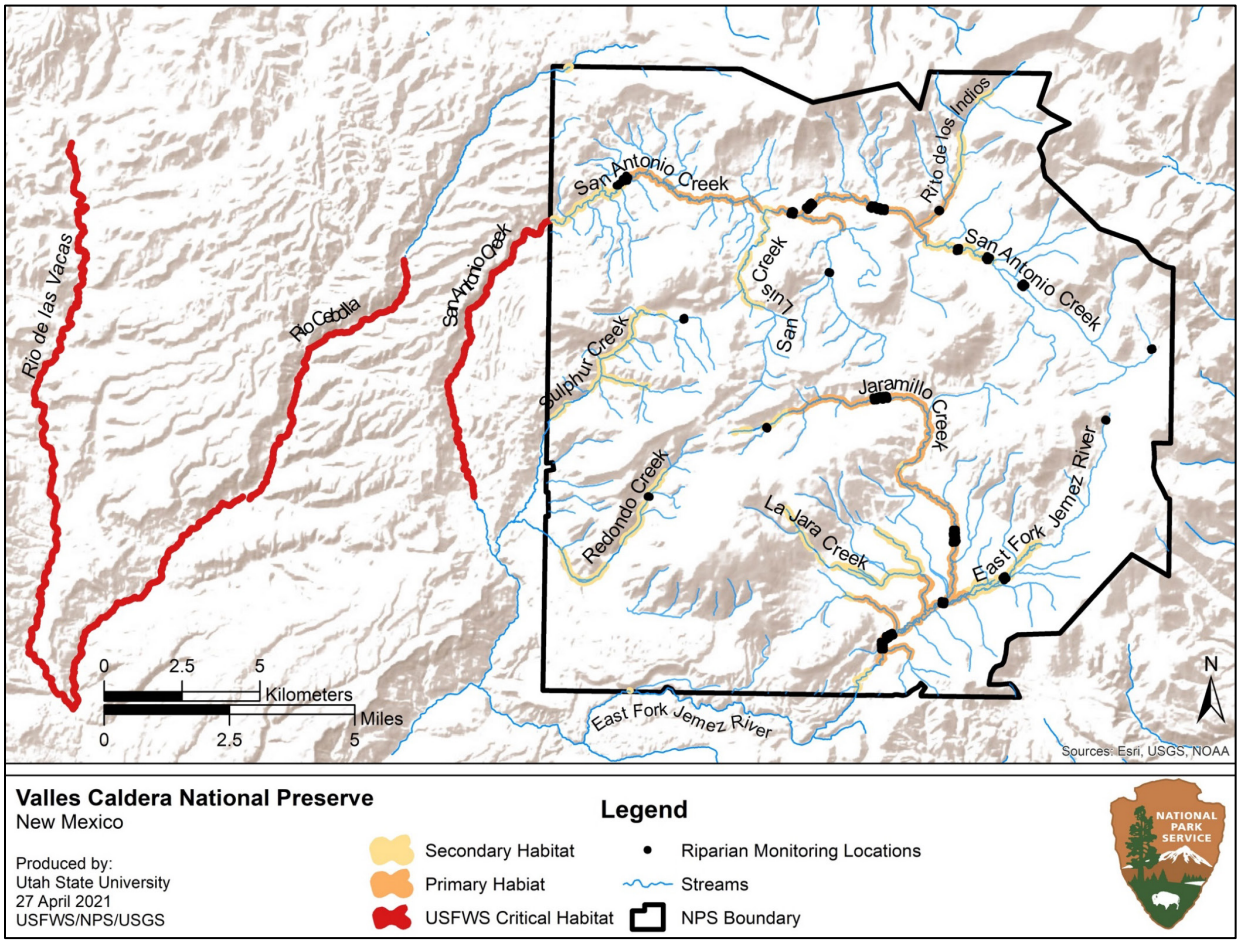


Figure 3.5.2-1. USFWS designated critical habitat and potential habitat for the New Mexico meadow jumping mouse in and around VALL.

The USFWS critical habitat subunits include the San Antonio Creek (two current populations), the Rio Cebolla (six current populations), and the Rio de las Vacas (one current population) (see Figure 3.5.2-1). The tenth population was recently discovered along Redondo Creek in VALL. When the USFWS designated critical habitat in 2016, this population had not yet been discovered, although there is a historical record at this location from the 1970s (USFWS 2020a).

In 2018, NPS staff at VALL, in cooperation with Northern Arizona University, used track plates to detect jumping mice at two locations on Redondo Creek (USFWS 2020a). The tracks along Redondo Creek were confirmed with the capture of an adult male on 25 August 2018 (NPS VALL, M. Peyton, wildlife biologist, e-mailed file to Lisa Baril, Utah State University, 15 April 2021; USFWS 2020a). These were the first confirmed observations of jumping mice in VALL in more than 40 years, but no formal surveys have occurred in the preserve prior to this observation, so it's possible that jumping mice have persisted at this location since the 1970s sighting (NPS, M. Peyton, wildlife biologist, comments to draft assessment, 6 April 2021).

There are three historical observations of jumping mice in the preserve (one confirmed and two that need verification). In the mid-1970s, a jumping mouse was confirmed at a beaver pond "on a gentle northwest slope of Redondo Peak" along Redondo Creek (Frey and Malaney 2009). The remaining two locations occurred along San Antonio Creek and were included in the USFS' Natural Resources Inventory for the Santa Fe NF (NPS VALL, M. Peyton, wildlife biologist, e-mailed USFS file to Lisa Baril, Utah State University, 20 April 2021). According to the GIS database, one location originated in Findley et al. (1975 as cited in Frey (2007)) and the other in Morrison (unknown date as cited in Frey (2007)). Although the USFWS GIS shapefile does not include a date, Morrison (1985) reported the results of jumping mice surveys in the Jemez Mountains, and one or both surveys are the likely sources from which the locations originated. Utah State University was unable to obtain copies of the original reports.

Notably, in a review of historic locations in the Jemez Ranger District of the Santa Fe NF, Frey (2007) did not include the San Antonio Creek locations but reviewed Findley et al. (1975) and Morrison (1985, 1989). However, earlier reports may have incorrectly identified some observations of the New Mexico meadow jumping mouse as the western jumping mouse (*Z. princeps*) (NPS, M. Peyton, wildlife biologist, comments to draft assessment, 6 April 2021), which is now confirmed as absent in the Jemez Mountains (Frey 2008). Some of the confusion may also be due to the various classifications of *Z. h. luteus*. The New Mexico meadow jumping mouse was first classified as a separate species (*Z. luteus*) in 1911, then as a subspecies of the western jumping mouse (*Z. princeps luteus*) in 1954, and finally as a subspecies of meadow jumping mouse (*Z. hudsonius luteus*) by 1981 (Malaney et al. 2012).

To identify the potential jumping mouse habitat in VALL, we used the wetlands map created for the restored wetlands condition assessment (refer to section 3.4 for details on methods) and the field data collected along perennial streams in the preserve from 2002 to 2011. The UFWS considers a 30-m (100-ft) buffer along a perennial stream of at least 9 km (5.6 mi) as required to support multiple, resilient jumping mouse populations (USFWS 2020a). This results in a patch size of 28–74 ha (68–182 ac). Based on these criteria, we created a 30-m (100-ft) buffer on either side of all perennial streams in VALL, using the United States Geological Survey's (USGS) National Hydrography Dataset (USGS 2020). The results were then summarized by patch size, the number of patches, and the connectivity between patches, according to the habitat characteristics described above (USFWS 2020a). Four areas of potential habitat in VALL met the minimum patch size for supporting multiple, resilient jumping mouse populations (Table 3.5.2-1).

Table 3.5.2-1. Summary of patch size and connectivity for potential New Mexico meadow jumping mouse habitat in VALL.

Stream	Presence of Perennial Flowing Water	# of Suitable Patches along Streams of Minimum Area for Population Viability	Stream Length in km (mi)	Total Area in ha (ac)	Connectivity to Other Suitable Patches
Jaramillo Creek (upper)	Yes	1	9 (5.6)	27 (66.7)	No
East Fork Jemez Complex	Yes	1	14.3 (8.9)	54 (133.4)	No, but this complex is large enough to potentially support multiple populations.
San Antonio Creek	Yes	2	14.8 (9.2)	47 (116.1)	No. The distance between the two patches is > 600 m (>1,969 ft).

One patch was along the upper Jaramillo Creek; another was along the East Fork Jemez River, La Jara Creek, and lower Jaramillo Creek (referred to as East Fork Jemez Complex); and the last two patches were along San Antonio Creek (see Figure 3.5.2-1). All four patches were separated from each other by more than 200 m (656 ft), which is the maximum recommended distance for connectivity between subpopulations (USFWS 2020a), but connectivity within each patch was continuous.

Although jumping mice may disperse more than 1 km (0.6 mi), and perhaps as far as 4 km (2.5 mi), they need suitable habitat to make these forays (USFWS 2014c). The distance between the East Fork Jemez Complex and the upper Jaramillo Creek is about 0.4 km (0.2 mi). The distance between the two San Antonio Creek patches is about 0.6 km (0.4 mi). Both are potentially within the dispersal and exploratory distances that jumping mice may undertake, but if appropriate habitat does not link these patches, then jumping mice may not be able to travel between them.

Additional jumping mouse habitat was identified in VALL along the western San Antonio Creek, eastern San Antonio Creek, Rito de los Indios, Sulphur Creek, Redondo Creek, and La Jara Creek (Figure 3.5.2-1), which may meet the minimum habitat requirements if potential habitat is mapped outside of the preserve. For example, the western portion of San Antonio Creek, which is in the preserve, is considered secondary habitat but may be primary habitat when considered along with downstream habitat in the Santa Fe NF (Figure 3.5.2-1).

It's important to note that the 2018 capture of a jumping mouse along Redondo Creek did not occur in an area of the mapped potential habitat, suggesting that small, but important, habitat patches were not adequately identified using the wetland classification. Note that ongoing wetland restoration efforts (beginning in 2012) have not yet connected Redondo Creek to other known occupied jumping mouse habitat, but this is of high priority for additional work in 2021 (NPS, M. Peyton, wildlife biologist, comments to draft assessment, 6 April 2021).

The USFWS (2020a) considers certain stream channel types as supporting primary jumping mouse habitat. In 2012, surveyors applied the Rosgen Classification System (Rosgen 1994, 1996) to streams in the preserve (McWilliams 2012). San Antonio Creek, East Fork Jemez River, and the Jaramillo Creek (except in the extreme upper reaches) were all classified as Rosgen E-type streams (McWilliams 2012). C and E streams, characterized by low gradient (≤2%), moderately meandering channels with a shallow groundwater table capable of supporting herbaceous and woody shrubs, are ones that the USFWS considers suitable habitat.

In addition, the USFWS (2020a) considers Rosgen B-type streams as potential dispersal corridors to more suitable habitat patches. B-type streams are characterized by a moderate gradient (2–4%), meandering stream channel with limited floodplain development or small, patchy floodplains resulting from the accumulation of woody debris. The Rito de los Indios was characterized as a B/E stream, depending on the reach (McWilliams 2012). Sulphur Creek was classified as a B-stream type along much of its length, until exiting the preserve where it is classified as an A-stream type (McWilliams 2012). Redondo Creek begins as an A-type stream but exits the preserve as a B-type stream. A-type streams are generally entrenched or characterized by gradients too steep to support riparian vegetation and are not considered suitable for jumping mice (USFWS 2020a). The Rosgen classification of streams in the preserve are consistent with the potential habitat mapped in Figure 3.5.2-1. Primary habitat was generally mapped along E-type streams, while secondary habitat was generally mapped along B-type streams.

From 2002 to 2019, VALL staff monitored vegetation in 24 riparian plots and seven headwater plots, although annual effort varied by plot type. Because few plots were monitored post-2011, we excluded data collected after this time. Headwater plots were located at the source of the San Antonio and Jaramillo creeks, and the East Fork Jemez River, as well as a few smaller tributaries in the preserve. Riparian plots were located along San Antonio Creek, Rito de los Indios, Jaramillo Creek, Redondo Creek, and the East Fork of the Jemez River. Riparian plots were stratified by grazing type: ungulate exclosure (n = 6), livestock exclosure (n = 6), and control (n = 12). The ungulate exclosure plots were designed to keep elk and other large grazers from entering. The livestock exclosure plots were designed to allow elk to enter but exclude cattle. The control plots were not fenced.

Canopy height of herbaceous vegetation and species composition was recorded at 1-m (3.2-ft) intervals along three 100-m (328-ft) transects in the 24 riparian plots. Because of the narrower riparian corridor in headwater sites, there were only two 50-m (164-ft) transects. All transects bisected the stream channel. Because jumping mice are generally found within 30 m (100 ft) of the stream channel, we subset riparian line transect data to the inner 30 m (98 ft), or 15 m (49 ft) on each side of the stream to coincide with the USFWS habitat characteristics described above. Plant cover and height were recorded using the line intercept method. We averaged herbaceous plant height by plot type/treatment and summarized species richness and cover of herbaceous plants based on their USDA wetland indicator status for the western mountain region (USDA 2014). Cover was calculated by determining the number of "hits" along a line transect, then dividing by the total number of points along the transect.

Herbaceous plant height increased from 2002 to 2011 in all plot types (Figure 3.5.2-2). Mean height was similar by plot type and ranged from 27.1 cm (10.7 in) in control plots to 30.9 cm (12.2 in) in ungulate exclosure plots.

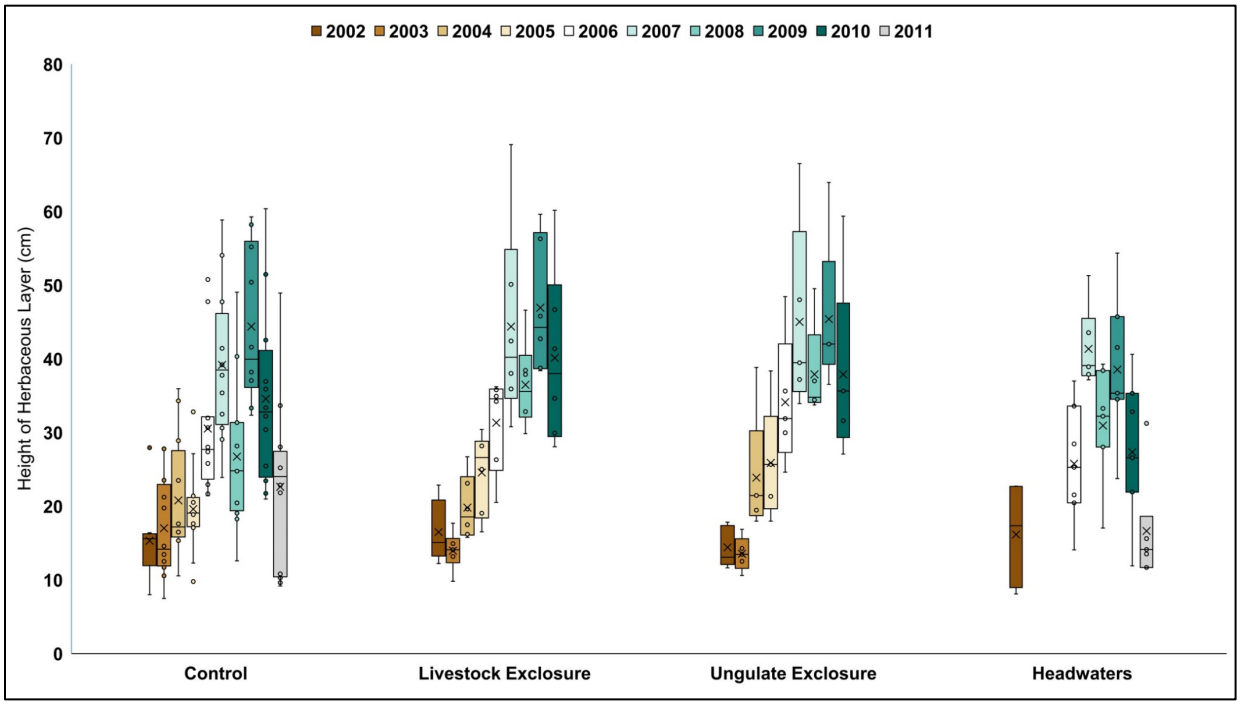


Figure 3.5.2-2. Boxplots of herbaceous plant height measured in the four riparian treatment types from 2002 to 2011.

The USFWS (2020a) cites a minimum herbaceous plant height of 61 cm (24 in) for ideal mouse habitat, but this is based on Frey (2017), who captured mice at sites with an average stubble height of 60.1 cm (~24 in), as opposed to sites with an average stubble height of 54.8 cm (21.6 in) where no mice were captured. In comments to an earlier draft of this evaluation, J. Frey wrote that the height criterion cited in USFWS (2020a) only applies to capture sites and was not meant to represent vegetation height across an entire site (New Mexico State University, J. Frey, professor of mammalian diversity and conservation, comments to draft evaluation, 9 April 2021). Furthermore, Frey (2017) used a Robel pole to measure all vegetation, including woody shrubs, while VALL used a measuring tape and only recorded the height of the tallest herbaceous plant.

Grasses were the dominant cover type in all treatments, (2002–2011), with similar amounts in each treatment type (Figure 3.5.2-3). Absolute grass cover averaged 157% across the four treatments. Cover exceeded 100% because observers recorded multiple layers of vegetation from the tallest herbaceous plant to the ground layer. Absolute forb/herb cover averaged 57% across the four treatment types with similar amounts in each. The livestock exclosure plots exhibited slightly higher cover than the other treatment types (Figure 3.5.2-3).

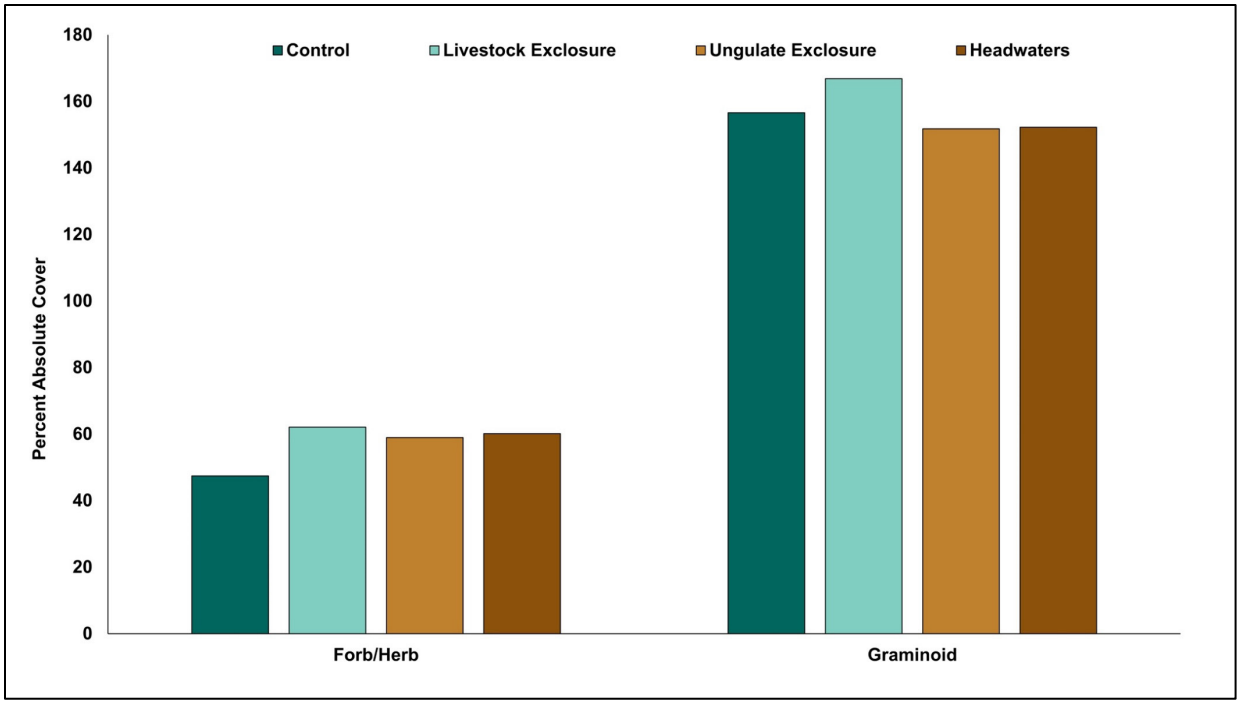


Figure 3.5.2-3. Average (2002–2011) absolute percent cover by lifeform in the four riparian treatment types.

Relative to the other wetland plant types, obligate wetland (i.e., always occurs in wetlands), facultative wetland (i.e., usually occurs in wetlands, but sometimes occurs in non-wetlands), and facultative (i.e., occurs in wetlands and non-wetlands) plants represented between 12% and 27% of forb/herb cover (Figure 3.5.2-4). Cover of wetland plants was highest in the headwater plots and lowest in the ungulate exclosure plots. Relative cover of the wetland plants was substantially higher for graminoids in all treatment types. Obligate and facultative wetland plants represented between 32% to 39% cover of grasses, sedges, and rushes. Cover of facultative plants was highest in all four treatment types, representing between 35% and 50% relative cover.

Of the grasses, Kentucky bluegrass, a non-native plant, was the most common species in all four treatment types. Other common graminoids included the native wetland obligates, mountain rush (*Juncus arcticus*) and water sedge (*Carex aquatilis*). The non-native facultative species, timothy grass (*Phleum pratense*), was also common in all treatment types, except headwaters. In the headwater plots, the native upland (i.e., does not occur in wetlands) species, Parry's oatgrass and tufted hairgrass, were common. Graminoid richness was highest in the headwater plots (56), control plots (55), and ungulate exclosure plots (52). Graminoid richness was lowest in the livestock exclosure plots (40).

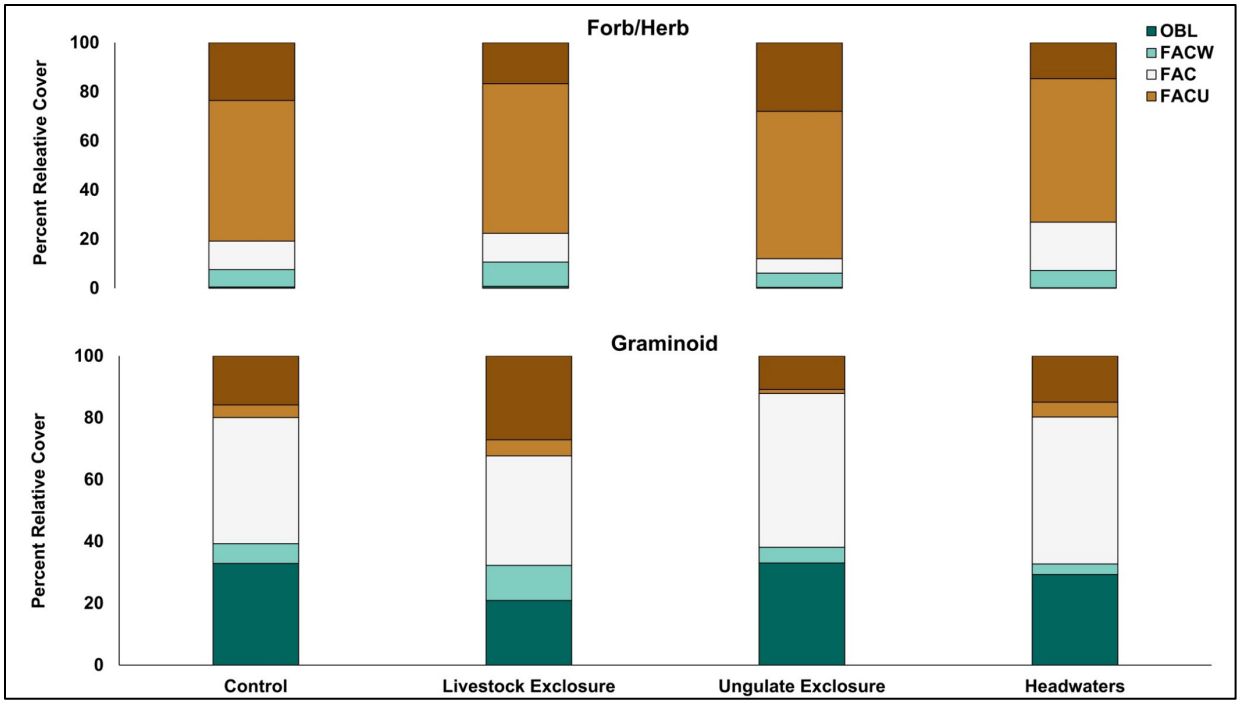


Figure 3.5.2-4. Average relative percent cover (2002–2011) by wetland status for forbs/herbs (top) and graminoids (bottom) in the four riparian treatment types.

In all four treatment types, the most common forb/herb was the native western yarrow (*Achillea millefolium*), followed by the non-native common dandelion. Both species are facultative upland plants. The natives, beautiful fleabane (*Erigeron formosissimus*) and western aster (*Symphyotrichum ascendens*), were also in the top five most common species. Beautiful fleabane is an upland species, while western aster is a facultative upland species. Forb/herb richness was highest in the headwater plots (64) and control (61) plots, with 40 species in each of the exclosure plot types.

Although jumping mouse habitat may also include woody shrubs like willow and alder (*Alnus* spp.), strapleaf willow (*S. ligulifolia*) was extremely rare, and only observed a few times in the control plots, while thinleaf alder was rarely observed in the headwater plots. The headwater plots also supported white fir, ponderosa pine, limber pine (*Pinus flexilis*), Douglas-fir, and quaking aspen. The bases of shrubs and trees may provide jumping mouse hibernation habitat and overstory cover for maternal nests (USFWS 2020a). Although we did not differentiate between riparian wetland types in the potential habitat mapping analysis, jumping mice occur in both types found in VALL (i.e., herbaceous wetlands and riparian shrublands dominated by a thick herbaceous understory) (Muldavin et al. 2006; USFWS 2020a). However, riparian shrublands are rare in the preserve (Muldavin et al. 2006).

3.5.3. Discussion

Two indicators and seven measures are proposed for conducting a future condition assessment of New Mexico meadow jumping mouse habitat in the preserve (Table 3.5.3-1). These were selected based on the USFWS (2020a) habitat criteria to support resilient populations of jumping mice. There are two measures of patch size and connectivity and five measures of within-patch habitat quality.

Because the number of individuals needed to maintain a viable and stable population of jumping mice is unknown, the USFWS uses patch size as a proxy (USFWS 2020a). The habitat patch size and stream length described in Table 3.5.3-1 have a higher likelihood of accounting for stochastic events, such as wildfire and floods (USFWS 2020a).

Table 3.5.3-1. Proposed study details for New Mexico meadow jumping mouse habitat (USFWS 2020a). Note: FAC = facultative plants (occurs in wetlands and non-wetlands); FACW = facultative wetland plants (usually occurs in wetlands, but sometimes occurs in non-wetlands); OBL = obligate wetland plants (almost always occurs in wetlands).

Indicator	Measure	Reference Criteria for Measure
Patch Size and Connectivity	Wetland Patch Size	30 m (100 ft) of wetland/riparian habitat across the active water channel along at least 9 km (5.6 mi) of perennial streams, which results in a patch size of 28–74 ha (68–182 ac).
	Connectivity Between Suitable Patches	All suitable patches are a maximum of 200 m (656 ft) apart.
Within-patch Habitat Quality	Presence of Perennially Flowing Water	Persistent streamflow with no stagnant water during summer.
	Soil Moisture	Soils moist, but little or no standing water.
	Height of Herbaceous Vegetation	≥60 cm (24 in) tall within 5 m (15 ft) of water.
	Herbaceous Vegetation Density	Present and dense (>75% cover), within 5 m (15 ft) of water present.
	Herbaceous Composition	Mix of >20 species classified as OBL, FACW, and FAC species.

We identified the patch size and connectivity measures via the potential habitat mapping analysis; however, the wetlands classification map needs to be ground-truthed. Additionally, the 30-m (100-ft) scale of the imagery used in the classification likely missed smaller habitat patches that may be important to jumping mice. While the reference criteria described in Table 3.5.3-1 detail the need for large habitat patches to sustain multiple resilient populations, smaller patches may serve as dispersal corridors or areas that support small populations. Larger patches may serve as the sources to populate these smaller areas.

We summarized the riparian monitoring data to report on some aspects of within-patch habitat quality, such as species composition and the presence of perennially flowing water; however, soil moisture and the density of herbaceous cover data were lacking. And while we summarized canopy height of the herbaceous vegetation, there appears to be more nuance to this measure than the USFWS (2020a) species status assessment suggests (New Mexico State University, J. Frey, professor of mammalian diversity and conservation, comments to draft evaluation, 9 April 2021).

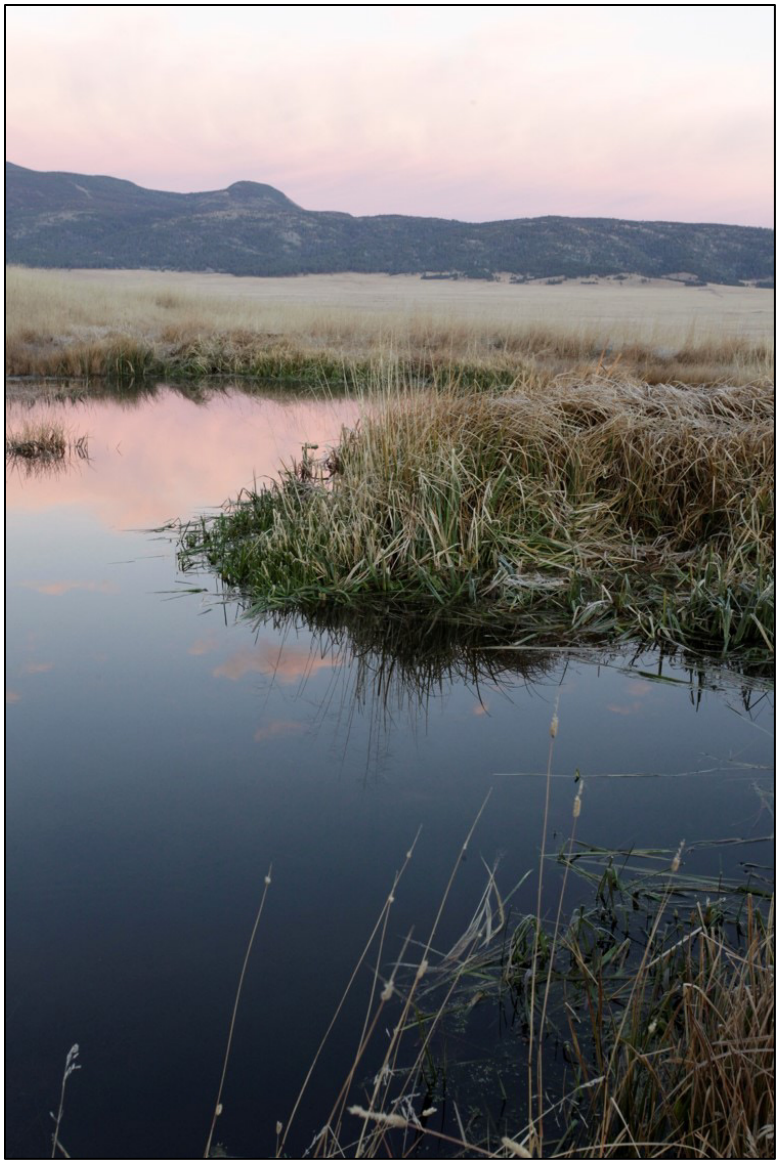
Jumping mice usually are found below 2,438 m (8,000 ft) (USFWS 2020a), but the 2018 capture site along Redondo Creek was at 2,689 m (8,800 ft), and the two San Antonio reports occurred above

2,500 m (8,202 ft). In the primary habitat, elevations ranged from 2,553 m to 2,735 m (8,376 to 8,973 ft), with a mean of 2,644 m (8,675 ft). In the secondary habitat, elevations ranged from 2,412 m to 3,003 m (7,913 to 9,852 ft), with a mean of 2,677 m (8,783 ft). Because most jumping mouse populations occur lower than the habitat in VALL, and most studies of jumping mouse habitat occurred in areas lower than 2,438 m (8,000 ft), it's possible that VALL's shorter growing season and harsher conditions prevent the tall growth of herbaceous riparian plants.

Adjustments to VALL's current riparian monitoring protocol may address some data gaps for the jumping mouse. For example, moist soils are an important habitat characteristic for jumping mice but standing water deeper than 2 cm (0.8 in) over large areas is undesirable (although jumping mice can swim short distances and may use these areas for dispersal). Jumping mice also require adjacent uplands with drier soils for rearing young and for hibernation. A simple, qualitative soil moisture metric recorded along riparian transects could fill this data gap. The herbaceous density data gap could be addressed by using a Robel pole to estimate cover at each of the 1-m (3-ft) intervals where vegetation is monitored. Sampling along additional stream reaches, especially ones identified as potential habitat, may better represent the extent of jumping mouse habitat.

An alternative (or perhaps complementary) approach is to use a rapid assessment scorecard. Colorado Parks & Wildlife (CWP) has developed a scorecard that includes six criteria, each with three levels of condition, ranging from good to poor (CWP 2020). Each criterion is assigned a value based on the three levels. The values are tallied for an overall score of how well the habitat meets jumping mouse requirements. For example, one criterion is the density of herbaceous plants within 5 m (15 ft) of flowing water. The three levels are: Good (>75% cover); Moderate (>50–75% cover); and Poor (35–50% cover) (CWP 2020). Some of the criteria in the CWP scorecard are less stringent than those outlined in the USFWS (2020a) species status assessment to account for smaller, but potentially important, habitat patches. The development and use of a scorecard could serve as an alternative approach to in-depth riparian monitoring, at least for an initial pass at potential habitat. VALL staff could then focus on the areas with the highest scores for more intensive monitoring.

Timing of the jumping mouse monitoring in the Jemez Mountains would coincide with when they are active—from late May or early June to late September or early October (USFWS 2020a). During the remainder of the year, jumping mice hibernate in drier upland areas close to riparian areas. Jumping mice are cued to emerge in spring by the rising soil temperature and to enter hibernation based on the photoperiod. Little is known about hibernacula since only one has been found to date, but possibly four others were found in 2016 (USFWS 2020a). All four sites were located underground and below shrubs at least 1 m (3 ft) from perennially flowing water (USFWS 2020a). While photoperiod is a fixed cue that does not change from year to year, soil temperature, cuing spring emergence, is variable. Elevation, snow cover, and air temperature influence soil temperature (USFWS 2020a). These factors are shifting with climate change to warmer temperatures in spring, earlier snowmelt, and less winter precipitation (USFWS 2020a) and would impact the timing of monitoring.



New Mexico meadow jumping mouse habitat in VALL. Image Credit: NPS.

The USFWS (2020a) assessed the condition of three critical habitat and demographic factors for the Jemez Mountains, and the overall condition for jumping mice was considered moderate. While the number of captures from 1988 to 2018 was high, the number of current populations is moderate, and connectivity between populations is considered very low. The size of suitable habitat to support population persistence was also low. These scores could improve if more populations were found in VALL's existing habitat. The USFWS goal for the Jemez Mountains is to expand existing population sizes by increasing suitable habitat in the drainages in which the jumping mouse currently occurs, and to restore additional populations in other unoccupied drainages (USFWS 2014c). Current threats include small, isolated populations, grazing (particularly by livestock), water utilization, loss of beaver, wildfires, and severe flooding in the aftermath of wildfires (USFWS 2020a).

3.6. Songbirds (Condition Assessment)

3.6.1. Background & Importance

VALL is a National Audubon Society (NAS) Important Bird Area (IBA) (NAS 2008), providing habitat to at least 40 species of concern, including cordilleran flycatcher (*Empidonax occidentalis*), northern goshawk (*Accipiter gentilis*), olive-sided flycatcher (*Contopus cooperi*), and Williamson's sapsucker (*Sphyrapicus thyroideus*) (NM-ACP 2016; NMDGF 2016; PIF 2017), and both species of eagle are protected under the Bald (*Haliaeetus leucocephalus*) and Golden Eagle Protection Act (USFWS 1940). While the IBA designation does not carry any regulatory status, the endorsement may provide leverage when requesting funds for research, restoration, and/or conservation activities that benefit birds. Although national parks are generally strongholds for wildlife and plants, climate change has already caused range shifts and changes in behavior for some bird species, including earlier nesting in spring and later migration in autumn (Wu et al. 2018). In addition to climate change, birds face numerous threats throughout their range, including loss of habitat, contaminants and pollution, reflective buildings and wind farms, bright city lights that disorient birds when migrating at night, and predation by domestic cats (Rosenberg et al. 2019). These and other threats have contributed to a nationwide decline of nearly 30% of total individuals (an estimated three billion birds) since the 1970s (Rosenberg et al. 2019).



Grace's warbler. Image Credit: ©Robert Shantz.

According to NPS Management Policies (NPS 2006), a major goal is to "manage state and locally-listed species in a manner similar to its treatment of federally listed species." The Policy also states that the "Service will inventory…native species that are of special management concern to parks (such as rare, declining, sensitive, or unique species and their habitats) and will manage them to maintain their natural distribution and abundance" (NPS 2006). Many of the species of concern in

VALL are neotropical migrants (i.e., long-distance migrants), which are also protected under the 1918 Migratory Bird Treaty Act (USFWS 1918).

3.6.2. Study Framework

The primary objectives of the songbirds condition assessment were to 1) update VALL's checklist of birds for both public and managerial use, 2) identify indicator species within each of the preserve's major habitats, 3) assess the current condition of songbird community composition by habitat type, and 4) address gaps in knowledge across bird groups and seasons.

The songbird community composition indicator included two measures, richness and abundance (Table 3.6.2-1), which are widely used to summarize point count data (Nur et al. 1999). A condition rating was reported for the community composition of songbirds (Order Passeriformes) and woodpeckers (Order Picoides) because point count surveys are not designed for other bird groups (e.g., hummingbirds, swifts, raptors, waterfowl, shorebirds) (Ralph et al. 1993). Data for other bird groups (e.g., owls) were reported, but conditions were not evaluated.

Table 3.6.2-1. Study details for songbirds.

Indicator	Measure	Reference Criteria for Measure
Community Composition	Richness	Species expected to occur in each of the five habitat types surveyed are present.
	Abundance	No significant declines in abundance over the five to eight years of point count surveys for species of concern by habitat type.

The bird studies in VALL include songbird monitoring (Hawks Aloft, Inc. 2017, 2018; Fettig et al. 2013); diurnal raptor surveys (Johnson 2001, 2003, 2005; Keller 2009); nocturnal raptor surveys (Foy et al. 2012; Hathcock et al. 2004; Hathcock and Keller 2005); and a habitat, movement, and survival study of the Merriam's wild turkey (*Meleagris gallopavo merriami*) (Peyton et al. 2014). Of these, only the songbird studies are part of VALL's long-term monitoring efforts, although owls were re-surveyed beginning in spring 2020 as part of a 3-year study on the preserve's owl community (NPS, R. Parmenter, Chief of science and resource stewardship, NRCA scoping meeting, 4 December 2019).

VALL's ongoing songbird monitoring studies are of two types. The first is a point count study conducted by Hawks Aloft, Inc. as part of the USFS' Southwest Jemez Mountains CFLRP (USFS 2015). The second is similar to a point count study and is modeled after the USGS' Breeding Bird Survey (BBS) (Fettig et al. 2001; Sauer et al. 2017). The four routes in the preserve (two surveyed by Hawks Aloft, Inc. and two surveyed by the Los Alamos National Laboratory (LANL)) are not part of the main USGS continent-wide BBS program. We summarized Hawks Aloft, Inc. and LANL data (NPS VALL, M. Peyton, wildlife biologist, file received by Lisa Baril, Utah State University, 7 November 2019). Note that Hawks Aloft, Inc. 2020 data became available after the analyses had been completed. Although we were unable to include these data in the analyses, we updated the species of concern checklist with the 2020 data.

3.6.3. Data & Methods

To identify indicator species for VALL's major habitat types, we used Birds of the World (2020) online subscription database and the Sangre de Cristo Audubon Society's (1997) checklist of birds in the USFS' Santa Fe NF, which includes habitat associations for each species. The major habitat types were based on Muldavin et al.'s (2006) vegetation map for VALL and included: mountain meadow (mesic), mountain valley grassland (xeric), aspen woodlands, ponderosa pine forest, mixed coniferous forest, spruce-fir forest, riparian shrublands/woodlands, and open water. Although the latter two habitat types represent <1% of the preserve (Muldavin et al. 2006), riparian habitat supports a disproportionate number of species given its limited distribution (Knopf et al. 1988), and open water habitat hosts species not found in other habitat types (e.g., wading birds and waterfowl) (Kushlan et al. 2002). All confirmed species, excluding vagrants, accidental species, and species with few observations, were listed by their habitat preferences; however, we considered only those species that occur primarily in one or two habitat types as indicator species for those habitats.

For the richness and abundance measures, our analyses included songbirds and woodpeckers, except for swallows, which are not adequately surveyed by point counts (Ministry of Environment, Lands & Parks 1998). The analyses included those species that are present during summer to coincide with the timing of the point count surveys (May–July).

Hawks Aloft, Inc. conducted surveys in five of the major habitats from 2012 to 2019, but the effort varied by habitat and by whether the habitat was burned or unburned (see Hawks Aloft, Inc. 2018 for more details) (Figure 3.6.3-1). Some plots, except for those in the mountain meadow habitat, burned during the 2011 Las Conchas and 2013 Thompson Ridge fires. Burned plots in each of the habitat types were analyzed separately. The sample sizes and survey dates varied: ponderosa pine (2012–2018) unburned (n = 28) and burned (n = 10); mixed conifer (2012–2019) unburned (n = 23) and burned (n = 14); mountain valley grassland (2012–2016) unburned (n = 6) and burned (n = 12); riparian (2012–2014) unburned (n = 10) and burned (n = 6); and mountain meadow (2012–2016) unburned (n = 1).

We assessed the songbird and woodpecker richness measure for each habitat type by comparing potential species based on the checklist to the species observed during the Hawks Aloft, Inc. surveys. We then determined the percent of potential species observed during the Hawks Aloft, Inc. surveys.

For the songbird and woodpecker abundance measure, we subset the species of concern list to those with at least 50 detections in each habitat type. This ensured a large enough sample size for a simple linear regression analysis of abundance over time.

Lastly, we analyzed songbird and woodpecker richness and abundance for the two BBS routes established by LANL in 2001 (BBS East) and 2002 (BBS West). We also summarized data collected by Hawks Aloft, Inc. along two BBS routes that were established in 2016 (Redondo Border and Valle Grande). The Hawks Aloft, Inc. BBS routes follow very similar paths as the LANL BBS routes (Figure 3.6.3-1).

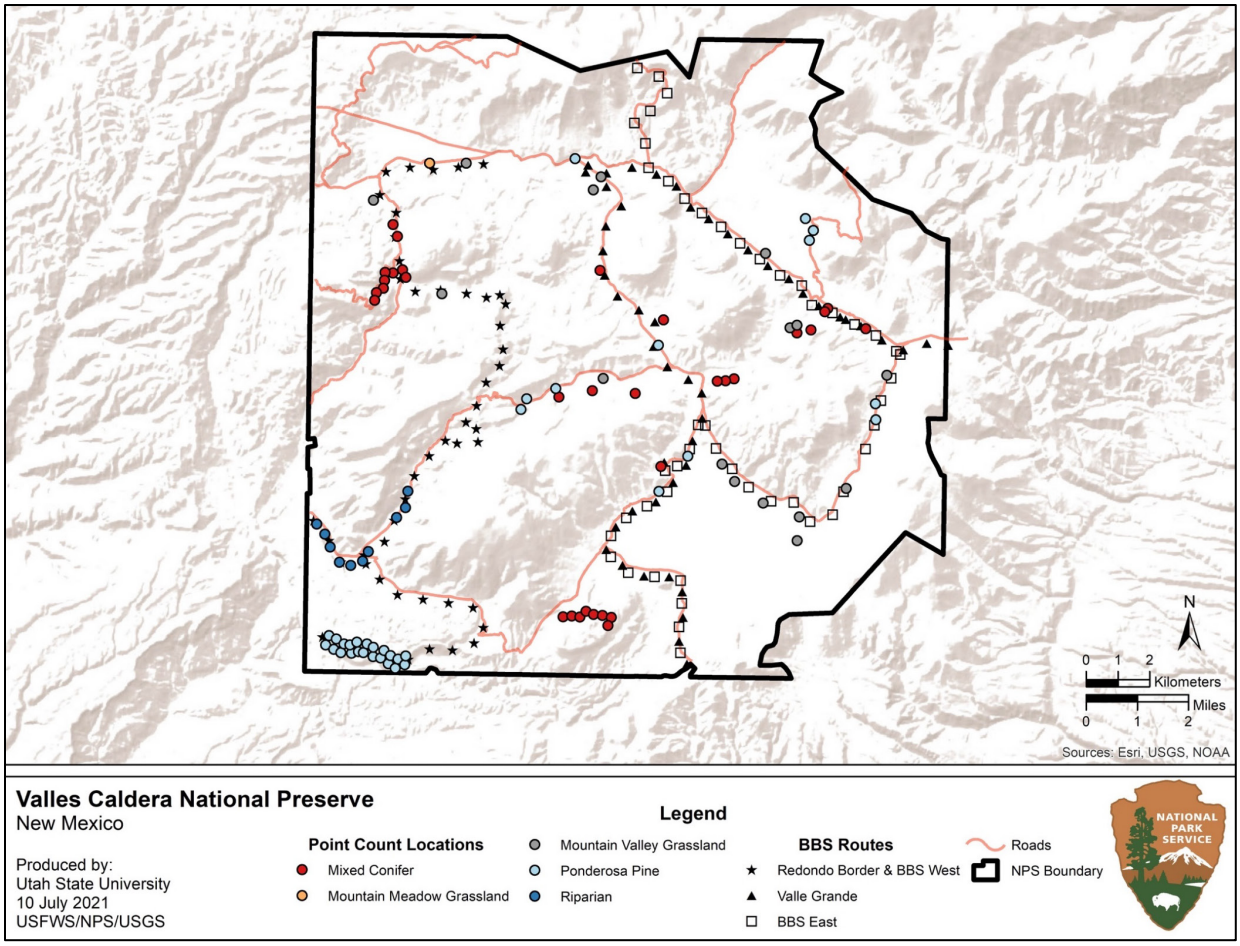


Figure 3.6.3-1. Bird point count locations by habitat and breeding bird survey (BBS) routes in VALL.

Prior to all analyses, we checked for normally distributed data using normal probability plots and plots of the distribution of residuals. For data that did not meet the assumption of normality, we used a natural log transformation. Statistical significance was set at $\alpha = 0.05$.

3.6.4. Results & Discussion

We confirmed 196 bird species for VALL, 117 of which breed in or are suspected of breeding in the preserve. Excluding vagrants, accidental species, and species with few observations, we determined habitat preferences for 143 species. Total potential species richness is highest for ponderosa pine forests (69) and lowest for open water (23) (Figure 3.6.4-1). Mixed coniferous forest and riparian habitat support 64 and 59 species, respectively. Although richness in open water habitats suggests this community is species-poor, this habitat type has not been surveyed in the preserve. Observations of open water habitat were based entirely on observational data reported in eBird (2017). Similarly, there have been no surveys in aspen and spruce-fir forests, although NPS staff conducted a bioinventory of Redondo Peak in 2014, which includes the latter habitat type. Those data were not available for inclusion in this assessment.

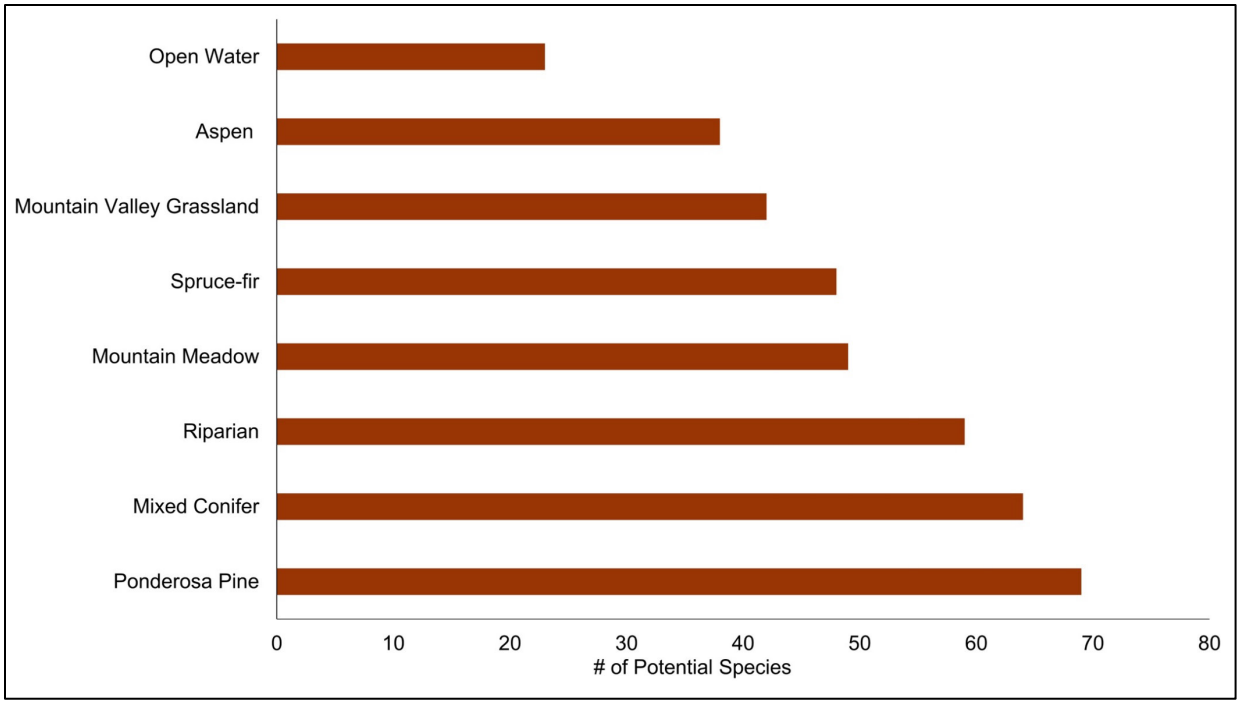


Figure 3.6.4-1. Total potential species richness by habitat type in VALL.

For summer richness, we found that mixed conifer-burned plots exhibited the highest overlap with the checklist (84% of potential species represented), followed by ponderosa pine (76% overlap) and ponderosa pine-burned plots (73% overlap) (Figure 3.6.4-2). While ponderosa pine plots, regardless of whether they were burned or not, exhibited similar species overlap, mixed conifer-burned plots exhibited substantially more species overlap with the checklist (84%) than mixed conifer plots that were unburned (53%). Not surprisingly, burning had the opposite effect on riparian habitat, which is generally not a fire-adapted habitat.

In riparian and mountain meadow (mesic) plots, there were fewer species observed than expected, but there was only one plot for the latter habitat type, and all riparian plots were located along Redondo Creek. A larger sample size and greater spatial distribution of plots within those two habitat types may increase overall richness because of differences in plant structure, species composition, and other factors that likely occur between sites.

We identified between two and 10 indicator species for each habitat type (Table 3.6.4-1). Only eastern meadowlark (*Sturnella magna*) and western meadowlark (*Sturnella neglecta*) are indicator species for more than one habitat type (mountain meadow and mountain valley grassland). These two species were also reported for more than one habitat type during Hawks Aloft, Inc. surveys. The absence of some indicator species does not necessarily reflect ecosystem degradation. It could be that a larger sample size would capture the remaining indicator species since all species listed in Table 3.6.4-1 are confirmed for the preserve.

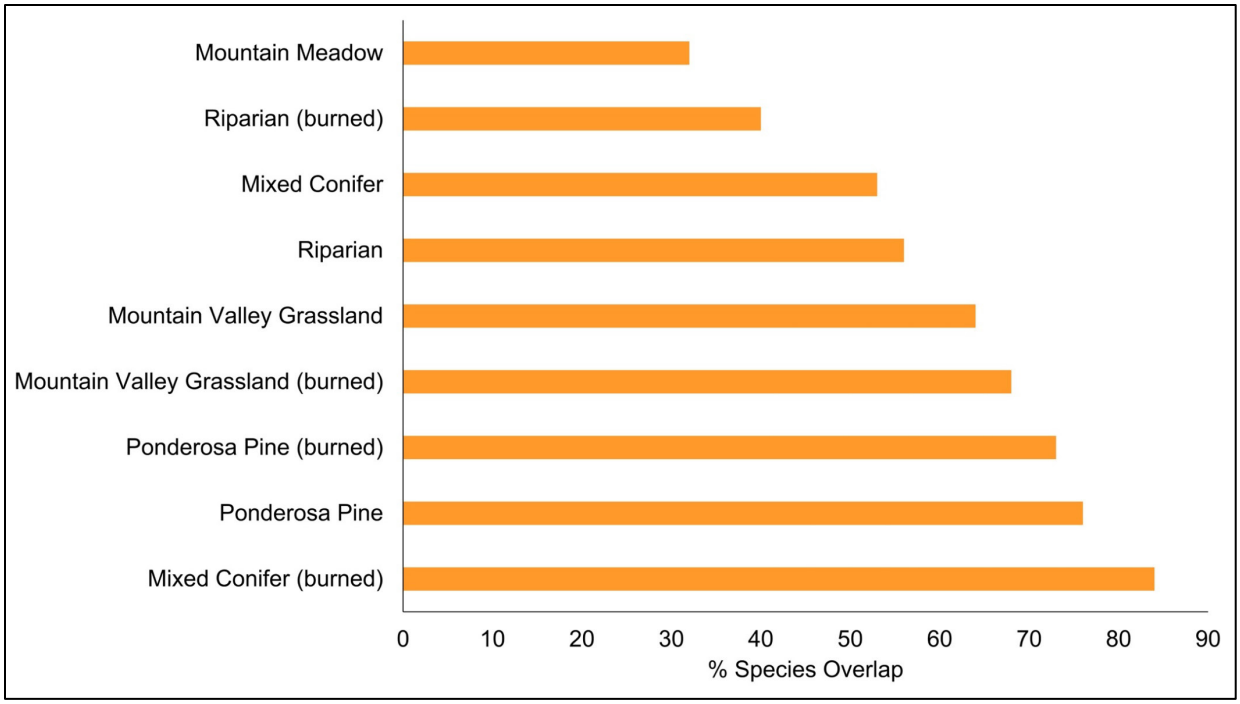


Figure 3.6.4-2. Percent of potential bird species present during the Hawks Aloft, Inc. surveys (2012–2019). Note that the potential bird species list was subset to songbirds (except for swallows) and woodpeckers that occur during the breeding season (May–July).

Based on the four species of concern lists (NMDGF 2016; USFWS 2020b; NM-ACP 2016; PIF 2017), there are 53 confirmed species of concern in VALL. Of the 53 species, eight passerines, woodpeckers, and woodpecker allies occurred with enough frequency to analyze trends over time (Table 3.6.4-2). Grace's warbler (*Setophaga graciae*) was the only species with a significant and positive trend over time. Mountain chickadee (*Poecile gambeli*) abundance declined while western bluebird (*Sialia mexicana*) abundance increased in ponderosa pine forest plots, but neither trend was significant. Although none of the species declined significantly over time, the number of years and point counts surveyed varied by habitat type, which may have influenced results.

Ponderosa pine forest and mixed conifer plots (burned and unburned) were surveyed for eight consecutive years, while mountain valley grassland plots (burned and unburned) were surveyed for only five consecutive years. Furthermore, sample sizes ranged from as many as 28 plots in ponderosa pine forest to as few as six plots in unburned mountain valley grasslands (xeric).

Table 3.6.4-1. Observations of indicator bird species, primarily songbirds, by habitat type during Hawks Aloft, Inc. surveys (2012–2019). Note: X = species detected; N/A = habitat was not surveyed; Non-target = species were not targeted for survey during Hawks Aloft, Inc. (2012–2019) study but were included to show that they are an indicator for that habitat. Note that some non-target species may have been documented during field surveys to maintain consistency in data handling.

Habitat	Indicator Species	Unburned Habitat		Burned Habitat	
		Present	Absent	Present	Absent
Mountain Meadow (mesic)	eastern meadowlark	X	–	N/A	N/A
	killdeer	Non-target	Non-target	N/A	N/A
	long-billed curlew	Non-target	Non-target	N/A	N/A
	red-winged blackbird	X	–	N/A	N/A
	sora	Non-target	Non-target	N/A	N/A
	western meadowlark	X	–	N/A	N/A
	Wilson's snipe	Non-target	Non-target	N/A	N/A
	yellow-headed blackbird	–	X	N/A	N/A
Mountain Valley Grassland (xeric)	American pipit	–	X	–	X
	Brewer's sparrow	–	X	X	–
	eastern meadowlark	X	–	X	–
	horned lark	X	–	X	–
	lark sparrow	X	–	X	–
	vesper sparrow	X	–	X	–
	western meadowlark	X	–	X	–
Riparian	Bewick's wren	X	–	X	–
	black phoebe	–	X	–	X
	black-chinned hummingbird	Non-target	Non-target	Non-target	Non-target
	black-headed grosbeak	X	–	–	X
	blue grosbeak	–	X	–	X
	Bullock's oriole	–	X	–	X
	MacGillivray's warbler	X	–	X	–

[1] These habitats or treatment types were not surveyed during Hawks Aloft, Inc. (2012–2019) study.

Table 3.6.4-1 (continued). Observations of indicator bird species, primarily songbirds, by habitat type during Hawks Aloft, Inc. surveys (2012–2019). Note: X = species detected; N/A = habitat was not surveyed; Non-target = species were not targeted for survey during Hawks Aloft, Inc. (2012–2019) study but were included to show that they are an indicator for that habitat. Note that some non-target species may have been documented during field surveys to maintain consistency in data handling.

Habitat	Indicator Species	Unburned Habitat		Burned Habitat	
		Present	Absent	Present	Absent
Riparian (continued)	song sparrow	–	X	–	X
	summer tanager	–	X	–	X
	yellow warbler	X	–	–	X
Ponderosa Pine	Grace's warbler	X	–	X	–
	pygmy nuthatch	X	–	X	–
Mixed Conifer	Canada jay	X	–	–	X
	golden-crowned kinglet	X	–	X	–
	orange-crowned warbler	X	–	X	–
	pine grosbeak	–	X	–	X
	pine siskin	X	–	X	–
	ruby-crowned kinglet	X	–	X	–
	sharp-shinned hawk	Non-target	Non-target	Non-target	Non-target
Spruce-fir 1	boreal owl	N/A	N/A	N/A	N/A
	golden-crowned kinglet	N/A	N/A	N/A	N/A
	orange-crowned warbler	N/A	N/A	N/A	N/A
	pine grosbeak	N/A	N/A	N/A	N/A
	sharp-shinned hawk	N/A	N/A	N/A	N/A
Open Water 1	Waterfowl, wading birds	N/A	N/A	N/A	N/A

[1] These habitats or treatment types were not surveyed during Hawks Aloft, Inc. (2012–2019) study.

Table 3.6.4-2. Trends in abundance by habitat type for songbird species of concern with at least 50 observations.

Habitat	Species	*F* statistic (df)	*P*	R^2
Ponderosa Pine	Grace's warbler	11.97 (1,6)	0.01	0.66
Ponderosa Pine	pygmy nuthatch	0.51 (1,6)	0.50	0.08
Ponderosa Pine	mountain chickadee	4.63 (1,6)	0.07	0.44
Mixed Conifer	mountain chickadee	1.15 (1,6)	0.32	0.16
Mixed Conifer-burned	mountain chickadee	0.23 (1,6)	0.65	0.04
Ponderosa Pine	Steller's jay	0.01 (1,6)	0.94	0.03
Mixed Conifer	Steller's jay	0.03 (1,5)	0.87	0.01
Ponderosa Pine	Townsend's solitaire	0.38 (1,6)	0.56	0.06
Ponderosa Pine	western bluebird	4.64 (1,6)	0.07	0.44
Ponderosa Pine-burned	western bluebird	0.18 (1,6)	0.69	0.03
Mixed Conifer-burned	western bluebird	1.62 (1,6)	0.25	0.21
Mixed Conifer-burned	mountain bluebird	0.49 (1,5)	0.51	0.09

A total of 85 and 77 species were observed on the BBS East and BBS West routes, respectively. Annual richness along BBS West was stable from 2002 to 2017 (F (12) = 1.5, p = 0.24, R^2 = 0.11), but richness declined along BBS East from 2001 to 2015 (F (12) = 13.5, p = 0.003, R^2 = 0.53) (Figure 3.6.4-3 top). However, the decline began in 2011 when a new observer began surveying the route (observer data were not included for BBS West). Similarly, annual abundance also significantly declined along BBS East (F (12) = 5.9, p = 0.03, R^2 = 0.33) but remained stable along BBS West (F (12) = 1.31, p = 0.27, R^2 = 0.10) (Figure 3.6.4-3 bottom). Again, declines in abundance began in 2011 and is probably due to observer bias rather than actual declines in richness and abundance.

Of the 53 species of concern known to occur in the preserve, 33 were observed in at least one year along at least one of the two routes. These included band-tailed pigeon (*Patagioenas fasciata*), broad-tailed hummingbird (*Selasphorus platycercus*), Grace's warbler, Lewis's woodpecker (*Melanerpes lewis*), and peregrine falcon (*Falco peregrinus*).

The Redondo Border BBS route surveyed by Hawks Aloft, Inc. follows a similar route as BBS West (Figure 3.6.3-1). From 2016 to 2020, the most detected (of the 56 species) along this route were western tanager (*Piranga ludoviciana*) (~12% of all detections), chipping sparrow (*Spizella passerina*) (~6% of all detections), and dark-eyed junco (*Junco hyemalis*) (~6% of all detections) (Hawks Aloft, Inc. 2021). On the Valle Grande BBS route, the most commonly detected of the 64 species were eastern meadowlark (~13% of all detections), common raven (*Corvus corax*) (~9% of all detections), and vesper sparrow (*Pooecetes gramineus*) (~9% of all detections). Neither route was

surveyed in 2018 due to extreme fire danger closures (Hawks Aloft, Inc. 2021). Between the Redondo Border and Valle Grande BBS routes, 25 of the 53 species of concern were observed in at least one year (Hawks Aloft, Inc. 2021). These included band-tailed pigeon, Grace's warbler, Lewis's woodpecker, and pygmy nuthatch (*Sitta pygmaea*).

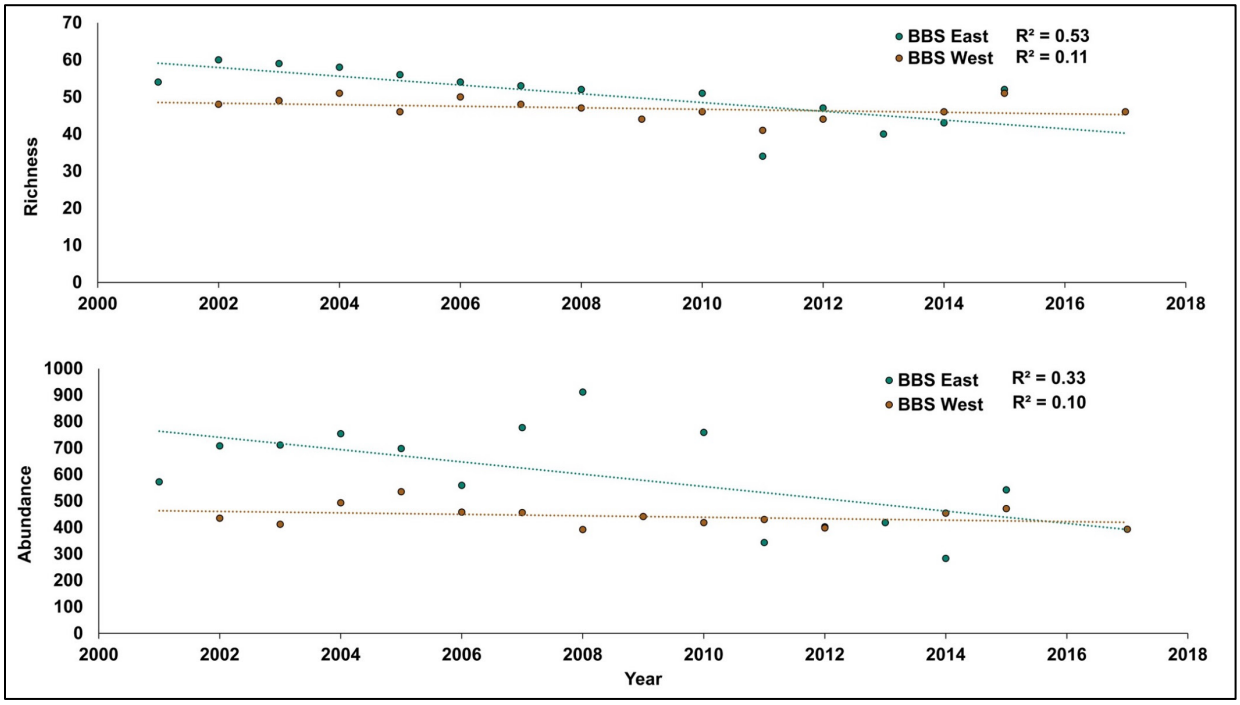


Figure 3.6.4-3. Richness (top) and abundance (bottom) for bird species observed along BBS East (2001–2017) and BBS West (2002–2017).

In conclusion, based on the condition rating statements (Appendix C, Table C-5), community composition indicates a good condition, with a stable to improving trend (Table 3.6.4-3). However, we have moderate confidence in the condition rating because of the uneven sampling effort by habitat type. Monitoring the vegetation structure and richness in each of the bird point count plots would be helpful to understand the different habitat conditions, especially since there have been, and will continue to be, major changes in habitat structure as part of the CFLRP and unplanned fires. Riparian and wet meadow habitats are also changing dramatically with restoration activities.

Table 3.6.4-3. Songbirds condition ratings summary.

Indicator	Condition Rating [1]	Trend	Condition Evaluation
Community Composition	Good	Stable/ Improving	Songbird community composition reflects near pristine conditions with no indication of compromises to ecological integrity. Confidence in the condition rating is medium because of uneven sampling effort by habitat type.

[1] See Appendix C, Table C-5, for the 5-level condition rating statements for each indicator.

Breeding songbird surveys are ongoing, but high elevation spruce-fir forests are not included in these efforts. The only surveys in spruce-fir forests occurred as a one-time biodiversity study of Redondo Peak in 2014. Additionally, wet meadows and riparian areas are not adequately monitored through current songbird surveys, and no waterfowl surveys have occurred to date. Autumn and winter waterfowl observations reported to eBird (2017) indicate that thermally influenced ponds may serve as stopover sites during migration and as habitat during winter.

Surveys for diurnal raptors (i.e., eagles, hawks, and falcons) would also address a data need. Previous autumn surveys for diurnal raptors suggest that the preserve may be located along a migration corridor (Johnson 2001, 2003, 2005). This is supported by data collected at the HawkWatch International migration site in the Manzano Wilderness of the Cibola NF (Oleyar and Watson 2018). The HawkWatch site is directly south of the preserve, and the Jemez Mountains are the last mountain range available before crossing the Santa Ana Mesa. Mountain ranges are critical landscape features for migrating raptors because of the orographic uplift and leading lines they provide. In 2017, nearly 6,000 raptors were observed migrating over the HawkWatch site from late August through late October. Perhaps many of these individuals also migrate through the Jemez Mountains.

In 2020, 40 nocturnal owl call points were established in the preserve (Hawks Aloft Inc., T. Fetz, research director, received by Tammy Cook, NRCA Program, comments to draft assessment, 20 March 2021). Surveyors sampled for owls using the USFS Multiple Species and Inventory Monitoring nocturnal bird survey protocol (Manley et al. 2006). Five species of owl were detected: flammulated owl (*Psiloscops flammeolus*) (n = 69), great horned owl (*Bubo virginianus*) (n = 65), northern saw-whet owl (*Aegolius acadicus*) (n = 34), long-eared owl (*Asio otus*) (n = 42), and northern pygmy-owl (*Claucidium gnoma*) (n = 10) (Hawks Aloft Inc., T. Fetz, lead avian biologist, received by Tammy Cook, NRCA Program, comments to draft assessment, 20 March 2021). No western screech-owls (*Megascops kennicotti*) were detected, but this species is present in the preserve (Hawks Aloft Inc., T. Fetz, research director, received by Tammy Cook, NRCA Program, comments to draft assessment, 20 March 2021). Surveyors were unable to access high-elevation spruce-fir habitat where boreal owls may occur, and Covid-19 restrictions delayed surveys until mid-May. Thus, the detections listed above are probably lower than if surveys had occurred earlier when owls are more vocal.

Mexican spotted owl (*Strix occidentalis lucida*) surveys were also conducted in 2020 using USFWS protocols (USFWS 2012), but none were detected. However, on 20 May 2021, Trevor Fetz, research director at Hawks Aloft, Inc., confirmed a subadult pair (male and female) in VALL while surveying for other owl species. On 21 May 2021, a possible nest/roost site was also discovered, but it was unclear whether the pair attempted to breed. The most likely scenario is that the two owls are a young-bonded pair that are not yet breeding (Hawks Aloft, Inc., T. Fetz, research director, email communication to R. Parmenter and M. Peyton, 23 May 2021). This is the first confirmed pair of spotted owls in the preserve despite apparently abundant habitat. Mexican spotted owls are also found elsewhere in the Jemez Mountains.



Mexican spotted owl pair in VALL. Image Credit: ©Trevor Fetz.

3.7. Jemez Mountains Salamander (Gap Analysis)

3.7.1. Background & Importance

The Jemez Mountains salamander (*Plethodon neomexicanus*) (hereafter JMS) is a federally endangered species endemic to the Jemez Mountains (USFWS 2013a). The USFWS listed the species as endangered because of significant threats to its persistence, including altered fire regimes, recreational activities, and potential susceptibility to chytridiomycosis—a disease caused by the chytrid fungus *Batrachochytrium dendrobatidis* (*Bd*). Chytrid has caused major population declines in amphibians worldwide, but whether *Bd* causes chytrid in the JMS is unknown. Between 2002 and 2018, two of 155 JMS tested positive for *Bd*, neither of which were found in the preserve, although other species in VALL carry the disease (Christman and Jennings 2018). It's important to note that although the *Bd* detection rate in the JMS was low (1.3%), it does not necessarily indicate that prevalence of *Bd* in the salamander population is also low. The statewide infection rate among the 21 species of amphibian tested averaged 9.6%, and at least a few individuals for 12 of the 21 species tested positive for *Bd* (Christman and Jennings 2018).



Jemez Mountains salamander. Image Credit: ©Dr. Nancy Karraker, University of Rhode Island.

The JMS occurs primarily in mixed coniferous forests, with a well-developed understory and moist soils, although salamanders have been found in pure stands of ponderosa pine and open meadows (USFWS 2013a). Mixed-conifer forests are structurally complex, with abundant course woody debris and rocky soil with interstitial spacing, allowing for vertical and horizontal subsurface movements. Igneous subsurface rock with fractures or loose rocky soils is an important habitat feature. This is because the species spends most of the year underground, usually surfacing after late summer monsoon rains saturate soils and when air temperatures average 55 °F (13 °C) (USFWS 2013a), although they have also been observed in May and October (NPS, M. Peyton, wildlife biologist, comments to draft gap analysis, 1 April 2021).

A high volume of large, downed trees (primarily Douglas-fir) provides refuge while salamanders are aboveground. The JMS is usually found between 2,200 to 2,900 m (7,200 to 9,500 ft); however, they are sometimes found above and below this elevation range if conditions are favorable. Many aspects of JMS ecology, particularly with respect to reproduction, are poorly understood. Table 3.7.1-1 lists habitat requirements, life history characteristics, and movement and dispersal data, as they are currently understood (USFWS 2013a,b).

The USFWS is currently compiling information for the five-year JMS status review and assessment since its listing (USFWS 2019). Based on this new information, the USFWS intends to develop a recovery plan by 2022 (NPS, M. Peyton, wildlife biologist, comments to draft NRCA study plan, 14 February 2020). JMS life history characteristics and sensitivity to disturbance have made surveying and monitoring this species extremely difficult. Despite these challenges, ongoing studies in and around VALL have provided and continue to provide important information on the status of this species throughout its range. According to the USGS Gap Analysis Program (USGS 2019), VALL is one of the largest fully protected areas in the JMS's historical range. The USFWS states that the JMS "has likely occupied the Jemez Mountains for at least 10,000 years, but this could be as long as 1.2 million years, colonizing the area subsequent to the volcanic eruption" that created the caldera (USFWS 2013a).

Table 3.7.1-1. Life history characteristics of the Jemez Mountains salamander (USFWS 2013a,b).

Group	Feature	Description	Note
Habitat	Soil Moisture	Soils are persistently saturated (4.85–59.7% saturation)	The JMS is lungless, which means it requires moist conditions to breathe through its skin.
	Soil pH	6.6 (± 0.08)	–
	Soil Texture	Sandy clay loam, clay loam	–
	Elevation	2,200–2,900 m (7,200–9,500 ft)	A strictly terrestrial species that does not require water bodies at any life stage.
	Aspect	All aspects occupied but may spend more time underground on south-facing slopes than on north-facing slopes.	–
	Subterranean Features	Igneous subsurface rock with fractures or loose rocky soils.	Spends most of the year underground. Surfaces only when conditions meet temperature and moisture requirements, usually during and after monsoon rains (July–September).
	Aboveground Temperature	Mean of 12.7 °C (54.9 °F) and a range of 6.0–17.0 °C (43–63 °F)	Significantly more salamanders when temperature is near or at the mean.
	Canopy Cover	>50%	–
	Dominant Canopy Species	Mature forests dominated by any combination of Douglas-fir, blue spruce, Engelmann spruce, white fir, limber pine, ponderosa pine, and aspen.	Individuals have occasionally been found in pure stands of ponderosa pine and in high elevation meadows.
	Shrub Cover	Dominated by Rocky Mountain maple (*Acer glabrum var. glabrum*), New Mexico locust (*Robinia neomexicana*), oceanspray (*Holodiscus dumosus*), or shrubby oaks.	–
	Coarse Woody Debris	Moderate to high volume of coniferous logs at least 25 cm (10 in) in diameter.	Provides protection when aboveground as well as prey habitat for invertebrates. Feeding likely occurs mostly on the surface under rocks, and in or under logs.
	Other Structural Features	Moderate to high number of rocks, bark, moss mats, rotted tree root channels, and/or rodent burrows or presence of large invertebrates	Features listed may substitute for a lack of subterranean features.

Table 3.7.1-1 (continued). Life history characteristics of the Jemez Mountains salamander (USFWS 2013a,b).

Group	Feature	Description	Note
Demography	Average Life Span	Unknown	A single marked individual was recaptured 14 years after initial capture. Estimated to be 15–17 years of age.
	Age at First Breeding	Individuals reach sexual maturity at 3–4 years of age for females and 3 years for males.	Breeding is thought to occur aboveground sometime during July and August, which coincides with the rainy season.
	Frequency of Breeding	Every 2–3 years	Not confirmed.
	# of Eggs Laid	7–8	Eggs thought to be laid underground in spring, 9–10 months after mating occurs.
	Prey	Ants (Hymenoptera, Formicidae), mites (Acari), and beetles (Coleoptera)	Does not appear to specialize on any particular group.
Movement and Dispersal	Daily Movements	0–33 m (0–108 ft)	75% of movements have been less than 1 m (3 ft).
	Annual Movements	5.98 m (19.6 ft), with a maximum distance moved from original capture site of 18.5 m (60.7 ft)	Data suggest limited movements.
	Home Range	• Mean: 8.0 m^2 (86 ft^2) • Males:12.7 m^2 (137 ft^2) • Females: 7.2 m^2 (78 ft^2)	Those with the largest home ranges returned to the same cover object, while those with small home ranges used multiple cover objects.

3.7.2. Status of Knowledge

The NHNM compiles observational and formal survey data into a central database, including surveys conducted by the NMDGF. Although these data are largely observational, Figure 3.7.2-1 shows a high of nearly 350 salamanders observed in 1992, after which observations fell dramatically to only a few in recent years. Other studies that were not included in the NHNM database indicate a much larger population during the 1960s and 1970s.

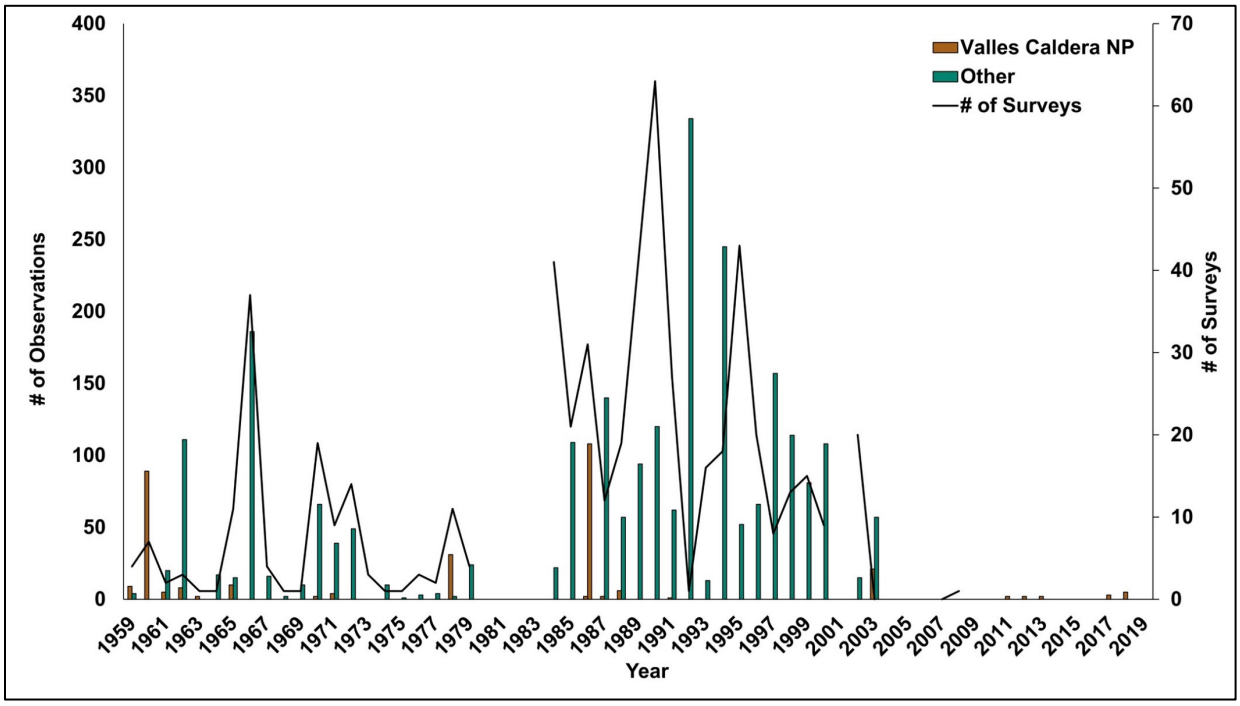


Figure 3.7.2-1. Observational data of the Jemez Mountains salamander in and around VALL. While the number of annual surveys was available, consistent observational data from those surveys were lacking in the NHNM database from 1959 to 2008.

The NHNM data presented in Figure 3.7.2-1 and compiled by USFWS (2013a) suggest that many areas where JMS were historically present are now unoccupied, and those that continue to be occupied support fewer individuals (USFWS 2013a). While the number of annual surveys was available, consistent observational data from those surveys were lacking in the NHNM database from 1959 to 2008. Missing data within this timeframe may indicate that no surveys occurred and/or that none were detected. However, it's important to note that the JMS has a low rate of detection, and areas considered unoccupied warrant additional surveys to confirm its absence.

Figure 3.7.2-1 mirrors the annual precipitation regime from the 1970s onward, with a moist period during the 1980s and into the 1990s, and 20 years of drought after that, which may contribute to the observed pattern (NPS, B. Parmenter, chief of science and resource stewardship, comments to draft evaluation received by K. Struthers, 7 April 2021).

The USFWS designated JMS critical habitat in two areas in and around the preserve (USFWS 2013b) (Figure 3.7.2-2). VALL contains 26% of the total critical habitat identified by the USFWS, but the

historical range covers a much larger area. In 2012, researchers from the USFS Rocky Mountain Research Station developed an occupancy model for the JMS (Bird and Baggett 2012). Occupancy models recognize and account for imperfect detection; detection probabilities are always less than 100%, and they may be especially low for secretive species like the JMS.

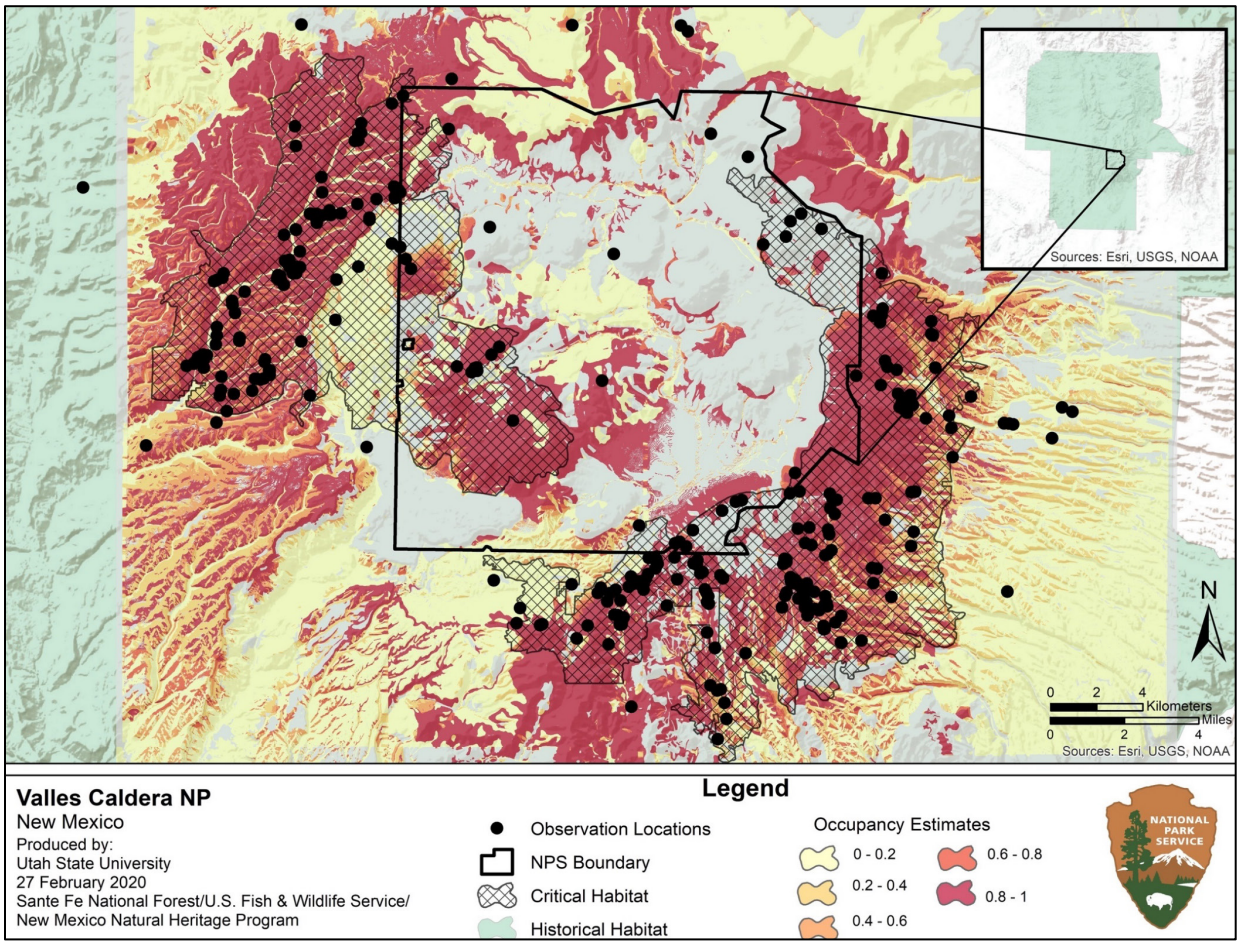


Figure 3.7.2-2. Historical range, critical habitat, and occupancy model (Bird and Baggett 2012) of the Jemez Mountains salamander in and around VALL, including previously observed locations.

The model was developed for 16 USGS quadrangles centered on the preserve, and it corresponds well with the extent of the USFWS' JMS critical habitat boundary. However, there are some areas where potential occupancy is high but not considered critical habitat (Figure 3.7.2-2). The three variables used to develop the model were geology, elevation, and aspect (Bird and Baggett 2012).

Another model (that was unavailable at the time of this writing), developed by The Nature Conservancy, indicated that geologic formation was the top factor in predicting salamander occupancy (22.1% model contribution). Soil:rock fragment class, July–September precipitation, soil:particle size class, and January–March precipitation contributed an additional 54% to the model's explanation (The Nature Conservancy, A. Bradley, forest conservation program manager, all hands CFLRP PowerPoint presentation received by Lisa Baril, 7 November 2019).

Figure 3.7.2-2 also shows the observation locations presented in Figure 3.7.2-1. Because these locations were used to build the Bird and Baggett (2012) JMS occupancy model, most are within the high probability areas of occupancy, except for an area in the northeastern portion of the preserve around Cerro Toledo. This area, which includes several historical salamander observations and is designated critical habitat, was not mapped as potentially occupied by salamanders. This suggests that while the model is useful as a first attempt at predicting salamander locations, additional data are needed to develop a more precise model. On the other hand, salamanders have not been observed at this site despite annual surveys by the NMDGF since 2012 (M. Watson, terrestrial habitat specialist, e-mail message, 18 February 2020).



The Jemez Mountains salamander spends most of the year underground using logs and rocks for cover. Image Credit: ©Mark Losleben, University of Arizona.

One factor that may account for the apparent (or observed) absence of salamanders at Cerro Toledo is the survey method. Cerro Toledo is surveyed using a permanent coverboard array (artificial habitat using plywood) and surveys of natural ground cover structures (e.g., logs, rocks). Coverboards, however, may not be an effective tool for surveying JMS (Karraker 2018). In 2018, Karraker (2018) tested newly developed artificial log cover objects for surveying salamanders in VALL. Artificial rock piles and artificial rocks were also included. In a pilot study, detections of the eastern red-backed salamander (*Plethodon cinereus*) were more than twice as high when using artificial logs versus coverboards. This new method was implemented at three sites in VALL and at three sites adjacent to the preserve.

Another factor likely contributing to the lack of JMS detected in the Cerro Toldeo area is the 2011 Las Conchas Fire that burned this portion of the preserve with high severity (NPS 2018a). In 2013, the Thompson Ridge Fire burned in the south-central portion of the preserve (NPS 2018a). Combined, these two fires burned the majority of areas where salamanders have been observed in the past. Not only did these fires likely lead to direct mortality, but they also destroyed suitable habitat.



Las Conchas Fire, burning in VALL. ©Rourke McDermott.

In 2018, fire restrictions and a mild monsoon season hampered JMS surveys; only seven were found at six sites by incidental observations. In 2019, 27 salamanders were observed among the six sites, eight of which were outfitted with passive integrated transponders (PIT-tags), which will help researchers understand underground versus aboveground use correlated with environmental variables, namely temperature and precipitation (University of Rhode Island, N. Karraker, herpetologist, data presented at the 2019 annual Southwest Jemez Collaborative Landscape Restoration Project (CFLRP)). Karraker (2018) also deployed temperature dataloggers under each artificial treatment and at 2 m (6.6 ft) aboveground.

Although only in its second year, Karraker (2018) located salamanders in two canyons where JMS presence hasn't been confirmed since the 1980s. A female with eggs and a female/male pair were found together, which confirms breeding in and around the preserve. Whether JMS emerge from their below-ground environment depends on soil moisture and air temperature, which changes

annually, seasonally, and daily. Therefore, the lack of observations at a given site does not necessarily indicate absence.

Goals for the 2020 field season and beyond include tracking the PIT-tagged salamanders, tagging additional salamanders, determining critical moisture and temperature thresholds, surveying historical and potential sites, and identifying target areas for restoration (University of Rhode Island, N. Karraker, herpetologist, data presented at the 2019 annual CFLRP).

Finally, the Catalina-Jemez Mountains Critical Zone Observatory, in cooperation with the University of Arizona and the NPS, initiated a study in 2015 to quantify the micro-environmental parameters important for JMS (University of Arizona, M. Losleben, research specialist, e-mail message, 20 February 2020). Instruments were installed in September of 2015 at four sites: two control sites and two treatment sites. Data were collected at all four sites to gather baseline information for two years before treatment. In year three, the two treatment sites were thinned, and the following year, both sites were treated with controlled fire.

The study is in its initial stages, but preliminary data suggest that forest thinning increased air temperature, solar radiation, and wind speeds at ground level (University of Arizona, M. Losleben, research specialist, e-mail message, 20 February 2020). Below ground, thinning may also increase soil temperature. Additionally, precipitation effects on soil moisture appear more variable under the thinning treatment. Staff at VALL are concurrently sampling surface-active arthropods at the same study sites, which serve as the prey base for JMS, as well as vegetation cover and composition, and fuel loading (NPS, B. Parmenter, chief of science and resource stewardship, comments to draft evaluation received by K. Struthers, 7 April 2021). VALL also provided funding to the University of Northern Arizona to conduct studies on soil biota, soil nutrient content, and soil texture (e.g., bulk density) to assess impacts of logging equipment on the soil ecosystem with respect to JMS habitat (NPS, B. Parmenter, chief of science and resource stewardship, comments to draft evaluation received by K. Struthers, 7 April 2021). As time since treatment increases, the micro-environmental response will be valuable for understanding how disturbance affects salamander habitat. While forest restoration activities associated with the CFLRP will ultimately improve habitat for the salamander by reducing the risk of large, high-severity fires, there may be changes that temporarily reduce habitat quality in some areas (USFS 2015).

3.7.3. Discussion

Using the information from Table 3.7.1-1, we present indicators and measures to help frame a future JMS condition assessment (Table 3.7.3-1). The species status assessment, as well as the recovery plan, which should be published by the USFWS in 2022, will help refine the reference criteria listed in Table 3.7.3-1. There may also be additional indicators or measures deemed important in the recovery plan.

Data for some of these measures are currently being collected through the studies summarized above, and an updated JMS occupancy model, using data from current studies, may inform habitat connectivity. Although, connectivity and existing habitat can be partially assessed using a geographic information system based on an updated occupancy model as well.

Table 3.7.3-1. Proposed study details for Jemez Mountains salamander (USFWS 2013a,b).

Indicator	Measure	Reference Criteria for Measure
Habitat Connectivity	Area of Suitable Habitat	A sufficient area throughout the JMS range is considered high quality. Suitable areas should be well distributed throughout its range.
	Distance Between Suitable Habitat Patches	Subpopulations are connected by suitable habitat to facilitate dispersal and gene flow.
Occupancy	Proportion of Suitable Patches Occupied	Most of the available patches are occupied.
Demography	Population Size	Population size is large enough that the risk of extinction is no longer imminent.
	Proportion of Subadult to Adult Salamanders	The ratio of subadult to adult salamanders indicates a successfully breeding population with a suitable proportion of subadults to replace senescing adults.
Health Status	Disease Prevalence	*Bd* prevalence is low or absent. For individuals testing positive for *B*d, there is no evidence that the fungus has developed into the chytrid disease. No other diseases are present (e.g., ranavirus).

The USFWS identified historical fire exclusion and suppression leading to more severe fire events as the principal threat to JMS habitat (USFWS 2013a). Throughout the JMS range, fires were historically frequent but of generally low severity. The JMS tolerated low-severity fires because they historically burned before the monsoon in late spring and early summer while salamanders were underground (Margolis and Malevich 2016; USFWS 2013a), and the low severity of the fires did not raise soil temperatures above the thermal tolerance of the JMS. However, more than a century of fire suppression has led to large, high-severity fires that occur over greater areas and, raise soil temperatures beyond the thermal tolerance of the JMS (Margolis and Malevich 2016; USFWS 2013a).

Other threats to JMS that pertain to the preserve include recreation and livestock grazing. Outside of the preserve, mining, road construction, private land development, and geothermal activities may have adverse effects on salamanders in VALL if connectivity is not maintained (USFWS 2013a). Addressing these threats is critical given the limited information on JMS, including basic life history knowledge, such as frequency of breeding and average life span.

Chapter 4. Management Considerations

Chapter 2 of the NRCA report considered the direct or indirect impacts that selected drivers and/or stressors may have (now or in the future) on focal resource conditions at VALL. Drivers and stressors often exert influences on resource conditions over a broader regional or landscape scale and may arise from inside or outside of the preserve, which influences the feasibility of acting and affecting change in natural resource conditions.

Chapter 3 provided condition evaluations for each preserve-selected focal natural resource. The project team developed condition assessments for resources when adequate data were available or when expertise could be engaged to assess one or more indicators of condition. Resources lacking adequate data or expertise were evaluated at a lower level of evaluation (gap analysis) so that preserve managers could still receive useful condition-related information for future consideration.



Sheep grazing in Valle Grande in 1935. See repeat photo taken in 2001 below. Image Credit: ©T. Harmon Parkhurst, Museum of New Mexico image # 51457.

This chapter suggests useful activities or responses based on a manager-scientist review of key findings and a discussion of next steps. Responses that include multiple natural resources, other

preserve divisions, and/or partnerships will provide managers with a comprehensive portfolio of actions to consider in the near-term or over a longer-term planning horizon.



A 2001 retake of the 1935 sheep grazing photograph in Valle Grande. See photo above. Image Credit: ©Steve Tharnstrom and John Hogan, USGS Jemez Mountains Field Station, image #JMFS306 BAC retake.

This chapter suggests useful activities or responses (denoted as "R" within the DPSSR conceptual framework) based on the manager-scientist review of key condition findings and a discussion of next steps. These next steps or activities/responses that may integrate multiple resources, preserve divisions, and/or partnerships will provide managers with a portfolio of actions to consider in the near-term or over a longer-term planning horizon.

4.1. Manager-Scientist Review

To complete VALL's NRCA process, the project team held two meetings to review the condition findings and implications for each of the seven evaluated resources—an all-managers' meeting on 18 May 2021 and a natural resource manager-scientist meeting on 3 June 2021. A desired outcome of the manager-scientist meeting was to identify near-term and future responses/strategic actions that may help VALL managers further understand, maintain, and/or improve resource conditions. These responses and actions consider the drivers and stressors occurring within and surrounding the

preserve. Managers can directly manage some of these stressors through specific actions (e.g., non-native invasive plant control), while others are beyond a manager's ability to change (e.g., drought, climate change). Some require an inter-divisional focus and effort, while others benefit from external agency partnerships because of the scale of the resource and its associated drivers and stressors. Thus, a more comprehensive, multi-resource/disciplinary and inter-divisional strategic approach when targeting follow-on activities or actions can benefit resource resiliency and management response toward achieving management goals.

To facilitate identifying manager responses, a conceptual model included the priority drivers and stressors for each resource, depicting the interactions between these and the focal resource. Appendix D, Figure D-1, includes a combined conceptual model for all resources and drivers and stressors reviewed during VALL's manager-scientist meeting. In addition, we present a tabular depiction of the model in Table D-1. This type of information may be useful for conducting future impact analyses during various preserve planning efforts and is scalable to accommodate changing drivers and stressors and management priorities.

Following the review of each resource's drivers and stressors conceptual model, a matrix that included seven action categories (Table 4.1-1) and each resource's primary drivers and stressors guided the identified actions.

Table 4.1-1. Action categories used to facilitate manager-scientist discussion of responses.

Action Categories [1]	Description [2]
Land, Water, or Species Field-based Management	These "on-the-ground" actions directly manage or restore sites, individual or groups of species, and/or ecosystems by targeting or mitigating a stress or threat(s).
Research, Monitoring, & Inventory	These actions collect data that can ultimately be applied to inform other conservation actions.
Education & Interpretation	These are actions directed at reducing threats by increasing positive behaviors. These include raising awareness of key issues at targeted audiences to affect behaviors.
Partnerships	These actions create and provide knowledge and data-sharing and capacity to address conservation goals on a larger scale.
Zoning & Planning	These types of actions create the conditions necessary for other conservation efforts to ultimately succeed.
Law Enforcement	These actions monitor and enforce compliance with existing laws, policies, and guidance to deter threats or promote positive actions.
Laws, Policies, & Guidelines	These actions develop and influence legislation, policies, and voluntary standards affecting conservation.

[1] Categories were adapted from the Conservation Measures Partnership (2016) actions classification levels v2.0 and common NPS Resource Stewardship Strategy activity categories v3.0 (NPS n.d.).

[2] Descriptions extracted and/or adapted from Conservation Measures Partnership (2016) actions classifications.

We selected the action categories from the NPS Resource Stewardship Strategy activity categories (NPS n.d.) and from the Conservation Measures Partnership (2016) Classification of Conservation

Actions and Threats, which defines a common nomenclature to support collaboration among conservationists and consistency across NRCA reports. These combined categories capture multiple levels of NPS management activities, they are broad, and they are tailored to meet each park's needs.

4.2. Review Outcomes by Focal Resource

The activities and actions (i.e., responses) discussed during VALL's manager-scientist meeting that are presented in Appendix E, Tables E-1 to E-7, are summarized for each focal resource below. In addition, the summaries below include any manager question and/or information need identified during the project's scoping process that remained unanswered (refer to Appendix A).

4.2.1. Landscape Permeability Summary

A functional analysis that considers a suite of species' survival needs, including food, cover, hazard avoidance, reproductive habitat needs, etc., would focus on areas where a wide variety of activities could have the greatest increases in permeability for a group of wildlife. This could include remediation of unused roads and/or installation of wildlife crossings and could inform future infrastructure development and fire management activities. Furthermore, the functional analysis results could be ground-truthed to identify additional disturbances negatively impacting connectivity. The advantage of understanding patterns at an ecosystem level is that it helps to provide additional information for a suite of species as various rates of mobility are considered in the analysis.

The landscape permeability results (GIS datasets) can be combined with other park data as summarized below:

- Overlay with locations of wildlife-proof fencing, under-/over-passes, and road-grade analyses to further refine the locations of high permeability and/or identify areas to restore permeability and remove/retrofit human modifications.
- Overlay fuel treatments/forest thinning activities, particularly in the Rocky Mountain Mixed Conifer Forests (e.g., Douglas-fir) in the lower montane ecosystem to identify priority areas in and out of the preserve where thinning activities are still needed.
- Further prioritize the forest thinning activity areas with locations of invasive species, particularly those that significantly alter ecological processes (e.g., cheatgrass).
- Overlay wildlife movements with highly permeable areas to 1) determine overlaps (e.g., mountain lion movement densities), and 2) determine areas of potential restoration.
- Prioritize jumping mouse habitat inventories in highly permeable landscape areas, especially in the locations identified as high priority habitat in the Santa Fe NF.
- Prioritize JMS follow-up surveys in areas of high permeability.
- Prioritize the wetland restoration opportunities with the highly permeable landscape analysis. The riparian/valley bottom ecosystem had a wider distribution, so identifying the intersections of high permeability, needed riparian restoration, and potential jumping mouse habitat, especially along the western half of VALL and into the Santa Fe NF, would inform several management actions. Results could also be further refined by overlaying habitats for the songbird species of special concern. These areas of overlap would identify areas of high

resource value, incorporating information from multiple taxa and biophysical data used in the permeability analysis.

- Prioritize the preservation and protection of Redondo Peak, which represents a significant contributor to potential regional climate adaptation. This is especially true for areas west of the preserve, which serve as a source for high-elevation species and potential areas into which lower-elevation species can expand should warming push life zones into higher elevations.



Double rainbow over Valle Grande. Image Credit: ©Eric Draper.

4.2.2. Visual Resources Summary

Repeat photography can provide objective visual evidence of landscape change. VALL has photos from the early and mid-20th century, including ones taken by geologist Bob Smith, that can serve as baseline photos. A comprehensive program to document landscape change may include monitoring a combined haze/light/sound and visual resources approach. With water availability decreasing, resulting in snowpack reduction for winter recreational activities, the visibility of snow on the landscape, in addition to resource impacts (throughout the seasons), could be photo-documented over time.

Additionally, wildfire has had negative and positive impacts on VALL's resources. Many visitors stop during prescribed burns and ask questions about the fires, which provides an excellent interpretive opportunity. Post-fire landscapes represent a debilitated scenery, which eventually regenerates approximately 15–20 years later, transforming the landscape. This transformation is a phased visual impact, which may influence how the public perceives and favors VALL's management activities (e.g., wetlands restoration or prescribed fire).

The ongoing removal of livestock infrastructure (e.g., barbed wire fences) not only improves wildlife movements; it can also improve the condition of VALL's visual resources, although the removal of fences may impact the visual qualities of the historic landscape and is a zoning/planning need to define the preserve's standards. In addition, understanding the resource value of scenic vistas is important in knowing how and where to develop visitor infrastructure (e.g., roads and vehicles,

placement of parking lots, reflectivity). VALL roads were located for programmatic purposes by the private landowners prior to government acquisition vs. blending into the landscape, and now the planning question becomes: When are features intrusions? A visual style guide to infrastructure development would be beneficial.

Prioritizing key vistas and partnering with adjacent land agencies/owners would leverage resources. Locating visitor camera spots for collecting standardized scenes of interest lends itself as a citizen science project and interpretive opportunity. Priority vistas could include additional management objectives, such as monitoring for expansions of cheatgrass and oxeye daisy (*Leucanthemum vulgare*) populations.

4.2.3. Redondo Peak Diversity Summary

Redondo Peak is culturally and naturally significant, and the preserve takes a hands-off approach in its management of the area to protect its significance and sensitivity. It is also a difficult location to access, and the road to the peak has been closed since the 2013 Thompson Ridge Fire due to fallen burned tree trunks. Its relative inaccessibility begs the question of what's the cost/benefit of additional inventory time of the peak's flora and fauna? VALL managers will continue to maintain the long-term weather station near Redondito Peak, however, which is at 3,231 m (10,601 ft).

Targeted, periodic inventories to determine how rapidly plants and wildlife are changing may help inform climate adaptation strategies, expecting that the bird communities will probably change the fastest because of their mobility. Conducting audio recording for boreal owls and winter bat use of the talus/felsenmeer slopes where bats may hibernate, would also inform future management actions.

A more focused approach to investigate rare species along streams and in special environments vs. randomized surveys may more quickly and efficiently inform missing baseline information. VALL managers know which species occupy the preserve's lower elevations and can compare/contrast to understand what isn't at the peak. It's likely that there are species unknown to science on Redondo Peak, and a complete identification of the already collected invertebrates will help inform this data gap (NPS VALL, B. Parmenter, chief of science & resource stewardship, comment during manager-scientist meeting, 3 June 2021).

There's also a need for improved information on the springs and seeps that are on Redondo Peak. Park staff are currently establishing plant plots near some springs and seeps for 1) long-term monitoring and 2) identifying plants of Native American importance to inform tribal gathering and partnerships. This will also help VALL managers understand how to treat forest and fire management differently for Redondo Peak than other areas in the preserve. Aerial imagery to monitor pests and disease, as well as understanding the preserve's forest structure change, both pre- and post-logging, will help inform and determine whether managers are meeting the goals of the CFLRP restoration stewardship plan.

Undoubtedly, managers can expect VALL's visitor use to change over time and may need to take actions to maintain the remoteness of Redondo Peak. Managers will consider options for managing visitor use and maintaining minimal human presence (e.g., How much is enough? What's the

carrying capacity?). The dissimilarities between Redondo Peak and other areas throughout the preserve likely warrant further (more focused) protection of its resources.

4.2.4. Wetlands Summary

Beaver is a keystone wetland species that was present in the present-day preserve until the 1930s, and the reintroduction of herbivores, including beaver and bison (*Bison bison*), would help maintain and encourage wetland development in the preserve. Because of pre-preserve wildlife management efforts, the stressor of removing beaver from the wetland and riverine systems eliminated the natural damming of hydrology and thus eliminated the hydrologic input to palustrine wetlands resulting from the spread of surface water out into the floodplains of the riverine wetlands. Former management recommended the reintroduction of beavers into the present-day preserve's streams as part of an effort to restore and enhance wetland vegetation, enhancing stream function by trapping sediment, thereby reducing stream turbidity, and creating and improving fish habitat. The change in management objectives allowed the restocking of beaver in the preserve between 1947 and 1958 (NPS WRD, K. Noon, wetlands program lead).

To evaluate wetland restoration opportunities throughout VALL, Kevin Noon, wetlands program lead with NPS NRSS WRD, performed a desktop analysis of satellite imagery to evaluate previous land-use impacts, such as roads or cattle tanks, to the preserve's wetlands. In addition, he also investigated the presence of non-native invasive plants using Muldavin and Tonne's (2003) vegetation survey. Kevin Noon's findings are presented below.

VALL wetland impacts and restoration opportunities
excerpted from K. Noon unpublished report

An opportunistic inventory of the physical (i.e., incised or head-cutting channels, roads, cattle tanks) and biological (i.e., non-native invasive plants) presence and impacts to VALL's wetlands (palustrine and riverine) was completed by Kevin Noon, wetlands program lead with the NPS NRSS WRD, via desktop analysis of satellite imagery and working with VALL staff.

VALL's 668 ha (1,650 ac) of palustrine wetlands, consisting of montane wetlands and montane wet meadows, have a significant percentage of non-native plant species (Muldavin and Tonne 2003). Non-native plants degrade the water quality function of wetlands by reducing those native plants that best filter sediments from floodwaters, stabilize streambanks, and provide shade. The montane wetlands plant association is primarily Northwest territory sedge (*Carex utriculate*), smallwing sedge (*C. microptera*), woolly sedge (*C. pellita*), and common spikerush (*Eleocharis palustris*) (Muldavin and Tonne 2003). These are species that indicate an extensive period during the growing season where the soils are saturated at or near the surface. Kentucky bluegrass and common dandelion are non-native, secondary components that comprise at least 10% of the area of the montane wetland plant association. The montane wet meadow plant association is primarily tufted hairgrass, woolly cinquefoil (*Potentilla hippiana*), and Baltic rush, along with non-native Kentucky bluegrass and dandelion; secondary components are comprised of sedges and rushes (Muldavin and Tonne 2003).

Non-native plants are major portions of the primary assemblage or part of the secondary assemblage in both the palustrine montane wetlands and montane wet meadows. The disturbance that facilitated establishment and spread of dandelion and Kentucky bluegrass was likely sheep and/or cattle trampling and grazing. Cattle trampling and grazing no longer impact the palustrine wetland vegetation, as it did in the past. Thus, removing the non-native plants and restoring the degraded areas with native plants should improve the condition of palustrine wetlands, especially since other physical and biological functions within the palustrine wetlands do not appear to be impaired.

To evaluate the preserve's riverine wetlands, Kevin Noon and VALL staff inventoried the physical features and impacts to the wetland systems from previous land-use practices. Four incised/head-cutting drainage wetlands, 45 cattle tanks, and six road crossings were identified, although more of these features exist. The inventory revealed that the hydrology and hydraulic processes of a significant number of first- and second-order intermittent or perennial-flow riverine channels have been disrupted with either cattle tanks or road crossings. These disruptions interfere with the natural transport of sediment and water, nutrient cycling, invertebrate habitat development, and species migration. Additionally, some first-order riverine wetland channels have incised severely because of increased runoff from denuded slopes in the watersheds. The head-cutting and incising channels are of high concern because they will continue to erode deeper and wider unless the stressor–high volumes of water over short periods of time–is mitigated.

This erosion process distributes a significant amount of sediment that washes through to the second-order streams. Restoration would involve grading the side slopes, filling the channel, and placing grade-change structures across the channel at strategic locations to reduce erosion by dropping the water down-elevation. The increased runoff is reduced by re-vegetating the adjacent upland slopes that are directing precipitation runoff toward the stream channel, concurrent with restructuring the channel.

VALL's hydrologist will ground truth all locations of identified restoration opportunities, then rank them in terms of feasibility for restoration.

<u>Other Manager Actions Identified for Wetlands Include:</u>

- A comprehensive seeps and springs inventory—the preserve has a map, but it is incomplete.
- Managing trespass grazing by rebuilding fence along the north, turning over responsibility to permittees on USFS land, and having rangers call owners quickly to remove trespass cattle.
- Understanding the influence of recent past wildfire, and by extension, the areas that haven't burned recently. What are the future burning effects for managed and unmanaged ignitions?
- Protecting planted willows from browse.
- Siting appropriate access locations and facilities development (e.g., trails) for the protection of wetland and streamside fisheries.
- Managing non-native invasive plants of concern.

- Prioritizing wetlands for restoration through the continued collaboration with 39 organizations.

4.2.5. New Mexico Meadow Jumping Mouse Habitat Availability Summary

There are limited research and monitoring projects for the New Mexico meadow jumping mouse at the preserve. The track plate surveys that are conducted focus on areas of future management activities, such as restoration or prescribed burns. Researching the prescribed fire impacts in grassland habitat, particularly in areas where the forest edge is next to riparian areas, would help inform activities, and align with the USFWS' and Santa Fe NF's mouse habitat goals. Research on mouse hibernacula would also inform management activities to conserve this species.

Direct management activities for mouse habitat include keeping trespass cattle off the riparian areas and inventorying and retrofitting culverts to improve mouse movement up and downstream (i.e., if plugged, mice travel over roads). Installing shelves in culverts would assist with mice movements. The stressors for mouse habitat are the same as those for wetlands, and Kevin Noon's wetland impact analyses may help target areas of high priority habitat restoration (e.g., roads, fire scars, improperly functioning road culverts, channelization of streams during ranching and fire). Enhancements to mouse habitat and stream function (e.g., improved water quality, increased plant diversity, presence of beaver ponds/dams) will also benefit wetlands.

An improved research and monitoring effort of elk (and other ungulate) impacts (e.g., grazing) would inform habitat protection activities. VALL currently has elk exclosures in place, but there may be opportunities for improvements. In addition, an extensive literature search to understand how invasive grass species relate to the mouse's dietary items may guide future management actions, such as targeted species removal.

There are currently many unknowns regarding visitor use and facilities development that would ideally be considered to avoid impacts to habitat. The Santa Fe NF has taken many actions to improve visitor use and impacts to mouse habitat, but VALL's objectives need to be clarified. Future monitoring could influence some habitat connectivity (e.g., maintenance repair work). Studying the downstream use (e.g., visitor use and cattle grazing) on the Santa Fe NF's riparian areas, which has direct and indirect impacts to habitat, would inform connectivity. Also, monitoring angler impact on the preserve would be helpful, especially as the density of users increases.

Targeting interpretation, education, and partnership efforts, including stream restoration activities, toward the angler organizations would be helpful, especially since they are the highest users of the mouse habitat. Integrating and customizing (per Jennifer Frey) the Scorecards (Colorado Parks and Wildlife) Rapid Assessment could be very useful with future management actions.

4.2.6. Jemez Mountains Salamander Summary

Partnerships to research and monitor surface activity time periods for the JMS would help to inform VALL's forest thinning and fire management activities (using pre- and post-burn data) and understand how ongoing restoration activities impact the salamander. Leaving a certain number of logs/acre in thinning units would benefit JMS habitat. The New Mexico Endemic Salamander Team

could help identify best management practices and recovery actions, improving habitat connectivity through road reclamation, evaluating existing infrastructure, and creating permeability for a low mobility species.

In 2019, The Nature Conservancy, along with members of the Jemez Pueblo, partnered with Conservation Canines to "sniff out" the JMS using scent samples to better understand where the elusive salamanders live so forest restoration activities do not harm the species (The Nature Conservancy 2021). VALL managers could also use this type of effort for locating JMS.

Monitoring for chytrid fungus and the vector of disease transmission (e.g., earthworms, Tiger salamander, visitors) from riparian wetlands to upland conifer forests would be useful information to manage this species. Managing for soil compaction, microhabitat trampling, decontamination activities, areas open/closed to hunting, and infrastructure development within JMS habitat could mitigate habitat loss in the preserve.

Understanding how VALL's management activities affect the proposed indicators and measures presented in the Chapter 3 gap analysis is critical for determining whether they are useful for future biological assessments. VALL's wildlife biologist is currently working with NHNM to update the preserve's database.

An interpretive component, perhaps a resource brief or StoryMap, to highlight this species would help visitors understand its existence in the preserve and could highlight ways visitors could help mitigate potential impacts to the species and habitat.

4.2.7. Songbirds Summary

Actions to manage songbirds are to conduct prescribed burns outside of the breeding season, although some species do in fact thrive with controlled fire, and to monitor changes in sound and light pollution impacts to birds (and other wildlife). Additionally, monitoring waterfowl and wading birds during the breeding season would inform a current data gap. Currently, only elk and turkeys are hunted in season, and New Mexico has not proposed hunting upland game or waterfowl in the preserve.

Partnerships with Bandelier National Monument's mist-netting and interpretive activities related to bird-banding programs would be beneficial for VALL. Additional partnership activities could include fall migration monitoring for diurnal raptors, expanding surveys to other areas of the preserve, such as the volcanic domes, including opportunistic hikes in the spruce-fir habitat and areas away from roads, actively monitoring visitor reports of birds and tying VALL's bird checklist to an easily submitted form (e.g., iNaturalist, eBird, preserve email). In addition, establishing thresholds for maintaining good or improving conditions for birds and other wildlife includes the understanding of critical levels of sound and light levels.

4.3. Conclusion

VALL is a high elevation national preserve in its entirety and is warming at a slower rate than areas in the surrounding region. With the preserve's robust science program and landscape-level

partnership with the CFLRP, reliable information on current and trending conditions for natural resources is a requisite for making informed decisions and implementing timely management actions.

Given the diversity of ecosystem resources and the breadth of factors influencing conditions at the preserve, including two major fires in 2011 and 2013 that have drastically altered the vegetation communities in VALL and the surrounding area, identifying the interconnectedness between multiple resources and partners is crucial for achieving resource sustainability on a scale that matters.

VALL managers can consider NRCA findings in different combinations to identify resource-rich areas throughout the preserve, where multiple species and habitats can be collectively managed. The landscape connectivity for all ecosystems inside the preserve is higher compared to areas beyond VALL's boundary. This is especially true for the upper montane ecosystem (e.g., Redondo Peak) where management actions in VALL can significantly contribute to areas outside of the preserve, especially when considering climate-wise strategies.

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Appendix A. Manager Questions and Information Needs

Questions and information needs were posed by VALL managers during the NRCA study scoping process. All are summarized in the preserve's study plan, which is included in the final deliverables packet. The ones that were considered for VALL's NRCA project are listed in Table A-1. When possible, information to address the questions and needs were presented in Chapters 2–4. If a question or need remained unaddressed in the NRCA, suggestions for informing the knowledge gap were presented in the Chapter 4 resource summaries to inform future management activities.

Table A-1. VALL natural resource manager question, need, abbreviated answer, and NRCA report chapter/section for further information summary.

Manager Questions or Needs	Abbreviated Answer(s)	Chapter/Section for Additional Information
A general understanding of air quality conditions in the preserve is desired. In addition, silica dust is an issue due to VALL's rock composition.	The wet nitrogen and sulfur deposition levels over a 5-year average (2014–2018) were rated as poor and fair, respectively, with unknown trends (NPS ARD 2021a). Airborne silica sampling resulted in a recommendation to reevaluate levels during cement-pouring and UTV driving (Ryan-Miller 2021).	2.3: Pollution (Air Quality)
Synthesize and present forest pest outbreak data as a time series.	A series of comparative slides in PowerPoint presentation presented USFS FHP Insect Detection Survey data (USFS 2018), showing that annually, <1% to 60% of the preserve's forested areas have been affected by forest pests from 2000 to 2018.	2.4: Forests Pests and Final Deliverables PowerPoint
The preserve seeks to develop improved understanding and documentation of historical reference conditions for a variety of biological resources in VALL. Traditional ecological knowledge held by the many tribes that have deep ties to the land and continue to collect plants and wildlife on preserve lands, will be considered to help address this information need.	Traditional ecological knowledge is limited. Preserve managers are developing partnerships to address this, beginning with vegetation plots on Redondo Peak to monitor plants that are of ecocultural importance. The Jemez Pueblo also partnered with the Nature Conservancy to locate JMS. VALL managers could consider a similar partnership, which may expand the preserve's understanding of traditional knowledge related to the preserve's natural resources.	4.2.3: Redondo Peak Diversity Summary 4.2.6: Jemez Mountains Salamander Summary

Table A-1 (continued). VALL natural resource manager question, need, abbreviated answer, and NRCA report chapter/section for further information summary.

Manager Questions or Needs	Abbreviated Answer(s)	Chapter/Section for Additional Information
Managers seek to synthesize and analyze 105-year climate data set. Link temperatures with preserve's water quality and streamflow data. Predictive model compared to current forecasts will guide future timing of management activities. Is the preserve a cold sink that will aide species movements as temperature and precipitation patterns shift?	The development of a predictive model was beyond the scope of an NRCA. A study proposal could be submitted to the NRCA Program's Focused Condition Assessment funding call.	N/A
Correlate water discharge and water quality data to climate data for modeling/ forecasting purposes. Preserve is considering applying for a Wild and Scenic Rivers (WSR) designation for the East Fork Jemez River. Active watershed restoration effort (i.e., stream bank and channel) is underway.	These long-term data sets require expertise in hydrology for analyses. J. Albright inquired with Dave Thoma and Dave Tercek about their water balance modeling and availability for VALL's NRCA study, but schedules could not be coordinated. A study proposal could be submitted to the NRCA Program's Focused Condition Assessment funding call. J. Albright also introduced preserve managers to the lead for Wild & Scenic River for a formal designation just downstream of the preserve boundary line and preserve staff would be very interested in assessing potential designation of the upper reaches of the Jemez River within VALL in the Valle Grande.	N/A
Need assistance with Crown of the Continent Research Learning Center effort by performing an extensive literature search and uploading reports/data to NPS IRMA.	Copies of newly created GIS data and metadata for songbirds, Jemez Mountains salamander, and the New Mexico meadow jumping mouse and all literature cited in VALL's NRCA were included in the preserve's final deliverables packet. This information can be used on the Crown of the Continent Research Learning Center website.	Literature Cited and Project Deliverables packet
Park is applying for International Dark Sky Place certification and NRCA information may be helpful in improving certification designation level.	All available night sky data were summarized and shown by location and condition in Figure 2.1.3-1 and Table 2.1.3-1.	2.3: Pollution (Light)

Table A-1 (continued). VALL natural resource manager question, need, abbreviated answer, and NRCA report chapter/section for further information summary.

Manager Questions or Needs	Abbreviated Answer(s)	Chapter/Section for Additional Information
Identify areas throughout the preserve that are darkest, quietest, and have untrammeled views.	Based on NPS NSNSD's night sky all-sky light pollution and the sound pressure level models, the area in the preserve with the least amount of predicted light and sound pollution is along the western half of the preserve, away from the old logging roads that are accessible to visitors. This information, coupled with a comprehensive visual resources evaluation, could help determine a landscape-scale monitoring plan to protect the darkest, quietest, and least visually trammeled areas in the preserve	2.3: Pollution (last paragraph summary) (See entry on next page for additional information.)
What is the broader structural connectivity among major ecosystems ("habitat") within VALL landscape and surrounding areas?	Structural connectivity is highest for the upper montane ecosystem, and the patterns of ecosystem permeability are much more variable, nuanced, and specific to the remaining four ecosystems. Connectivity is greatest along the western half of the study area. Further analyses that include small, but important, human structures and activities will improve the results.	3.1.4: Landscape Permeability 4.2.1: Landscape Permeability Summary
What are the potential synergies or conflicts of active or potential activities, such as forest thinning and riparian management in relation to landscape connectivity?	This is an important question but remains an open topic that requires further analyses of these datasets; it would benefit from more specific management questions. Synergetic analyses would typically proceed by identifying locations that meet specific conditions of high or low permeability for a given ecosystem, and then overlayed by a map generated by identifying other locations that meet a second condition.	N/A
Use assessment of habitat connectivity patterns to inform landscape planning and identify opportunities for mitigation or restoration actions that improve connectivity of corridors. Apply to all planning/zoning efforts. Currently developing a wildlife management plan to address overall management approach. The badger and the porcupine could both be interesting and provide information on species we are currently not studying.	Addressing these general questions remains an open topic that may require further analyses of these datasets and would benefit from more specific management questions. Potentially, life history characteristics of the badger and, separately, the porcupine, would inform the typical ecosystem type that provides general habitat for each species. Specific management actions that are being considered, for example, locations for potential forest thinning, could then be evaluated by calculating the average ecosystem permeability within a given forest thinning polygon to serve as a metric to compare locations. The degree to which a given species is more of a generalist or specialist of a given habitat (ecosystem) type will also be an important consideration.	N/A

Table A-1 (continued). VALL natural resource manager question, need, abbreviated answer, and NRCA report chapter/section for further information summary.

Manager Questions or Needs	Abbreviated Answer(s)	Chapter/Section for Additional Information
Update species in NPSpecies.	Jeff Albright discussed with Alison Loar, who is with the NPS Inventory & Monitoring Division (IMD) and provides technical support on NPSpecies, the process of providing technical assistance to VALL for reviewing and documenting supporting evidence to the current batch of uploaded NPSpecies records (~2,400). The amount of time and effort that this would entail, even for a subset of taxa (e.g., songbirds), including assistance from preserve staff, was beyond the scope of the NRCA. Instead, a proposal for hiring a biological resources intern or GIP professional may be a future option, and IMD's NPSpecies Evidence Template was provided in VALL's final deliverables packet, which outlines the SOP for translating raw data to the Evidence Template using Access.	VALL's final deliverables packet includes the correspondence and IMD's Evidence Template for NPSpecies updates.
The visual resources condition assessment will serve as a baseline for future zoning or wilderness planning. It may also guide the preserve's research permitting process to maintain pristine conditions.	Because only seven locations were evaluated and most were along roads or in the front country, these results serve as a baseline only for those seven locations. Additional sampling is required to inform zoning and wilderness planning, to serve as a guide for the preserve's research permitting process, and for obtaining baseline condition of visual resources. A citizen science project was identified for augmenting photos for evaluating the visual resources in the preserve.	3.2: Visual Resources Condition Assessment 4.2.2: Visual Resources Summary
The NRCA will evaluate sound and dark sky models with scenic view analyses to identify the darkest, quietest, and most pristine (i.e., untrammeled) views.	With only seven locations clustered in one area of the preserve (south-central), we could not determine the areas where the most pristine, untrammeled views were located with respect to the sound and night sky models; however, data from the NPS Natural Sounds and Night Skies Division show that the western portion of the preserve is the most pristine in terms of low light and sound pollution.	3.2: Visual Resources Condition Assessment 2.3: Pollution (last paragraph summary)
How does Redondo Peak biodiversity compare with areas that are similar in climate, elevation, and soils?	In 2014, NPS staff and cooperators conducted a comprehensive inventory of the flora and fauna in spruce-fir forests, upper montane meadows, and felsenmeer rock fields on Redondo Peak. While these data can be compared to biodiversity data in these habitat types elsewhere in the southern Rocky Mountains, similar biodiversity studies in the region are lacking. Moreover, comparing species richness from one place to another may be less informative than monitoring key indicator and climate-sensitive species within each of the three habitat types over time. However, the 2014 bioinventory was the first effort to explore biodiversity at this location.	3.3: Redondo Peak Gap Analysis

Table A-1 (continued). VALL natural resource manager question, need, abbreviated answer, and NRCA report chapter/section for further information summary.

Manager Questions or Needs	Abbreviated Answer(s)	Chapter/Section for Additional Information
Has richness or diversity of Redondo Peak changed over time?	Although the bioinventory hasn't been repeated, there have been continued efforts to sample terrestrial invertebrates and nocturnal owls. Some collections still need to be identified. Additional data are needed to answer this question.	3.3: Redondo Peak Diversity Gap Analysis 4.2.3: Redondo Peak Diversity Summary
Which Redondo Peak species are the most vulnerable to climate change, and how is the biological community likely to change given future climate scenarios?	In a climate change vulnerability assessment published for the state of New Mexico, the Jemez Mountains ranked highest in terms of climate exposure (Enquist and Gori 2008). The ranking for the Jemez Mountains conservation area was the result of significantly warmer and more highly variable temperatures since 1970 and significantly less precipitation since 1991. Between 1991 and 2005, precipitation declined by an average of only 3%, but from 2000 to 2005 precipitation declined by 17% (Enquist and Gori 2008). Because Redondo Peak is the highest point in the preserve and the second highest point in the Jemez Mountains, species dependent on the cool, moist conditions typically found at higher elevations may be extirpated from the region given future climate change scenarios. The landscape permeability condition assessment may be used to guide connectivity for vulnerable species.	3.1: Landscape Permeability Condition Assessment 4.2.1: Landscape Permeability Summary 3.3: Redondo Peak Diversity Gap Analysis 2.5: Climate Change
How much have wetlands increased following restoration efforts?	We were unable to address this question with the lack of available data.	N/A
Management needs included an updated wetland map and evaluation of wetland quality through the analysis of field data collected before and after restoration efforts	We attempted to address this question through a change analysis using Landsat satellite imagery. However, the unsupervised classification did not consistently identify known wetland areas and misclassified some xeric grasslands as wetlands. Field data were summarized as part of this assessment.	3.4: Wetlands Condition Assessment
Identify priority areas for new or further restoration work.	Please refer to the comment above, and the wetlands evaluation results from Kevin Noon's (wetlands program lead with the NPS Water Resources Division) analysis.	4.2.4: Wetlands Summary
Identify areas to survey and/or introduce New Mexico meadow jumping mouse.	The New Mexico meadow jumping mouse habitat assessment included in this report indicates that 128 ha (316 ac) of habitat along 38 km (24 mi) of streams in VALL are likely suitable mouse habitat.	3.5: New Mexico Meadow Jumping Mouse Habitat Availability Gap Analysis
Evaluate stock tank removal in wetlands.	A separate analysis conducted by Kevin Noon (wetlands program lead with the NPS Water Resources Division) identified 45 stock tanks that need restoration work (see Chapter 4 for more information).	4.2.4: Wetlands Summary

Table A-1 (continued). VALL natural resource manager question, need, abbreviated answer, and NRCA report chapter/section for further information summary.

Manager Questions or Needs	Abbreviated Answer(s)	Chapter/Section for Additional Information
Use results from wetland gain/loss map for identifying invasive plant locations and determining how many elk (*Cervus elaphus*) the preserve can sustain with minimal damage to wetlands and restoration efforts.	Field data will be the most accurate method for mapping non-native invasive plants. There are between 2,500 and 3,000 elk that reside in the preserve. During summer months elk primarily graze grassland vegetation; they shift to include more wetland browse species during winter. To what extent woody riparian vegetation is impacted by browsing in the preserve depends not only on the number of elk but also on elk behavior and spatial distribution.	4.2.5: New Mexico Meadow Jumping Mouse Habitat Availability Summary
Managers need a habitat map for New Mexico meadow jumping mouse showing patch size and connectivity between patches to target monitoring efforts and identify potential reintroduction areas.	Four patches met the minimum patch size for supporting multiple, resilient jumping mouse populations (Table 3.5.2 1). One patch was mapped along upper Jaramillo Creek, another along the East Fork Jemez River, La Jara Creek, and lower Jaramillo Creek (referred to as East Fork Jemez Complex), and the last two patches were mapped along San Antonio Creek (Figure 3.5.2-1). The four patches were separated from each other by more than 200 m (656 ft), which is the maximum recommended distance for connectivity between subpopulations (USFWS 2020a), but connectivity within these patches was continuous.	3.5.2: New Mexico Meadow Jumping Mouse Habitat Availability Status of Knowledge
What is the connectivity condition for the New Mexico Meadow Jumping Mouse habitat?	Although jumping mice may disperse more than 1 km (0.6 mi), and perhaps as far as 4 km (2.5 mi), they need suitable habitat to make these forays (USFWS 2014b). The distance between the East Fork Jemez Complex and upper Jaramillo Creek is about 0.4 km (0.2 mi). The distance between the two San Antonio Creek patches is about 0.6 km (0.4 mi). Both are potentially within the dispersal and exploratory distances that jumping mice may undertake, but if appropriate habitat does not link these patches, then jumping mice may not travel between them. Further investigation is needed to account for potential habitat patches outside of the preserve.	3.5: New Mexico Meadow Jumping Mouse Habitat Availability Gap Analysis
Managers need a comprehensive checklist of birds listed by habitat type, with emphasis on key indicator species. The list will help NPS staff identify potential impacts of current and future management activities on birds in the preserve.	We developed an Excel spreadsheet that includes a list of all species known to occur in or suspected to occur in the preserve based on a review of surveys conducted in VALL as of spring 2020, including sightings reported in eBird and the New Mexico Breeding Bird Atlas. We also developed a brochure-style checklist of birds for visitor use that includes a submission form for rare or unusual bird sightings. In the assessment, we included a table of key indicator species by habitat type. The Chapter 4 summary for songbirds identifies an opportunity to engage citizen scientists in reporting birds observed.	3.6: Songbirds Condition Assessment VALL's final deliverables packet includes the spreadsheet, brochure, and InDesign file for future updates 4.2.7: Songbirds Summary

Table A-1 (continued). VALL natural resource manager question, need, abbreviated answer, and NRCA report chapter/section for further information summary.

Manager Questions or Needs	Abbreviated Answer(s)	Chapter/Section for Additional Information
NPS staff requested a summary of data gaps for songbirds, particularly fall and winter use, to help prioritize future monitoring efforts.	Data gaps include the absence of regular songbird monitoring in high elevation spruce-fir forests, and to a lesser extent, wet meadows, and riparian areas. There is also the need for vegetation data to accompany songbird surveys, especially given restoration activities. The absence of current surveys for diurnal raptors and waterfowl during the breeding season, autumn migration, and winter is also a data gap.	3.6: Songbirds Condition Assessment
Managers need of a fine-scale habitat suitability map to target survey efforts and eventually determine population size, status, and trends for the Jemez Mountains salamander.	Because of the unique habitat requirements of Jemez Mountains salamander, some of which vary over small spatial and temporal scales, creating a habitat suitability map is not currently possible given available data. However, several studies are underway that will help meet preserve managers objectives in the future. These studies are described in the gap analysis.	3.7: Jemez Mountains Salamander Gap Analysis

Appendix B. Landscape Permeability Methods and Figures

The methodology used in the condition assessment for landscape permeability is summarized below and was developed by contributing author, David Theobald.

What to connect

We mapped permeability across the landscape from each of five major types of ecosystems (or life zones): upper montane, lower montane, shrubland/woodland, grassland, and valley bottom (riparian) types. To map the five ecosystems, we grouped 104 ecological systems found in the VALL study area from the biophysical settings dataset (BPS_NAME) (USGS 2016; LANDFIRE v1.4) grouped by the existing vegetation type "lifeform" class (Table B-1). We used a "gradient-based" approach (McGarigal et al. 2009) to identify numerous randomly selected locations from within each ecosystem, a more robust approach than arbitrarily creating "patches" of homogenous habitat.

Table B-1. LANDFIRE v1.4 (USGS 2016) ecological biophysical setting names and ecosystem categories evaluated for VALL's landscape permeability condition assessment.

Ecosystem Name	Ecosystem Group	Biophysical Setting Name
Upper montane	1	Perennial Ice/Snow
	1	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
	1	Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland
	1	Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland
	1	Rocky Mountain Alpine Fell-Field
	1	Rocky Mountain Alpine Turf
	1	Rocky Mountain Subalpine-Montane Mesic Meadow
Lower montane	2	Rocky Mountain Foothill Limber Pine-Juniper Woodland
	2	Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland
	2	Southern Rocky Mountain Ponderosa Pine Woodland
	2	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
	2	Rocky Mountain Aspen Forest and Woodland
	2	Rocky Mountain Lower Montane-Foothill Shrubland
	2	Rocky Mountain Gambel Oak-Mixed Montane Shrubland
	2	Rocky Mountain Aspen Forest and Woodland
	2	Rocky Mountain Lodgepole Pine Forest
	2	Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland
	2	Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland
	2	Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland
	2	Rocky Mountain Lower Montane-Foothill Shrubland

Table B-1 (continued). LANDFIRE v1.4 (USGS 2016) ecological biophysical setting names and ecosystem categories evaluated for VALL's landscape permeability condition assessment.

Ecosystem Name	Ecosystem Group	Biophysical Setting Name
Lower montane (continued)	2	Rocky Mountain Gambel Oak-Mixed Montane Shrubland
	2	Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland
	2	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
	2	Rocky Mountain Montane Riparian Systems
Shrubland	3	Inter-Mountain Basins Big Sagebrush Steppe
	3	Mojave Mid-Elevation Mixed Desert Scrub
	3	Inter-Mountain Basins Big Sagebrush Shrubland - Basin Big Sagebrush
	3	Inter-Mountain Basins Big Sagebrush Shrubland - Wyoming Big Sagebrush
	3	Inter-Mountain Basins Montane Sagebrush Steppe
	3	Inter-Mountain Basins Big Sagebrush Shrubland
	3	Inter-Mountain Basins Montane Sagebrush Steppe - Mountain Big Sagebrush
	3	Inter-Mountain Basins Semi-Desert Grassland
	3	Rocky Mountain Subalpine/Upper Montane Riparian Systems
	3	Inter-Mountain Basins Sparsely Vegetated Systems
	3	Colorado Plateau Pinyon-Juniper Woodland
	3	Inter-Mountain Basins Big Sagebrush Shrubland
	3	Inter-Mountain Basins Mixed Salt Desert Scrub
	3	Inter-Mountain Basins Juniper Savanna
	3	Southern Rocky Mountain Ponderosa Pine Savanna
	3	Inter-Mountain Basins Semi-Desert Shrub-Steppe
	3	Inter-Mountain Basins Greasewood Flat
	3	Colorado Plateau Pinyon-Juniper Woodland
	3	Southern Rocky Mountain Ponderosa Pine Woodland
	3	Southern Rocky Mountain Pinyon-Juniper Woodland
	3	Colorado Plateau Mixed Low Sagebrush Shrubland
	3	Inter-Mountain Basins Big Sagebrush Shrubland
	3	Inter-Mountain Basins Mixed Salt Desert Scrub
	3	Inter-Mountain Basins Juniper Savanna
	3	Southern Rocky Mountain Ponderosa Pine Savanna
	3	Inter-Mountain Basins Montane Sagebrush Steppe
	3	Inter-Mountain Basins Semi-Desert Shrub-Steppe
	3	Inter-Mountain Basins Semi-Desert Grassland

Table B-1 (continued). LANDFIRE v1.4 (USGS 2016) ecological biophysical setting names and ecosystem categories evaluated for VALL's landscape permeability condition assessment.

Ecosystem Name	Ecosystem Group	Biophysical Setting Name
Shurbland (continued)	3	Southern Rocky Mountain Ponderosa Pine Woodland
	3	Inter-Mountain Basins Big Sagebrush Steppe
	3	Inter-Mountain Basins Montane Sagebrush Steppe
	3	North American Warm Desert Sparsely Vegetated Systems
	3	Colorado Plateau Pinyon-Juniper Woodland
	3	Madrean Encinal
	3	Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland
	3	Southern Rocky Mountain Ponderosa Pine Woodland
	3	Southern Rocky Mountain Pinyon-Juniper Woodland
	3	Chihuahuan Creosotebush Desert Scrub
	3	Chihuahuan Mixed Salt Desert Scrub
	3	Chihuahuan Succulent Desert Scrub
	3	Inter-Mountain Basins Big Sagebrush Shrubland
	3	Chihuahuan Mixed Desert Shrubland
	3	Chihuahuan Grama Grass-Creosote Steppe
	3	Mogollon Chaparral
	3	Southern Rocky Mountain Juniper Woodland and Savanna
	3	Inter-Mountain Basins Semi-Desert Shrub-Steppe
	3	Southern Rocky Mountain Montane-Subalpine Grassland
	3	Inter-Mountain Basins Greasewood Flat
	3	Southern Rocky Mountain Ponderosa Pine Woodland
	3	Southern Rocky Mountain Pinyon-Juniper Woodland
	3	Rocky Mountain Lower Montane-Foothill Shrubland
	3	Rocky Mountain Gambel Oak-Mixed Montane Shrubland
	3	Inter-Mountain Basins Montane Sagebrush Steppe
	3	Southern Rocky Mountain Ponderosa Pine Woodland - North
	3	Rocky Mountain Lower Montane-Foothill Shrubland
	3	Rocky Mountain Gambel Oak-Mixed Montane Shrubland
Grassland	4	Barren-Rock/Sand/Clay
	4	Western Great Plains Foothill and Piedmont Grassland
	4	Western Great Plains Floodplain Systems
	4	Apacherian-Chihuahuan Semi-Desert Grassland and Steppe
	4	Inter-Mountain Basins Semi-Desert Grassland
	4	Southern Rocky Mountain Montane-Subalpine Grassland

Table B-1 (continued). LANDFIRE v1.4 (USGS 2016) ecological biophysical setting names and ecosystem categories evaluated for VALL's landscape permeability condition assessment.

Ecosystem Name	Ecosystem Group	Biophysical Setting Name
Grassland (continued)	4	Northern Rocky Mountain Subalpine-Upper Montane Grassland
	4	Apacherian-Chihuahuan Semi-Desert Grassland and Steppe
	4	Chihuahuan Gypsophilous Grassland and Steppe
	4	Chihuahuan Sandy Plains Semi-Desert Grassland
	4	Inter-Mountain Basins Semi-Desert Grassland
	4	Western Great Plains Shortgrass Prairie
	4	Chihuahuan Loamy Plains Desert Grassland
	4	Chihuahuan-Sonoran Desert Bottomland and Swale Grassland
	4	Western Great Plains Shortgrass Prairie
	4	Western Great Plains Floodplain Systems
	4	Western Great Plains Foothill and Piedmont Grassland
	4	Western Great Plains Floodplain Systems
Valley bottom/riparian	5	North American Warm Desert Riparian Systems
	5	Rocky Mountain Montane Riparian Systems
	5	Rocky Mountain Montane Riparian Systems
	5	Rocky Mountain Montane Riparian Systems
	5	Open Water
	5	Rocky Mountain Montane Riparian Systems

Resistance to Movement

Movement across the landscape is assumed to be preferentially restricted by land uses and human activities, such as built-up areas, roads, croplands, and energy development. To represent human land use, we used a map of human modification (Figure 3.1.3-1d; Theobald 2013; Theobald et al. 2020) where the footprint and intensity of a parsimonious list of stressors are quantified and combined into a map of overall modification, *H,* that ranges from 0 to 1. Primary stressors mapped here include built-up areas, roads, croplands, and accessibility (see Table B-2 for a full list of stressors adapted from Table 1 in Theobald et al. (2020)). The resistance, *R*, to movement was computed using a standard function to incorporate assumed increasing sensitivity at higher levels of higher human use (Theobald et al. 2012), where:

$R = (I + H)^{10}$.

Table B-2. Overview of the stressors data sets and their sources, resolutions, and dates of versions used to develop the landscape permeability human modifications map (adapted from Table 1, in Theobald et al. (2020)).

Class	Stressor	Source	Resolution (km^2)	Year(s) [1]
Urban & built-up	Built-up	Global Human Settlement Layer version R2018A (Pesaresi et al. 2015)	0.0009–0.90	1990, 2000, 2010 (1), 2015
Agriculture	Croplands & pasturelands	European Space Agency CCI land cover (Li et al. 2018)	0.90	1992, 2000, 2010, 2015
	Croplands & pasturelands	Unified Cropland Layer (Waldner et al. 2016)	1.00	2010
	Croplands & pasturelands	Global Land Systems v2 (Kehoe et al. 2017)	1.00	2010
	Grazing	Gridded Livestock v3 (Robinson et al. 2014, Gilbert et al. 2018)	10.00	2010
Energy production & mining	Oil & gas production	Nighttime flares from DMSP/OLS and VIIRS (Elvidge et al. 2009; Elvidge et al. 2016)	0.25–1.00	2016
	Mining & quarrying	S&P global mining dataset (S&P 2018; Valenta et al. 2019)	~1.00: 10000.00	1990, 2000, 2010, 2015, 2018
	Renewable & non-renewable power generation	World Resources Institute Power plants (WRI 2019)	~1.00: 100000.00	1990, 2000, 2010, 2015, 2018
Transportation & service corridors	Roads	OSM highway, minor, and two-track features (OpenStreetMap 2019)	~1:10–25000.00	2019
	Railways	OSM railway features (OpenStreetMap 2019)	~1:10–25000.00	2019
	Powerlines	OSM power line features (OpenStreetMap 2019)	~1:10–25000.00	2019

[1] Based on interpolation.

Table B-2. Overview of the stressors data sets and their sources, resolutions, and dates of versions used to develop the landscape permeability human modifications map (adapted from Table 1, in Theobald et al. (2020)).

Class	Stressor	Source	Resolution (km^2)	Year(s) [1]
Transportation & service corridors (continued)	Electrical infrastructure	Nighttime lights from DMSP/OLS and VIIRS (Elvidge et al. 2001; Doll 2008; Elvidge et al. 2013; Zhang et al. 2016)	0.25–1.00	1992, 2000, 2010, 2015, 2018
Biological harvesting	Logging & wood harvesting	Forest loss (Curtis et al. 2018) and forest change (Hansen et al. 2013)	0.09–100.00	2000, 2010, 2018
Human intrusions	Human intrusions	Human intrusion (Theobald 2008) using accessibility and population from GRUMP v1.01 (CIESIN 2017) and GPW v4 (CIESIN 2018)	1.00	1990 (1), 2000, 2010, 2015
Natural system modifications	Reservoirs	Global Reservoirs and Dams (GRanD v1.3; Lehner et al. 2011)	~1.00: 25000.00	1990, 2000, 2010, 2017
Pollution	Air pollution	Emissions Database for Global Atmospheric Research (EDGAR v4.3.2; Crippa et al. 2018) for nitrogen oxides	~100.00	1990, 2000, 2010, 2012

[1] Based on interpolation.

It was also assumed that moving from the "target" ecosystem, e_k, (the locations from which connectivity is measured) through other ecosystems, e_l, is preferentially avoided. To calculate the resistance weights, specific to each target ecosystem, the ratio of the length of the shared boundary, b, was calculated as:

$$w_{k,l} = \sqrt{1/(b_l/b_k)},$$

(Shown in Table B-3).

The resistance surface was then calculated, for ecosystem k, as:

$$R_k = (1 + w_{k,l}H)^{10}.$$

Table B-3. The ecosystem type-specific weights used to calculate resistance values that are used in the landscape permeability model for VALL. Weights are estimated as a function of the shared boundary length of each ecosystem type. Weights for a given ecosystem type (in column 1) are found along the corresponding row.

Ecosystems	Upper montane	Lower montane	Shrubland	Grassland	Riparian/ Valley bottom
Upper montane	1.0	1.1	5.8	10.2	3.2
Lower montane	7.6	1.0	2.8	24.4	2.2
Shrubland	34.7	2.3	1.0	2.4	1
Grassland	34.3	11.3	1.3	1.0	1.7
Riparian/Valley bottom	31.1	2.7	1.2	4.8	1.0

Model connectivity

The least-cost distance (Theobald et al. 2012) was then calculated from each starting location i across R. We examined three movement distances, d: 10, 30, and 50 km (6.2, 18.6, 31.1 mi) (following Saura et al. 2017). The measure of distance was converted to a "dispersal" probability, p, using an exponentially declining probability function, where p_{ij}=0.01 at distance d (Urban and Keitt 2001). This approach is advantageous because results are based on probabilities that are easily interpreted, robust, and provide a rigorous quantification of connectivity (Saura and Pascual-Hortal 2007; Theobald et al. 2012; Cushman et al. 2014). Because each non-patch location j has some probability of being reachable from i (patch or pixel), the probability from multiple starting locations, n, needs to be combined. A simple assumption is that if the dispersal probability from even just a single starting location i exceeds a threshold t (i.e., $p_{ij} > t$), then i and j are "connected" (e.g., Saura et al. 2017). To refine that assumption and account for the benefits of redundancy provided by multiple connections to nearby patches, the multiple values of p at j are combined using the fuzzy sum operator instead of the maximum or average value (Theobald et al. 2013; Theobald et al. 2020):

$$p'_j = 1 - \prod_j^n \times (1 - p_j).$$

For example, assume the p1,j = 0.6 and p2,j = 0.5. Summing the values results in 1.1, which exceeds the theoretical maximum of 1.0. Instead, the fuzzy sum is calculated, which is additive and increasing, but does not exceed 1. So, the fuzzy sum value is: 1−((1−0.6) x (1−0.5)) = 0.8. As with all connectivity modeling approaches, it remains challenging to validate these outputs, though opportunities to compare with other evidence (such as field experience, data on roadkill) should be explored. For convenience, below the mapped ecosystem, permeability is denoted simply as p(e) and the landscape permeability as p(L). Maps were generated to explore the permeability of the landscape context from the location of the landscape features that are connected: the connectivity from specific ecosystem types, or connectivity through the "matrix" between the ecosystem of interest. All input datasets are represented at 30 m (98 ft) resolution, and permeability outputs are modeled at 90 m (295 ft).

Quantify connectivity

To quantify the landscape per the measure, *probability of ecosystem connectivity*, the mean and standard deviation of the probability values for each ecosystem were summarized by calculating the *p'*, calculated separately for each of the five ecosystems, across the park boundary. Locations that are not connected (*p'*=0.0), but within the park boundary, are included in the summary statistics. The ecosystem and landscape permeability values range from 0.0 (not permeable, disconnected) to 1.0 (completely permeable, connected).

Additional Figures

Figures B1–B6 depict more detailed results for the landscape permeability condition assessment and are referenced throughout the evaluation in Section 3.1.

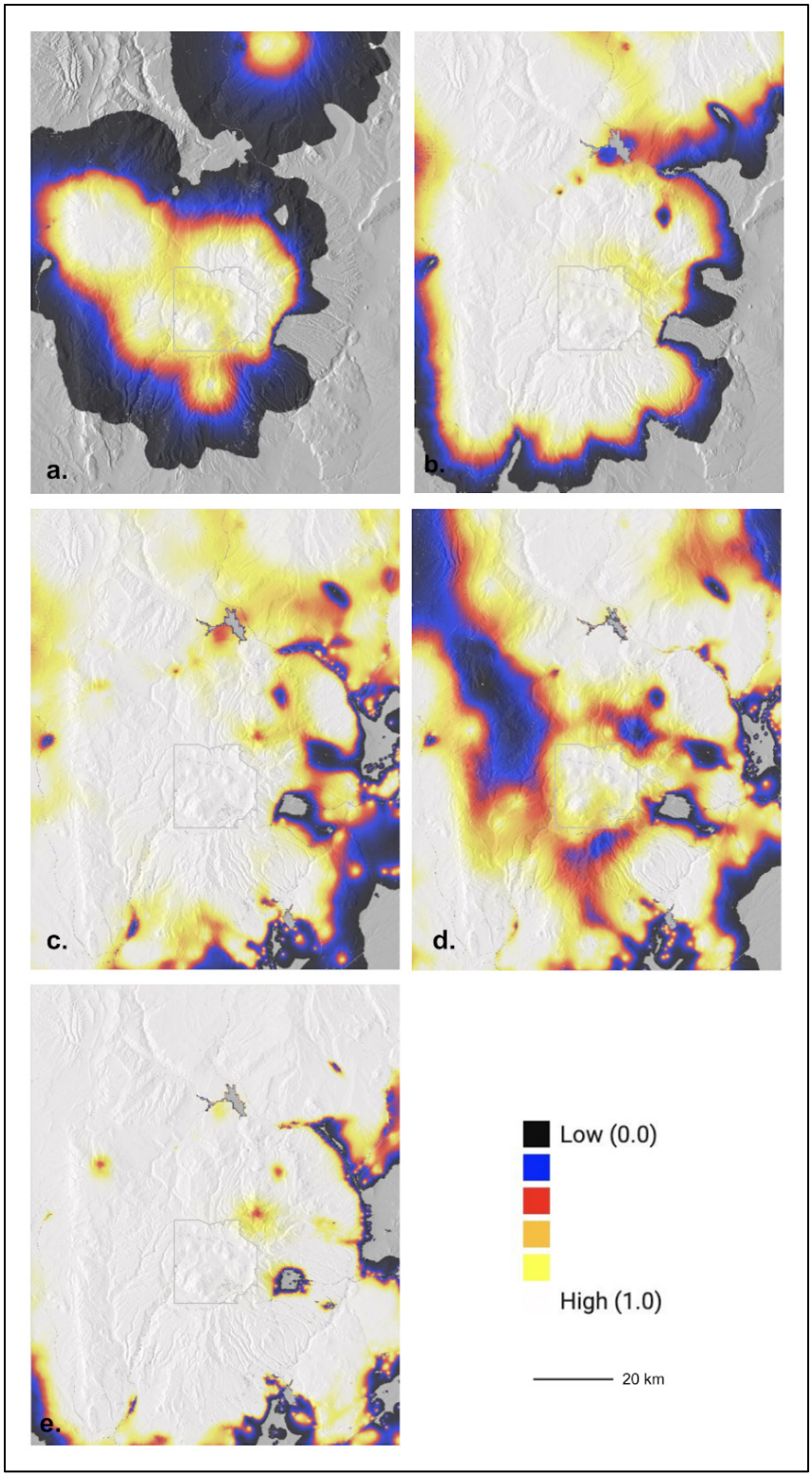


Figure B-1. Ecosystem permeability assuming a 30 km (18.6 mi) movement distance for the study area around VALL (center): a. upper montane; b. lower montane; c. shrubland; d. grassland; and e. riparian/valley bottom. Permeability remains generally highest in the center of the study area and is highly variable according to ecosystem type. Low permeability (0.0) is shown in black and high permeability (1.0) is in white.

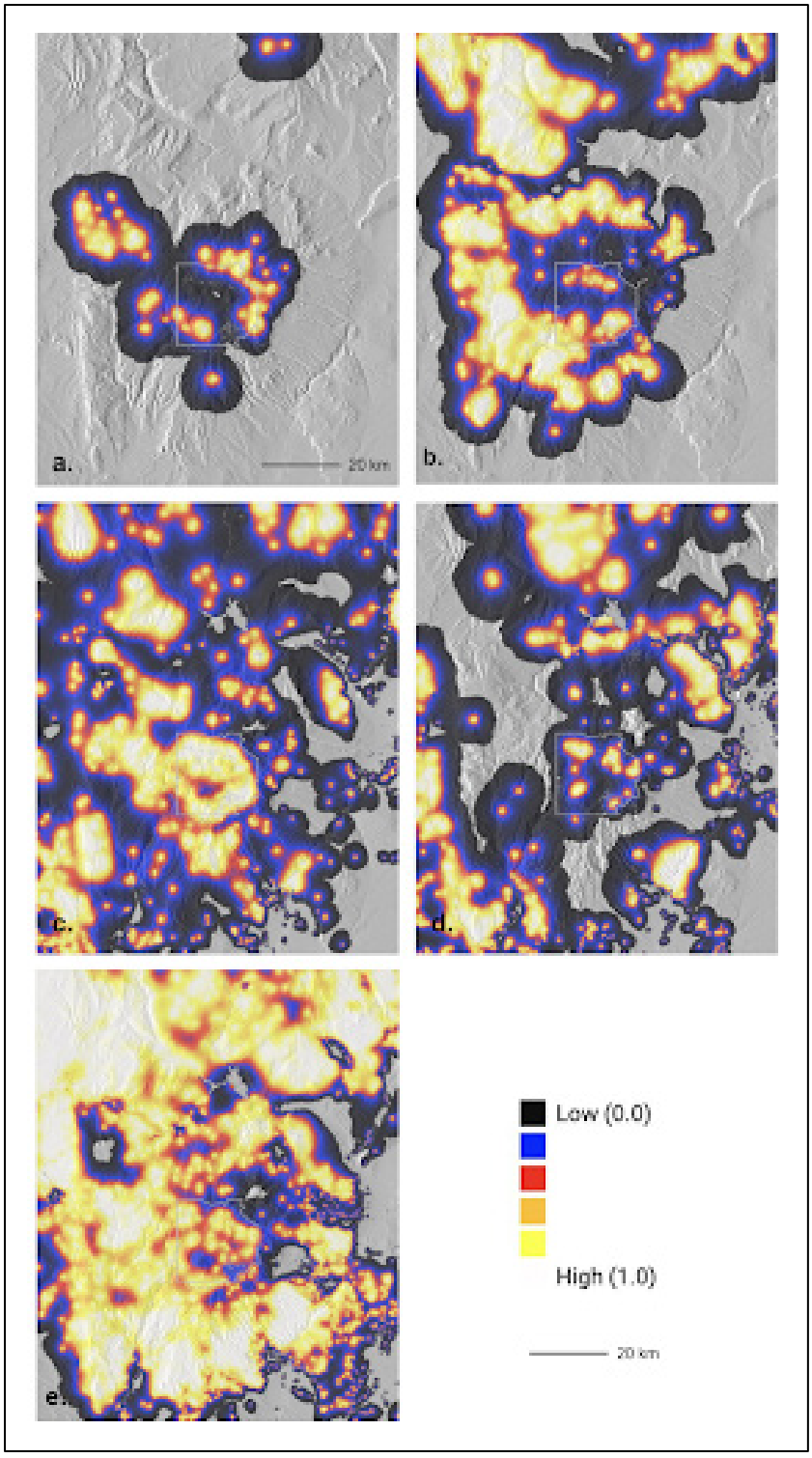


Figure B-2. Ecosystem permeability assuming a 10 km (6.2 mi) movement distance for the study area around VALL (center): a. upper montane; b. lower montane; c. shrubland; d. grassland; and e. riparian/valley bottom. Permeability remains generally highest in the center of the study area, though is highly variable according to ecosystem type. Low permeability (0.0) is shown in black and high permeability (1.0) is in white.

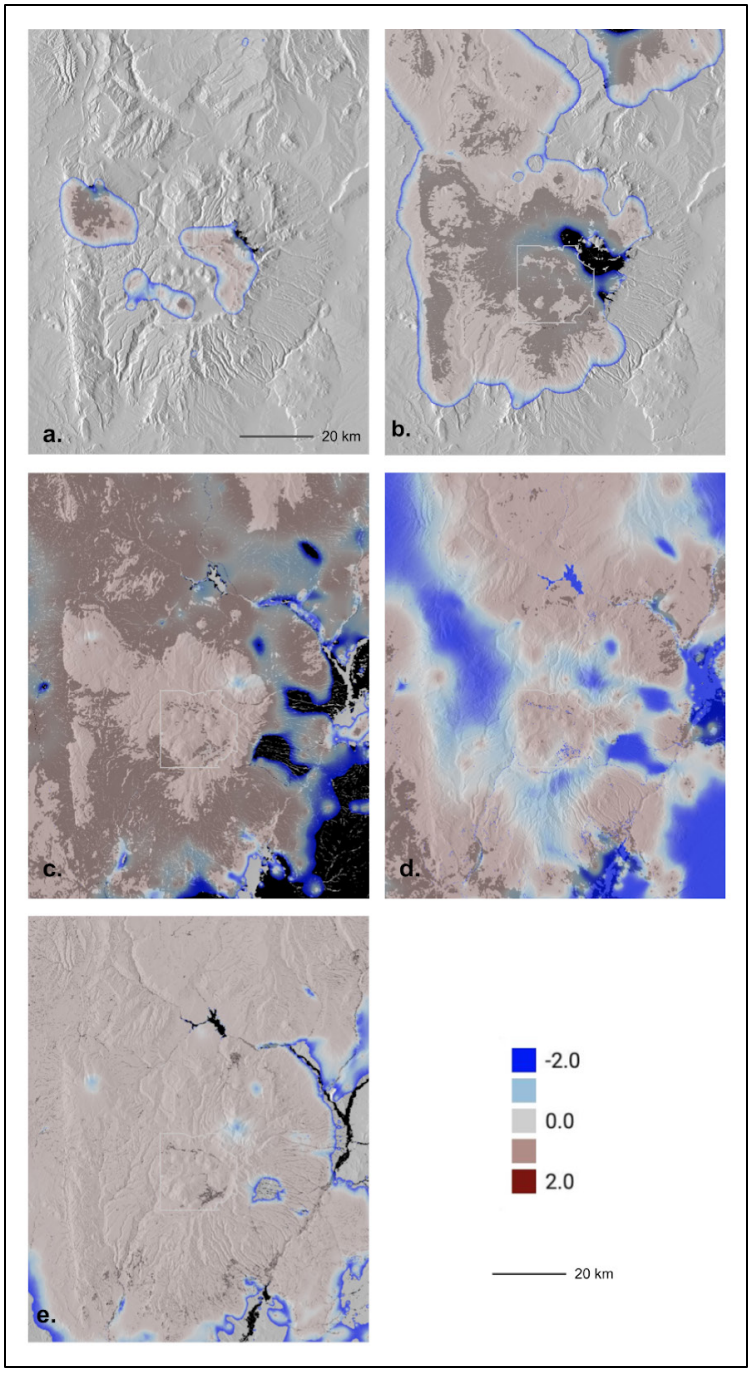


Figure B-3. Ecosystem permeability relative to permeability values for the *in situ* distribution of ecosystems within VALL, assuming a 30 km (18.6 mi) movement distance, organized by: a. upper montane; b. lower montane; c. shrubland; d. grassland; and e. riparian/valley bottom. The location of ecosystems is shown in black (which can appear as shades of grey underneath the z-score rendering), and locations with z-scores lower than −2.0 are not shown for clarity. Where higher permeability (red) coincides with current ecosystem locations (black, grey), management activities (e.g., fuel treatment in lower montane ecosystems) would also contribute to permeability for potential future adaptation. Conversely, places where management of current ecosystems would likely have very low benefit for potential adaptation (blue or clipped) are shown where ecosystems are shown in black.

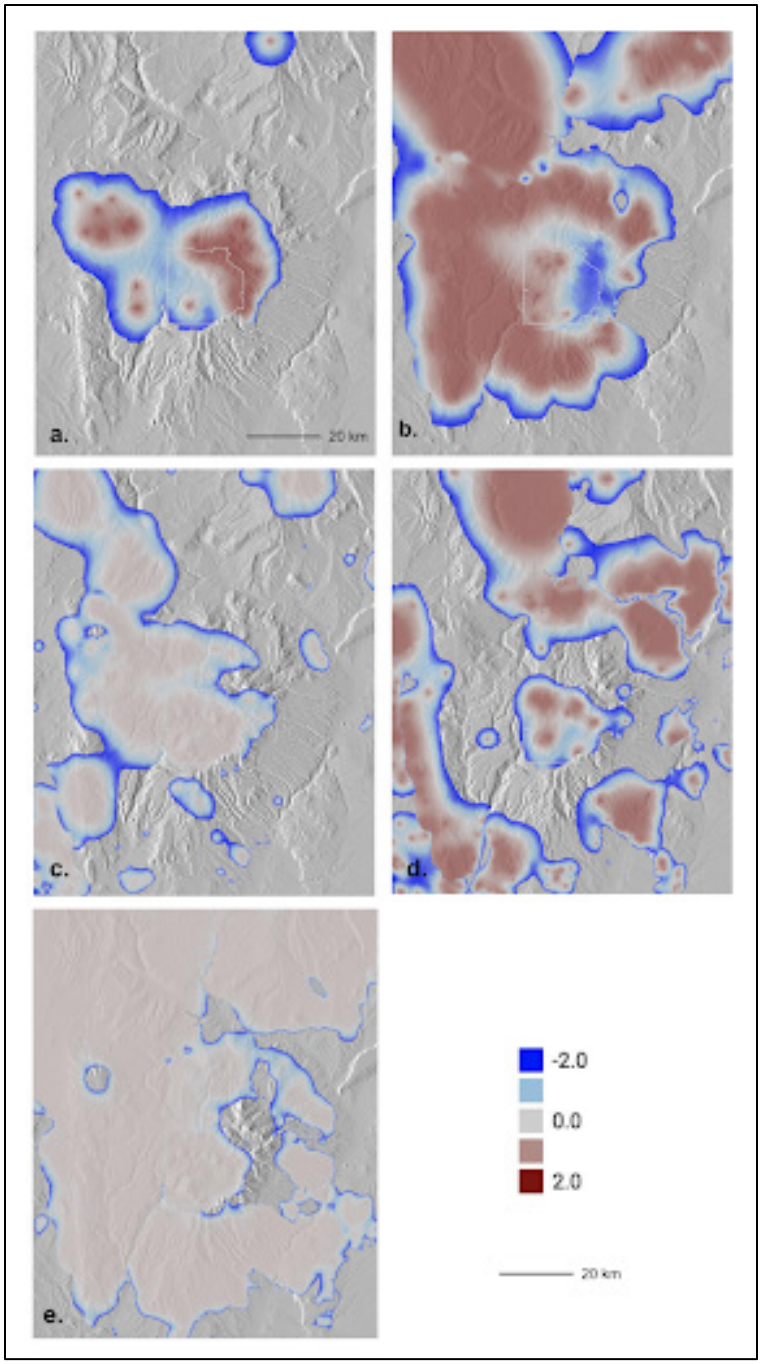


Figure B-4. Ecosystem permeability relative to permeability values from within VALL's boundary, assuming a 30 km (18.6 mi) movement distance, organized by: a. upper montane; b. lower montane; c. shrubland; d. grassland; and e. riparian/valley bottom. Higher permeability (red) shows locations where management actions that would contribute significantly to permeability would likely occur within/adjacent to the preserve. For the lower montane ecosystem (b), this would be primarily to the southwest, and to a lesser extent west and north, and minimally to the east/northeast. Relative to the preserve, management actions for the shrubland ecosystem have less to contribute (and to a limited extent for the riparian/valley bottom ecosystem, but these are difficult to estimate because of the narrow and limited amount, yet widespread distribution).

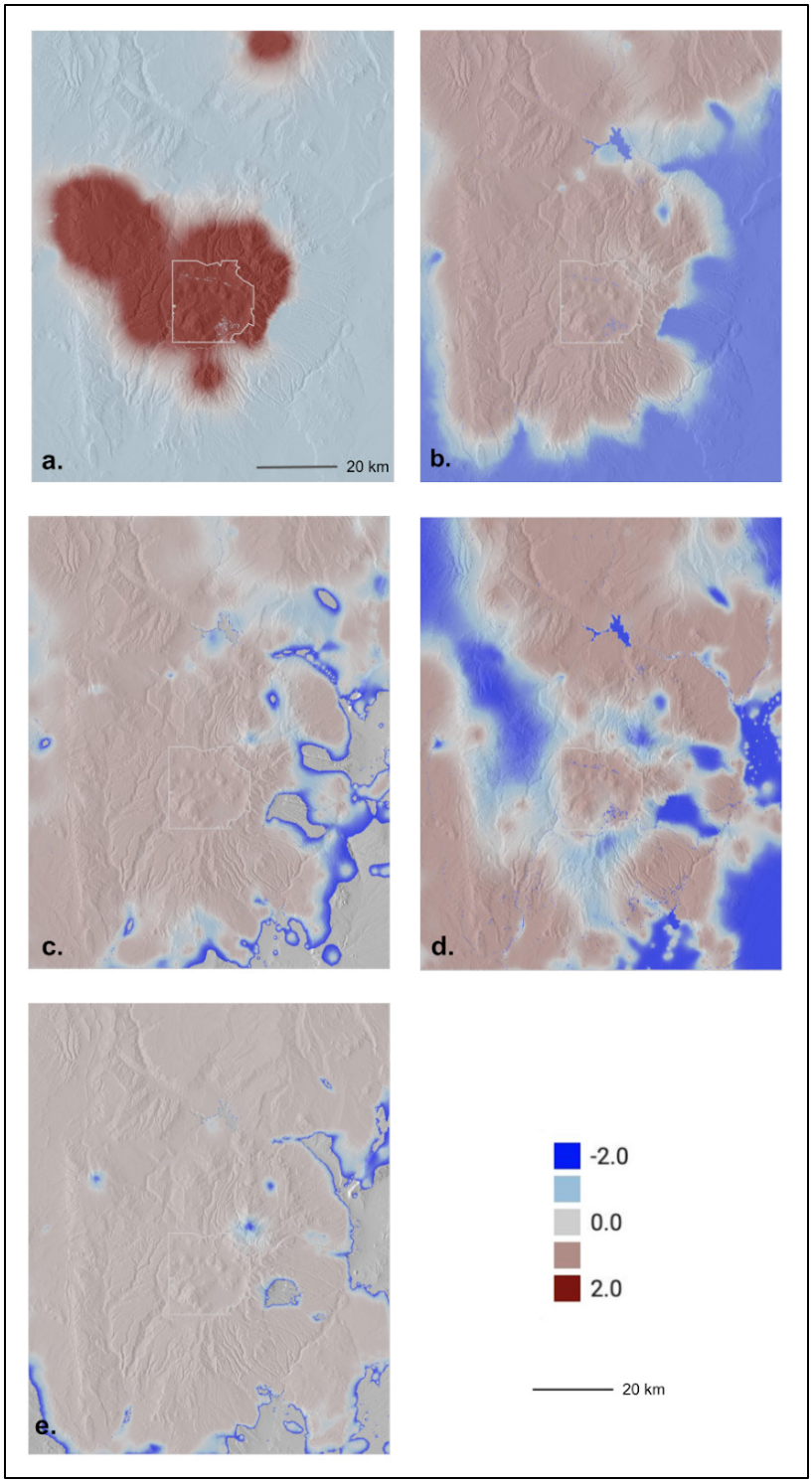


Figure B-5. Ecosystem permeability relative to permeability values from outside of VALL's boundary, assuming a 30 km (18.6 mi) movement distance, organized by: a. upper montane; b. lower montane; c. shrublands; d. grasslands; and e. valley bottoms. Higher permeability (red) shows locations where management actions within the preserve would contribute significantly to permeability across the study area. Management actions in the preserve can address highly permeable areas for upper montane ecosystems with significant contributions to lands outside of the preserve. Permeability for all ecosystems inside the preserve is slightly higher with respect to permeability beyond VALL.

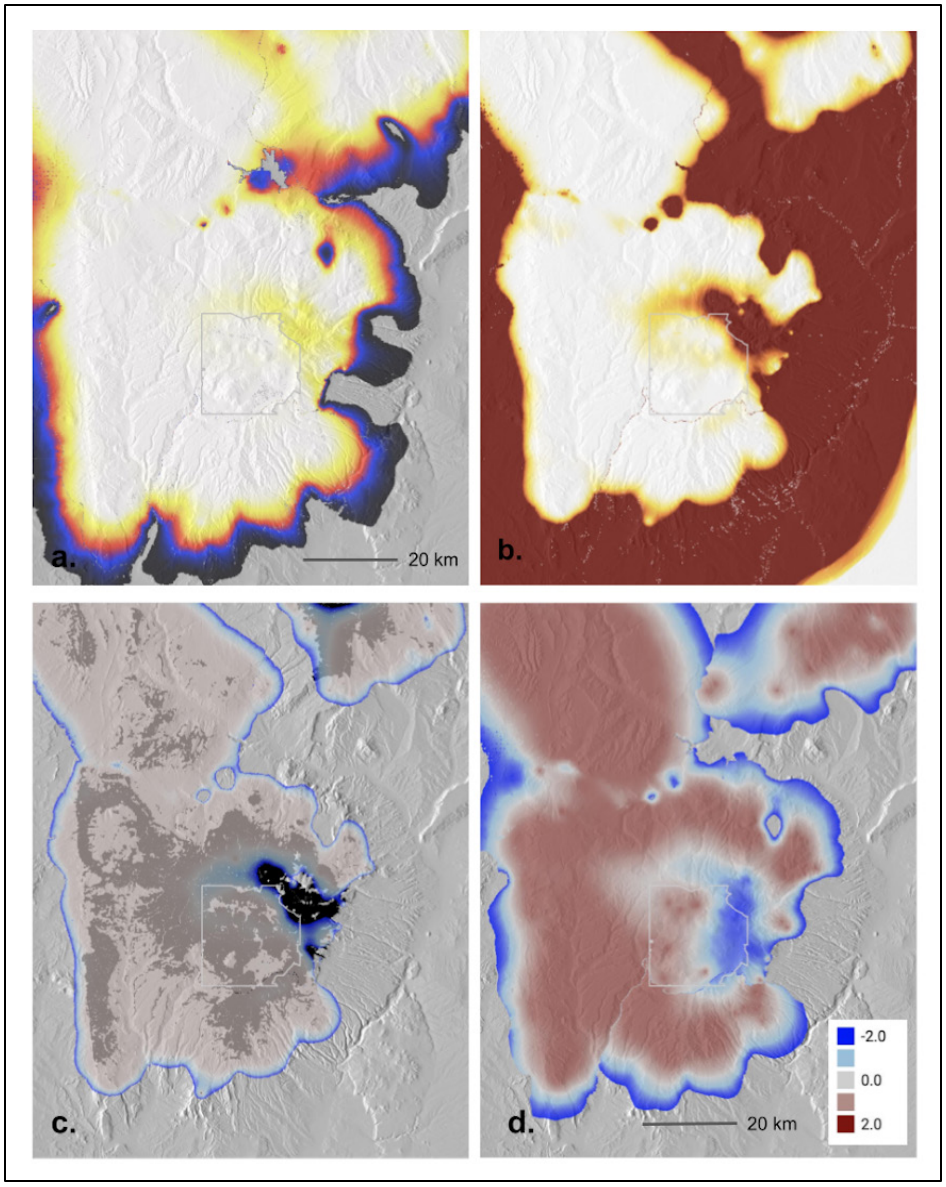


Figure B-6. Different aspects of ecosystem permeability, specific to the lower montane ecosystem, assuming a 30 km (18.6 mi) movement distance, organized by: a. dispersal probability from the lower montane ecosystem; b. departure of ecosystem permeability; c. permeability relative to values for the *in situ* distribution of lower montane; and d. permeability relative to values from within VALL's boundary.

Appendix C. Condition Rating Statements

The condition rating statements for the landscape permeability, visual resources, wetlands, and songbirds condition assessments are presented in Tables C-1 to C-5, respectively. Note, Tables C-2 and C-3 pertain to the visual resources evaluation.

Table C-1. Condition rating statements for the status of landscape permeability indicator.

Condition Rating [1]	Landscape Permeability
Good	A good condition rating assumes the current permeability value has declined by ¼ or less of the "natural" value and is greater than the upper percolation threshold of 0.6 for the average of the values from the 10 km (6.2 mi) and 30 km (18.6 mi) distances.
Good/Fair	A good/fair condition rating assumes the current permeability value has declined by ¼–⅓ of the "natural" value and is greater than the upper percolation threshold of 0.6 for the average of the values from the 10 km (6.2 mi) and 30 km (18.6 mi) distances.
Fair	A fair condition rating assumes the current permeability value has declined by ⅓–½ of the "natural" value and is greater than the upper percolation threshold of 0.6 for the average of the values from the 10 km (6.2 mi) and 30 km (18.6 mi) distances or has declined by ¼ or less of the "natural" value and is within the lower to upper percolation thresholds of 0.4–0.6 for the average of the values from the 10 km (6.2 mi) and 30 km (18.6 mi) distances.
Fair/Poor	A fair/poor condition rating assumes the current permeability value has declined by ¼–½ of the "natural" value and is between the lower and upper percolation thresholds of 0.4–0.6 for the average of the values from the 10 km (6.2 mi) and 30 km (18.6 mi) distances.
Poor	A poor condition rating assumes the current permeability value has declined by ½–1 of the "natural" value or is below the lower percolation threshold of 0.4 for the average of the values from the 10 km (6.2 mi) and 30 km (18.6 mi) distances.

[1] Condition rating statements are based on Theobald (2021; contracted to develop the landscape permeability condition assessment).

Table C-2. Criteria for selecting scenic quality and view importance ratings (NPS 2018b).

Measure	Rating	Description
Scenic Quality	High	Most views include landscapes in good condition with very few, or minor, features that detract from desirable visual characteristics. The majority of views are also aesthetically pleasing and memorable because of bold forms and colors.
	Medium	Most views include landscapes in moderate condition with some features that detract from desirable visual characteristics. The majority of views are somewhat aesthetically pleasing with forms and colors that add moderate visual interest.
	Low	Most views include landscapes in poor condition with many, or major, features that detract from desirable visual characteristics. The majority of views are not aesthetically pleasing with forms and colors that lack visual interest.
View Importance	High	Views are key to the purpose of the park and a primary reason that visitors come to the park/wilderness area. Views are highly publicized and extensive effort goes into facilitation the visitor experience for scenery.

Table C-2 (continued). Criteria for selecting scenic quality and view importance ratings (NPS 2018b).

Measure	Rating	Description
View Importance (continued)	Medium	Views add to the visual experience but are not the primary reason for visitation. Views receive some publicity and moderate effort goes into facilitating the visitor experience for scenery.
	Low	Views are not integral to the visitor experience. Views receive little or no publicity and minimal effort goes into facilitating the visitor experience for scenery.

Table C-3. Matrix for deriving visual resources condition category (NPS 2018b). Note: The NPS Air Resources Division condition rating scale differs from the NRCA Program's condition rating levels.

Rating	View Importance High	View Importance Moderate	View Importance Low
Scenic Quality *High*	Very Good	Good	Fair
Scenic Quality *Moderate*	Good	Fair	Poor
Scenic Quality *Low*	Fair	Poor	Very Poor

Table C-4. Condition rating statements for the status of wetlands indicators.

Condition Rating [1]	Flow Duration	Cover
Good	Flow duration has improved significantly, indicating persistent flows throughout the summer season.	Cover of wetland indicator species is at least 80%, with obligate and facultative wetland species comprising greater cover than facultative species.
Good/Fair	Flow duration has improved but increases may not be significant, and gaps in flow duration occur.	Wetlands are mostly dominated by facultative, facultative wetland, and obligate wetland species but sparse cover by upland plants also occurs. Wetland indicator plant species represent between 70% and 80% cover.
Fair	Flow duration has neither improved nor declined.	Wetlands are mostly dominated by facultative, facultative wetland, and obligate wetland species but sparse cover by upland plants also occurs. Wetland indicator plant species represent between 60% and 70% cover.
Fair/Poor	Flow duration has declined but declines may not be significant, and gaps in flow duration occur.	Wetlands are largely dominated by upland species with between 50% and 60% cover of wetland indicator species.
Poor	Flow duration has significantly declined, indicating absence of flows throughout large portions of the summer season.	Wetlands are dominated by upland species with less than 50% cover of wetland indicator species.

[1] Condition rating statements are based on Pritchard (1998) and Muldavin et al. (2011).

Table C-5. Condition rating statements for the status of songbirds indicator.

Condition Rating [1]	Community Composition
Good	Songbird community composition reflects near pristine conditions with no indication of compromises to ecological integrity. For example, all or nearly all potential species are present; trends in species of concern are stable or even increasing; and key indicator species present.
Good/Fair	Some changes in songbird community composition may have occurred, but degradation is not yet measurable. For example, nearly all potential species are present (including key indicator species), but trends in some species of concern indicate possible declines. However, declines are not statistically significant.
Fair	Songbird community composition indicates loss or change in ecological integrity, but changes are not severe. For example, most potential species are present, but some key species are absent; and/or trends in species of concern suggest possible declines, but declines are either not significant or the species in decline are still considered relatively abundant.
Fair/Poor	Songbird community composition indicates loss or change in ecological integrity. Changes may be severe but are not necessarily widespread across all attributes of community composition. For example, richness is high, but species of concern are in decline.
Poor	Songbird community composition suggests severe degradation in ecological integrity. For example, key indicator species are absent; abundance has declined for species of concern, or some species of concern are absent altogether; and/or species richness is substantially lower than expected.

[1] Condition rating statements are based on National Oceanic and Atmospheric Administration (2018).

Appendix D. Drivers and Stressors Diagram & Tabular View

Figure D-1 shows the drivers and stressors conceptual model by focal resource, including interrelationships between the stressors. Table D-1 shows the drivers and stressors conceptual model in tabular format.

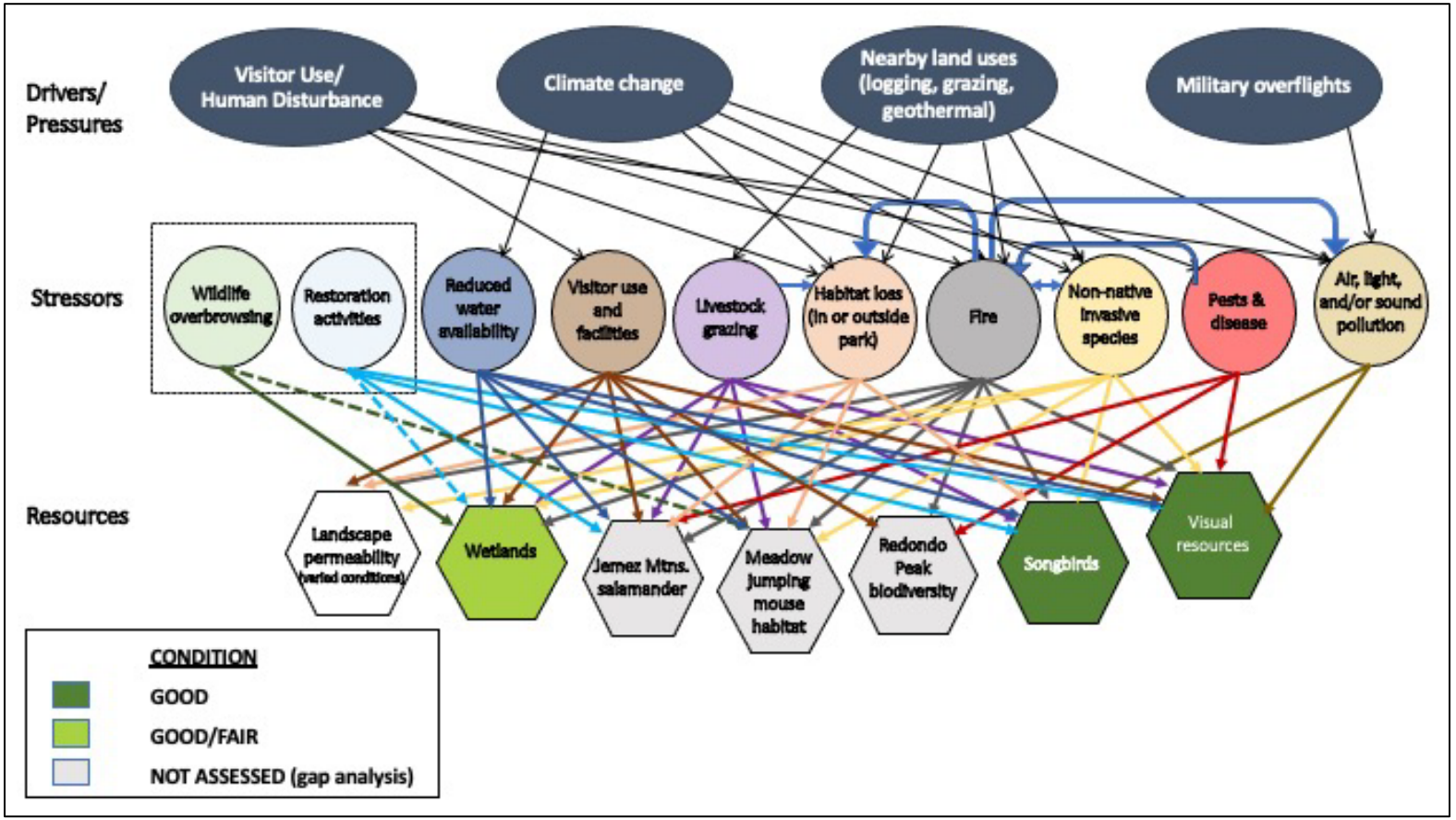


Figure D-1. The drivers and stressors conceptual model used to depict and discuss influences of resource conditions. Figure Credit: Mark Brunson.

Table D-1. The drivers and stressors conceptual model shown in Figure D-1, depicted in tabular format. An “X” indicates that a driver or stressor is of concern for a focal resource.

Focal Resources	Driver or Stressor Emphasis										
	Climate Change	**Fire & Fire Effects**	**Pollution**	**Livestock Use/ Structures**	**Non-native Invasive Species**	**Disease, Pests**	**Visitor Use**	**Restoration Activities**	**Adjacent Land Use**	**Park Developments**	**Other**
Landscape Permeability	X	–	–	–	X	–	X	–	X	X	–
Visual Resources	X	X	X	X	X	X	X	X	X	X	–
Redondo Peak Biodiversity	X	X	–	X	X	X	–	X	–	–	–
Wetlands	X	X	–	X	X	–	X	X	X	X	Over browse, beaver
New Mexico Meadow Jumping Mouse Habitat Availability	X	X	–	X	X	–	X	X	X	–	Isolated populations, beaver
Songbirds	X	X	X	X	X	–	–	X	X	X	Loss of habitat
Jemez Mountains Salamander	X	X	–	X	–	X	X	X	X	–	Connectivity

Appendix E. Manager-Scientist Responses by Resource and Driver or Stressor

Tables E-1 through E-7 summarize the VALL manager actions by focal resource and associated drivers or stressors.

Table E-1. Responses for landscape permeability.

	Primary Driver or Stressor Emphasis					
Action Category	**Visitor Use**	**Facilities Development**	**Habitat Loss**	**Wildfire**	**Non-native Invasive Species**	**Other**
Field-based Management	–	Remediation of unused roads, wildlife crossings.	Planting alder and willow in Redondo Creek. Other wetland restoration.	–	–	–
Research, Monitoring, & Inventory	–	Measure effects of infrastructure on key animal species. Migration monitoring to influence facility design.	Is habitat lost due to forest regeneration/ change caused by loss of intermittent low-intensity fire?	Landscape connectivity – how does it relate to fire breaks or fire connectivity? Relationship of forest change/ regeneration with loss of intermittent low-intensity fire.	Vegetation monitoring, mapping invasives (with Invasive Plants Management Team). Treatment – cheatgrass removal, volunteers are important. Increase invasive monitoring and treatment with increased visitor use.	Monitoring species on Redondo Peak. Hydrologic conductivity – connections to downstream uses.
Education & Interpretation	Access and circulation plan.	Visitor signage for sensitive species/times/ locations.	–	–	Educational signage “stop hitchhikers.”	–

Table E-1 (continued). Responses for landscape permeability.

Action Category	Primary Driver or Stressor Emphasis					
	Visitor Use	**Facilities Development**	**Habitat Loss**	**Wildfire**	**Non-native Invasive Species**	**Other**
Partnerships	–	–	Consider wildlife corridors in Southwest Jemez Mountains CFLRP.	Southwest Jemez Project – reduce fire fuel loads, prevent high severity large burns, habitat improvements.	–	Partnerships with local tribes interested in wildlife corridors.
Zoning & Planning	–	Planning on how to use road system. Incorporate info/goals for number of vehicles, speed, nature of road improvements (e.g., paving), wildlife crossings. Species-appropriate placement of infrastructure	–	–	–	–
Law Enforcement	–	–	–	–	–	–
Laws, Policies & Guidelines	–	–	–	–	–	–

Table E-2. Responses for visual resources.

Action Category	Primary Driver or Stressor Emphasis					
	Restoration Activities	**Visitor Use**	**Livestock Grazing**	**Wildfire**	**Non-native Invasive Species**	**Other**
Field-based Management	–	–	Removal of non-use grazing infrastructure (e.g., fences)	–	Cheatgrass control	–
Research, Monitoring, & Inventory	–	–	–	–	–	Monitoring air/ light/ soundscape Historical photographs retaken over time. Monitoring terrestrial light on the horizon/landscape not just upward (e.g., scene measure).
Education & Interpretation	Information about how restoration activity is changing or helping the environment.	–	–	During fires: public interpretation and interest in fire and prescribed burns Interp. opportunity for public teaching about landscape resilience and recovery from fire. Visual changes (scar to renewal) are impressive and show impact and natural processes.	–	Visitor “camera spot” for collecting new photos, submitting, and comparing to historical photos. Tracks landscape changes and daily air quality (haze).

Table E-2 (continued). Responses for visual resources.

Action Category	Primary Driver or Stressor Emphasis					
	Restoration Activities	**Visitor Use**	**Livestock Grazing**	**Wildfire**	**Non-native Invasive Species**	**Other**
Partnerships	–	Partnerships for siting facilities in surrounding areas (e.g., Santa Fe NF, private property owners, Pajarito Mountain Ski Area).	–	–	–	–
Zoning & Planning	–	What will the standards be for facilities placement (e.g., volcanic vistas, Valle Grande) identified in foundation document? Visual "style guide" for park infrastructure.	Removal of non-use grazing infrastructure (e.g., fences, cattle grates). What roads and how are roads used? Make decisions about preserving the historic and archaic landscape.	–	–	Perception of what is "good" in the visual landscape, which is unique to each observer.
Law Enforcement	–	–	–	–	–	Camping regulations. Santa Fe NF and Pueblo Parks agencies patrol for fire.
Laws, Policies & Guidelines	–	–	–	–	–	–

Table E-3. Responses for Redondo Peak biodiversity.

Action Category	Primary Driver or Stressor Emphasis			
	Wildfire	**Visitor Use**	**Pests & Disease**	**Other**
Field-based Management	–	Road to peak closed and blocked by fallen trees.	–	–
Research, Monitoring, & Inventory	Does VALL treat forest management and fire management differently for this ecosystem?	Monitor potential increase in Redondo Peak use.	Need for aerial imagery for forest pests and diseases.	• Tribal plant gathering, monitoring in high elevation areas (vegetation plots). • Need pika survey. • Monitoring periodically (10+ years) to monitor plant and animal succession over time. • Need baseline inventory. High effort to complete. • Audio Recording – Owls • Audio Recording – Bats • Need springs and seeps inventory for Redondo Peak and surrounding high-elevation areas. • More programmatic inventory of sensitive ecosystems. • Complete identification of invertebrate species collected. • Historical photographs retaken over time.
Education & Interpretation	–	Outreach about uniqueness of this high-altitude ecosystem even vs other surrounding montane ecosystems.	–	–
Partnerships	–	–	–	Local Native American tribes, consult on management decisions, solicit feedback.

Table E-3 (continued). Responses for Redondo Peak biodiversity.

Action Category	Primary Driver or Stressor Emphasis			
	Wildfire	**Visitor Use**	**Pests & Disease**	**Other**
Zoning & Planning	Does VALL treat forest management and fire management differently for this ecosystem?	Consider how much VALL encourages use in this area.	–	–
Law Enforcement	–	–	–	–
Laws, Policies & Guidelines	–	–	–	–

Table E-4. Responses for restored wetlands.

Action Category	Primary Driver or Stressor Emphasis						
	Wildlife Use	**Reduced Water Availability**	**Visitor Use**	**Livestock Grazing**	**Wildfire**	**Non-native Invasive Species**	**Other**
Field-based Management	Proposed bison reintroduction. Elk exclosures around streams and wetlands. Improve and increase beaver habitat.	–	Route recreation trails away from impacted/ sensitive areas.	No grazing in sensitive areas (appropriate placement). Allotments reduced in size, restricted to upland areas without perennial streams.	–	–	–
Research, Monitoring, & Inventory	–	Update springs and seeps inventory.	Measure intensity and type of visitor use (e.g., hikers, anglers) along streams.	Grazing allotments monitoring.	Understanding recent past fire and how that relates to burned and unburned areas (e.g., managed and unmanaged ignitions).	Monitoring: Kentucky bluegrass, timothy grass, yellow sweet clover (*Melilotus officinalis*, common yarrow (*Achillea millefolium*).	Are all remediation activities beneficial? How does each activity impact wetlands (e.g., forest thinning, road remediation, wetland remediation)?
Education & Interpretation	–	–	Signage.	–	–	–	–
Partnerships	–	–	Work with angler groups to identify where to locate stream fishing access points.	Rebuild fences where trespass grazing occurs. Permittee maintains fences.	–	–	Prioritize collaboration in wetland remediation projects (39 organizations in collaboration).
Zoning & Planning	–	–	Identify where to locate stream fishing access points.	–	–	–	–

Table E-4 (continued). Responses for restored wetlands.

Action Category	Primary Driver or Stressor Emphasis						
	Wildlife Use	**Reduced Water Availability**	**Visitor Use**	**Livestock Grazing**	**Wildfire**	**Non-native Invasive Species**	**Other**
Law Enforcement	–	–	–	Rapid response and communication with ranchers.	–	–	–
Laws, Policies & Guidelines	–	–	–	Require permittees to rebuild fences where trespass grazing occurs.	–	–	–

Table E-5. Responses for New Mexico meadow jumping mouse habitat availability.

Action Category	Primary Driver or Stressor Emphasis							
	Reduced Water Availability	**Visitor Use**	**Facilities Development**	**Livestock Grazing**	**Habitat Loss**	**Wildfire**	**Non-native Invasive Species**	**Other**
Field-based Management	Improve and increase beaver habitat. Improving stream function will improve mouse habitat.	–	Culvert retrofitting to allow mice movement up and downstream. Culvert shelves and working culverts.	Exclosures to prevent habitat damage.	Habitat improvement projects. Riparian wetland restoration. Keep trespass cattle out of riparian zones.	–	–	–

Table E-5 (continued). Responses for New Mexico meadow jumping mouse habitat availability.

Action Category	Primary Driver or Stressor Emphasis							
	Reduced Water Availability	**Visitor Use**	**Facilities Development**	**Livestock Grazing**	**Habitat Loss**	**Wildfire**	**Non-native Invasive Species**	**Other**
Research, Monitoring, & Inventory	–	Downstream use of water for grazing, direct and indirect impacts to habitat connectivity. Angler impacts on stream edges. Possible scorecard for rapid habitat assessment.	–	–	Track plate surveys, focused on areas of future activities. Research on overwinter hibernation. Erosion and channelization impacts degrading habitat from roads, fire scars, non-functioning culverts, and stock watering.	Impacts of prescribed fire in grassland habitat, especially where forest edge meets riparian.	What's the impact of introduced/ invasive grass species?	Influence of natural gas pipeline right-of-way. Impacts of elk and ungulate grazing.
Education & Interpretation	–	Communication tailored to anglers.	–	–	–	–	–	–
Partnerships	–	Anglers' organizations. Develop partnerships related to outreach and/or monitoring.	–	–	–	–	–	–
Zoning & Planning	–	–	Appropriate facilities development to avoid habitat impacts. How can we do this?	–	–	–	–	–
Law Enforcement	–	–	–	–	–	–	–	–
Laws, Policies & Guidelines	–	–	–	–	–	–	–	–

Table E-6. Responses for songbirds.

Action Category	Primary Driver or Stressor Emphasis			
	Restoration Activities	**Wildfire**	**Air and/or Light Pollution**	**Other**
Field-based Management	Wetland and riparian restoration. Maintain habitat.	Avoid prescribed burns during the breeding season.	–	–
Research, Monitoring, & Inventory	Monitoring soundscape and lightscape in future years. Expanding bird monitoring outside of breeding season. Fall migratory monitoring as an example. Trends and analysis of LANL data for birds pre- and post-fire.	–	Bird surveys on volcanic domes and further from roads. Spruce-fir hikes.	Breeding bird surveys by Hawks Aloft, every spring. Owl survey is a three-year project.
Education & Interpretation	–	–	Spruce-fir hikes.	Potential partnerships/visitor interactions for citizen science observations. Tie checklist of birds to an email or some easy way to submit data (e.g., eBird, iNaturalist).
Partnerships	Expand Bandelier National Monument mist netting and interpretive programs to VALL.	–	–	Possibility for future partnership.
Zoning & Planning	–	–	–	–
Law Enforcement	–	–	–	–
Laws, Policies & Guidelines	–	–	–	Limited hunting (turkey in season). No upland game bird or waterfowl hunting.

Table E-7. Responses for Jemez Mountains salamander.

Action Category	Primary Driver or Stressor Emphasis					
	Restoration Activities	**Visitor Use**	**Habitat Loss**	**Wildfire**	**Pests & Disease**	**Other**
Field-based Management	Enhance structure/habitat availability. Habitat enhancements.	If needed, implement decontamination activities.	Enhance structure/habitat availability. Habitat enhancements.	The number one threat is high severity fire. Manage for reduction of high severity fire.	–	–
Research, Monitoring, & Inventory	–	Monitor visitor use as a vector for disease.	–	Monitor and research surface activity time periods to inform fire management.	Presence/absence of disease, and mechanism for spread.	Studies of climate and habitat change related to salamander/ amphibian occurrence.
Education & Interpretation	–	Provide info on soil compaction, microhabitat, trampling,and decontamination activities.	–	–	Visitor outreach about presence and importance of species.	–
Partnerships	Endemic Salamander Team New Mexico. Restoration and future recovery planning.	–	–	Monitor and research surface activity time periods to inform fire management.	–	–
Zoning & Planning	Plan infrastructure for this low-mobility species.	–	–	–	–	–

Table E-7 (continued). Responses for Jemez Mountains salamander.

Action Category	Primary Driver or Stressor Emphasis					
	Restoration Activities	**Visitor Use**	**Habitat Loss**	**Wildfire**	**Pests & Disease**	**Other**
Law Enforcement	–	–	–	–	–	–
Laws, Policies & Guidelines	–	–	–	–	–	–

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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