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Natural Resource Program Center

Terrestrial Vegetation and Soils Monitoring at Gila Cliff Dwellings National Monument

2009 Status Report

Natural Resource Technical Report NPS/SODN/NRTR—2010/375

ON THE COVER

Cliff house, Gila Cliff Dwellings National Monument. Sonoran Institue/Lindsay Fitzgerald-DeHoog.

Terrestrial Vegetation and Soils Monitoring at Gila Cliff Dwellings National Monument

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Natural Resource Technical Report NPS/SODN/NRTR—2010/375

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Contents

Figures v
Tables vii
Photos ix
Acronyms xi
Executive Summary xiii
Acknowledgements xv

1 Introduction 1
- 1.1 Background 1
- 1.2 Goals and objectives 1
- 1.3 Scope of this report 2
- 1.4 Overview of terrestrial ecosystems 2
- 1.5 Natural resource management issues 8

2 Methods 11
- 2.1 Response design 11
- 2.2 Sampling design 11

3 Results 17
- 3.1 Vegetation monitoring 17
- 3.2 Soil monitoring results 21
- 3.3 Management assessment points 21
- 3.4 Evaluation of strata 21
- 3.5 Estimates of power and species detectability 27

4 Discussion 29
- 4.1 Contrasting habitats of mesa tops and canyons 29
- 4.2 Exotic invasive plants 29
- 4.3 Site stability and erosion 30
- 4.4 Implications for terrestrial vegetation and soils monitoring 31
- 4.5 Are terrestrial vegetation and soils within the range of natural variability? 31

5 Literature Cited 33

Appendix A. Supplemental Data 35

Appendix B. Plot Maps 75

Figures

Figure 1.4.1. General map of Gila Cliff Dwellings National Monument 3

Figure 1.4.2. Biogeography of Gila Cliff Dwellings National Monument. 4

Figure 1.4.4. Climate data in the context of 30-year normal, Gila Cliff Dwellings NM, 2004–2009. 6

Figure 1.5.2. Visitation at Gila Cliff Dwellings NM, 1934–2009. 10

Figure 2.1. Terrestrial vegetation and soils monitoring plot design. 12

Figure 2.2.1. Allocation of monitoring plots, Gila Cliff Dwellings National Monument. 13

Figure 2.2.3. Sampling frame for terrestrial vegetation and soils monitoring, Gila Cliff Dwellings National Monument. 15

Figure 3.1.2a. Lifeform cover in terrestrial vegetation monitoring plots, 400 stratum (4,500–6,000' elevation), Gila Cliff Dwellings NM, 2009. 18

Figure 3.1.2b. Lifeform cover in terrestrial vegetation monitoring plots, 500 stratum (>6,000' elevation), Gila Cliff Dwellings NM, 2009. 19

Figure 3.4.1. Non-metric multidimensional scaling indicates similarity of (a) canopy, (b) sub-canopy, and (c) field layer communities 26

Figure 3.4.5a. Species accumulation curves for terrestrial vegetation monitoring. 28

Figure 3.4.5b. Species accumulation curves for terrestrial vegetation monitoring, 400 stratum (4,500–6,000'). 28

Figure 3.4.5c. Species accumulation curves for terrestrial vegetation monitoring, 500 stratum (>6,000'). 28

Figure 4.1. Contrasting habitats and vegetation of dry, flat, and rocky mesa tops (foreground) and more protected canyons (background) along upper Cliff Dweller Canyon, Gila Cliff Dwellings NM 29

Tables

Main Report

Table 1.4.6. Status of natural resource inventories, Gila Cliff Dwellings NM, 2010. 8

Table 1.5.1. Non-native plants detected at Gila Cliff Dwellings NM, 2010. 9

Table 3.1.1. New plant species detected during terrestrial vegetation sampling at Gila Cliff Dwellings NM, 2009. 17

Table 3.1.3. Ubiquitous native species observed on monitoring and test plots, Gila Cliff Dwellings NM, 2009. 20

Table 3.1.4. Exotic plants detected on frequency subplots at upland vegetation monitoring sites, Gila Cliff Dwellings NM, 2009. 20

Table 3.2.1. Parkwide dynamic soil function vital signs, Gila Cliff Dwellings NM 2009. 22

Table 3.3. Terrestrial vegetation and soils monitoring data in the context of proposed management assessment points, Gila Cliff Dwellings NM, 2009. 23

Table 3.4.1. Results of SIMPER analysis of (a) canopy communities and (b) subcanopy communities indicating which species contribute most to the dissimilarity between strata. 24

Appendices

Table A1a. Within-plot cover values (%) for species measured in the "field" (<0.5 m stature) layer of the 400 stratum (4,500–6,000'), terrestrial vegetation and soils plots, Gila Cliff Dwellings NM, 2009. 36

Table A1b. Within-plot cover values (%) for species measured in the "field" (<0.5 m stature) layer of the 500 stratum (>6,000'), terrestrial vegetation and soils plots, Gila Cliff Dwellings NM, 2009. 39

Table A1c. Within-plot cover values (%) for species measured in the "field" (<0.5 m stature) layer of all strata (10 plots), terrestrial vegetation and soils plots, Gila Cliff Dwellings NM, 2009. 42

Table A2a. Within-plot cover values (%) for species measured in the subcanopy (0.5–2.0 m stature) layer of the 400 stratum (4,500–6,000'), terrestrial vegetation and soils plots, Gila Cliff Dwellings NM, 2009. 44

Table A2b. Within-plot cover values (%) for species measured in the subcanopy (0.5–2.0 m stature) layer, 500 stratum (>6,000'), terrestrial vegetation and soils plots, Gila Cliff Dwellings NM, 2009. 46

Table A2c. Within-plot cover values (%) for species measured in the subcanopy (0.5–2.0 m stature) layer, all strata (10 plots), terrestrial vegetation and soils plots, Gila Cliff Dwellings NM, 2009. 48

Table A3a. Within-plot cover values (%) for species measured in the canopy (>2.0 m stature) layer, 400 stratum (4,500–6,000'), terrestrial vegetation and soils plots, Gila Cliff Dwellings NM, 2009. 49

Table A3b. Within-plot cover values (%) for species measured in the canopy (>2.0 m stature) layer, 500 stratum (>6,000'), terrestrial vegetation and soils plots, Gila Cliff Dwellings NM, 2009. 50

Table A3c. Within-plot cover values (%) for species measured in the canopy (>2.0 m stature) layer, all strata (10 plots), terrestrial vegetation and soils plots, Gila Cliff Dwellings NM, 2009. 51

Table A4a. Within-plot and landscape frequency (%) for all plots and species sampled on monitoring plots in the 400 stratum (4,500–6,000'), Gila Cliff Dwellings NM, 2009. 52

Table A4b. Within-plot and landscape frequency (%) for all plots and species sampled on monitoring plots in the 500 stratum (>6,000'), Gila Cliff Dwellings NM, 2009. 56

Table A4c. Within-plot and landscape frequency (%) for all plots and species sampled on monitoring plots in all strata (10 plots), Gila Cliff Dwellings NM, 2009. 60

Table A5a. Soil substrate and surface aggregate stability by monitoring plot, 400 stratum (4,500–6,000'), Gila Cliff Dwellings NM, 2009. 63

Table A5b. Soil substrate and surface aggregate stability by monitoring plot, 500 stratum (>6,000'), Gila Cliff Dwellings NM, 2009. 64

Table A5c. Soil substrate and surface aggregate stability by monitoring plot, all strata (10 plots). 65

Table A6. Plot-specific 2009 monitoring data in the context of proposed management assessment points. 66

Table A7a. Within-plot frequency (%) for species sampled on frequency subplots in the 400 stratum (4,500–6,000'), Gila Cliff Dwellings NM, 2009. 67

Table A7b. Within-plot frequency (%) for species sampled on frequency subplots in the 500 stratum (>6,000'), Gila Cliff Dwellings NM, 2009. 70

Table A7c. Within-plot and landscape frequency (%) for species sampled on frequency subplots in all strata (10 plots), Gila Cliff Dwellings NM, 2009. 73

Photos

Field crew member at Cliff Dweller Canyon, Gila Cliff Dwellings National Monument. 1
Flooding near contact station at Gila Cliff Dwellings National Monument, Autumn 2007. 5
Cliff dwellings, Gila Cliff Dwellings National Monument. 7
American bullfrog (*Lithobates catesbeiana*). 10

Acronyms

AVG	average
GRTS	Generalized Random Tessellation Stratified
MDC	minimum detectable change
n	number
NM	national monument
NPS	National Park Service
RRQRR	Reversed Randomized Quadrant-Recursive Raster
SD	standard deviation
Sdiff	standard deviation of the differences
SE	standard error
SODN	Sonoran Desert Network

Executive Summary

This report summarizes results of the Sonoran Desert Network's first season of terrestrial vegetation and soils monitoring in upland areas of Gila Cliff Dwellings National Monument (NM), in southwestern New Mexico. Ten permanent field-monitoring sites were established and sampled in 2009. Our objectives were to determine the status of and detect trends, over five-year intervals, in vegetation cover, vegetation frequency, soil cover, and surface soil stability.

Our results reveal a mesa-and-canyon landscape in which local topography, rather than elevation, is the primary mediator of plant water status. Lower-elevation sites (<6,000') occurred along canyons where narrow walls limit evapotranspiration, the dominant constraint on plant growth in this semi-arid environment. As a result, these sites were composed of mixed-tree savannas and woodlands with relatively productive perennial grass understories. By contrast, higher-elevation sites were located on flat, rocky, and exposed mesa tops, producing relatively xeric local conditions that favored the development of pinyon-juniper woodlands composed of short-statured, well-spaced trees with clustered grasses and shrubs under their canopies.

Preventing the spread and dominance of exotic plants is an important management goal at the park. Two exotic species, common mullein (*Verbascum thapsus*) and silversheath knotweed (*Polygonum agrycoleon*), were found at 40% and 10% of the sites, respectively, but neither was detected on the line-point transects, indicating their very low cover in upland areas of the park. Although neither species is currently outcompeting (nor dominating) native flora, we recommend continued vigilance toward potential invasions of exotic plant species.

Uplands areas of the park, as a whole, appear to be free of substantial soil erosion, although a few sites had evidence of sheet flow and rill development. Soil surfaces are currently well-armored, with less than 3% of the soil surface consisting of unprotected, bare mineral soil. However, the majority of the resistant soil cover is composed of vegetation, leaf litter, and duff—materials that could be rapidly lost following wildfire or prolonged drought. In addition, surface soil aggregates are relatively unstable, suggesting the potential for substantial soil loss if protective cover is lost. As soil erosion has important consequences for natural and cultural resources at the park, this is an important consideration.

We conclude that terrestrial vegetation and soils in uplands of Gila Cliff Dwellings NM are well within the historic range of natural variability. Recognizing the limitations of historical data, the current park conditions contrast very favorably with those described in local and regional accounts. Gila Cliff Dwellings NM is relatively free of anthropogenic stressors, and is therefore an excellent reference site for evaluating other parks and protected areas with similar ecology and/or park settings. In addition, the park provides a unique opportunity to identify the signal of potential climate-change effects from the noise of other common stressors that are absent there.

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We thank Superintendent Steve Riley and the staff and volunteers of Gila Cliff Dwellings National Monument for their on-site support of the field effort and the overall Sonoran Desert Network (SODN) Inventory and Monitoring Program. Beth Fallon, Laura Crumbacher, Aaron Curtis, Aedan Berge, Kate Connor, Betsy Vance, Laura Bassaraba, and Steve Buckley conducted the field data collection, often under arduous (but always scenic) conditions. The University of Arizona Environmental Research Laboratory processed all of the soil samples, with analysis and interpretation provided by Travis Nauman, of Nauman Geospatial. Expert data processing and management was completed by SODN Data Manager Kristen Beaupré, and Lindsay Fitzgerald-DeHoog updated the master plant lists.

1 Introduction

1.1 Background

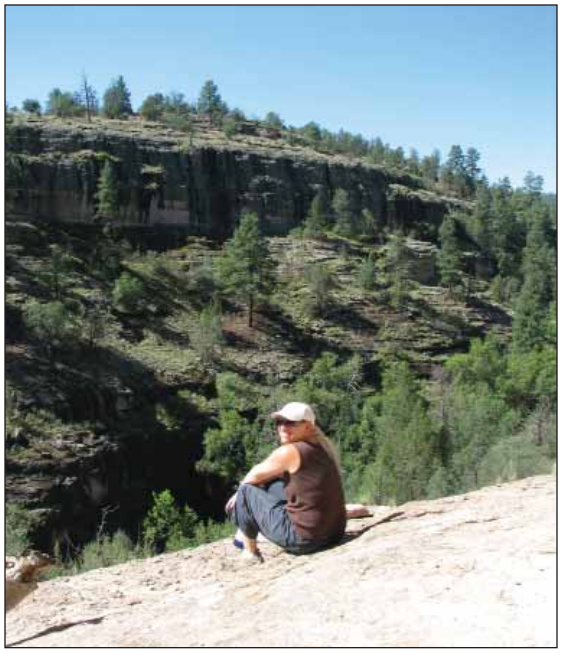
Generating more than 99.9% of Earth's biomass (Whittaker 1975), plants are the primary producers of life on our planet. Vegetation therefore represents much of the biological foundation of terrestrial ecosystems, and it comprises or interacts with all primary structural and functional components of these systems. Vegetation dynamics can indicate the integrity of ecological processes, productivity trends, and ecosystem interactions that can otherwise be difficult to monitor. Land management actions often focus on manipulating vegetation to achieve park management objectives, with defined conditions based on community structure or lifeform composition.

In the Sonoran Desert and Apache Highlands ecoregions (Bailey 1998), vegetation composition, distribution, and production are highly influenced by edaphic factors, such as soil texture, mineralogy depth, and landform type (McAuliffe 1999). Especially as they relate to water, these influences are magnified at local scales, as described by pioneering desert ecologist Forrest Shreve:

> The profound influence of soil upon desert vegetation is to be attributed to its strong control of the amount, availability and continuity of water supply. This fundamental requisite in plants is the most effective single factor in the differentiation of desert communities (Shreve 1951).

As such, a fundamental understanding of soils and landforms is essential for evaluating vegetation patterns and processes (McAuliffe 1999).

The Sonoran Desert Network (SODN), as part of the National Park Service's Inventory and Monitoring Program, has identified terrestrial vegetation and dynamic soil functional attributes as important ecosystem monitoring parameters, or "vital signs" (NPS 2005) that provide key insights into the integrity of terrestrial ecosystems at Gila Cliff Dwellings National Monument (NM). Indicators of terrestrial vegetation integrity include vegetation community structure, lifeform abundance, status and trends of established exotic plants, and early detection of previously undetected exotic plants. Indicators of soil dynamic function and erosion resistance include the cover of mineral soil and the stability of surface soil aggregates.



Field crew member at Cliff Dweller Canyon, Gila Cliff Dwellings National Monument.

1.2 Goals and objectives

The overall goal of the SODN terrestrial vegetation and soils monitoring program is to ascertain broad-scale changes in vegetation and dynamic soils properties in the context of changes in other ecological drivers, stressors, processes, and focal resources of interest. This integrated approach explores patterns and identifies candidate explanations to support effective management and protection of park natural resources in a cumulative fashion, such that the results of each successive round of monitoring build upon the knowledge gained from previous efforts and related research and monitoring activities.

Specific, measurable objectives for SODN terrestrial vegetation and soils monitoring (Hubbard et al. in review) at Gila Cliff Dwellings NM are to determine the status of and detect trends, over five-year intervals, in:

1. Terrestrial vegetation cover for common (≥10% absolute canopy cover) perennial species, including non-native plants, and all plant lifeforms.
2. Terrestrial vegetation frequency of uncommon (<10% absolute canopy cover) perennial species, including non-native plants.

3. Terrestrial soil cover by substrate classes (bare soil, litter, vegetation, biological soil crust, rock fragments of several size classes) that influence resistance to erosion.

4. Terrestrial soil stability of surface aggregates by stability class (1–6).

1.3 Scope of this report

This document reports and interprets the results of the first round of terrestrial vegetation and soils monitoring at Gila Cliff Dwellings NM. Our focus is necessarily on current status, with trend evaluations to commence after the next sampling period in 2014. We do, however, contrast current results with those from previous studies and interpret the information in the context of management objectives and ecological considerations. The thematic scope is limited to terrestrial ecosystems, as well; aquatic resources, including riparian and xeroriparian vegetation, are addressed in the SODN Streams and Washes protocols.

1.4 Overview of terrestrial ecosystems

1.4.1 Park establishment and purpose

Established in 1907, Gila Cliff Dwellings NM protects and interprets a complex of 15th century Mogollon cliff dwellings and other associated prehistoric sites, and the diverse natural environment that attracted and supported these early civilizations (Russell 1992).

Through the authority of the recently-passed Antiquities Act, President Theodore Roosevelt established a 65-hectare (160-acre) monument to be administered by the U.S. Forest Service, based largely on the impressive site reports from pioneering archeologist Adolf Bandelier in the late 19th century. Located near the heart of a 700,000-acre designated wilderness, the monument was difficult to access and infrequently visited until the wilderness area was modified and a road blazed to the mouth of Cave Dweller Canyon in the mid-20th century (Russell 1992). Increasing public interest and greater documentation of the park's cultural resources led to the addition of the 21-hectare (52-acre) TJ unit, near the visitor center, and the expansion of the original unit to 191 hectares (472 acres), including a contact station and visitor facilities at the mouth of Cave Dweller Canyon (Russell 1992; Figure 1.4.1).

Initially managed by the U.S Forest Service (USFS), Gila Cliff Dwellings NM was transferred to the National Park Service (NPS) in 1933, and added to the Southwestern Monuments group led by famed Superintendent Frank "Boss" Pinckley. In the 1940s, the monument and surrounding wilderness were briefly considered for a proposed, 650,000-acre Gila National Park that never came to fruition. Since the 1960s, the USFS and NPS have managed the unit cooperatively, despite an official shift back to USFS oversight in 1975, and return to the NPS a quarter-century later (Russell 1992).

As with other cultural sites in the American Southwest, the location of these important prehistoric resources is directly related to scarce and important natural resources: the perennial waters and associated rich natural resources of the upper Gila River.

1.4.2 Biogeographic and physiographic context

Though it is part of the Sonoran Desert Network, Gila Cliff Dwellings NM lies east of the Sonoran Desert, in the Arizona–New Mexico Mountains ecoregion (Bailey 1998; Figure 1.4.2), a 30 million-acre area that extends from the vicinity of Flagstaff, Arizona, through southeastern New Mexico. Located near the confluence of three major ecoregions in the American Southwest, Gila Cliff Dwellings NM shares many ecological traits with Chiricahua NM, Coronado National Memorial (NMem), and Fort Bowie National Historic Site (NHS), in the Apache Highlands ecoregion to the west; Bandelier National Park (NP) to the north (Arizona–New Mexico Mountains); and Guadalupe Mountains National Park, which straddles the Arizona–New Mexico Mountains and Chihuahuan Desert ecoregions. This continental position—a transition between the Sonoran and Chihuahuan deserts on the east and west, and the Rocky Mountains and Sierra Madre to the north and south—is reflected in the composition and biodiversity of the park's flora and fauna (Powell et al. 2006).

Lying between 1,700 and 1,900 m (~5,575–6,235') in elevation, Gila Cliff Dwellings NM encompasses steep but relatively shallow canyons that dissect surrounding mesas, as well as portions of the channels and associated floodplains of the Middle and West forks of the Gila River. Though riparian systems are not considered in this

Gila Cliff Dwellings National Monument

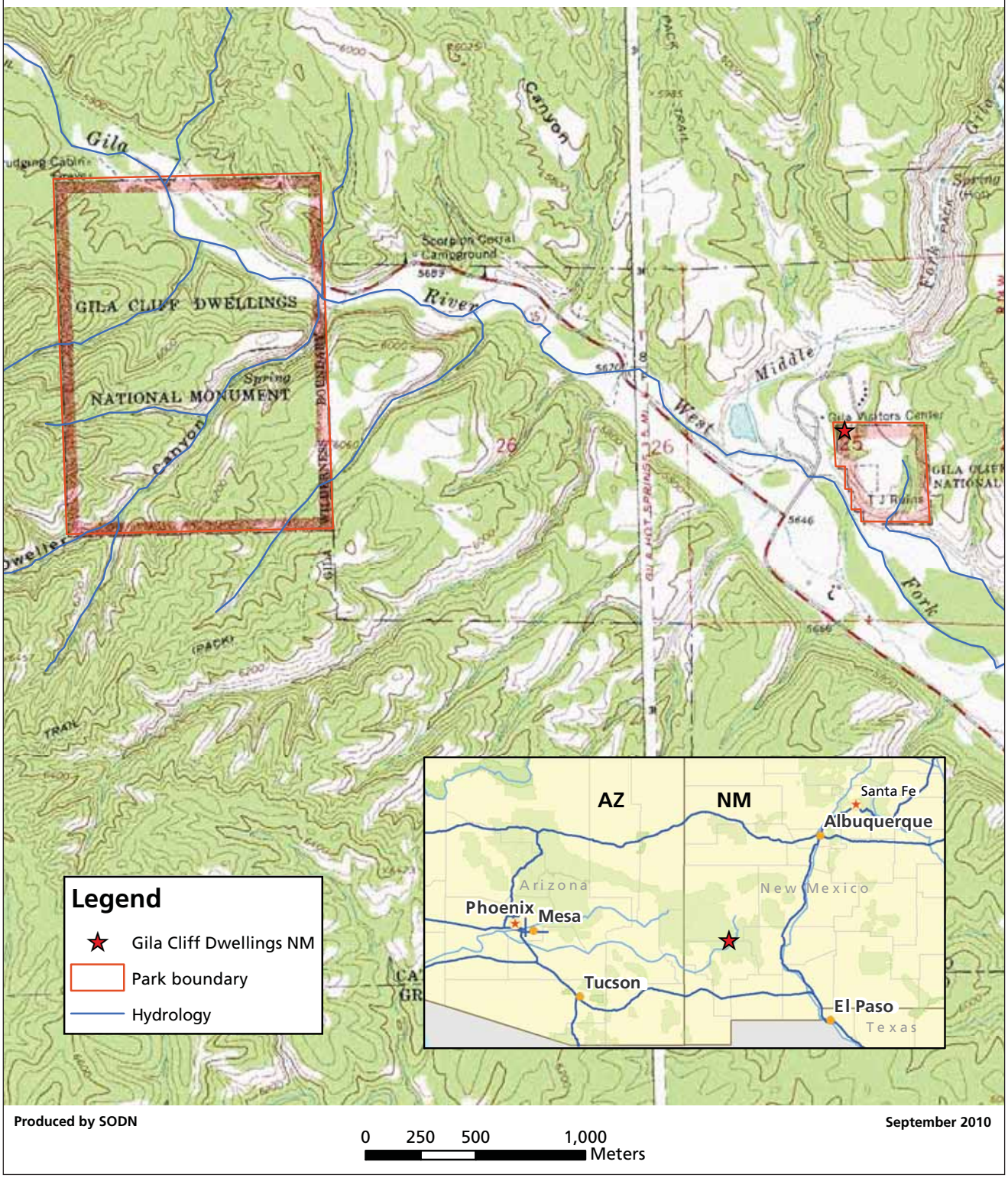


Figure 1.4.1. General map of Gila Cliff Dwellings National Monument. TJ Ruin unit is to the East (right).

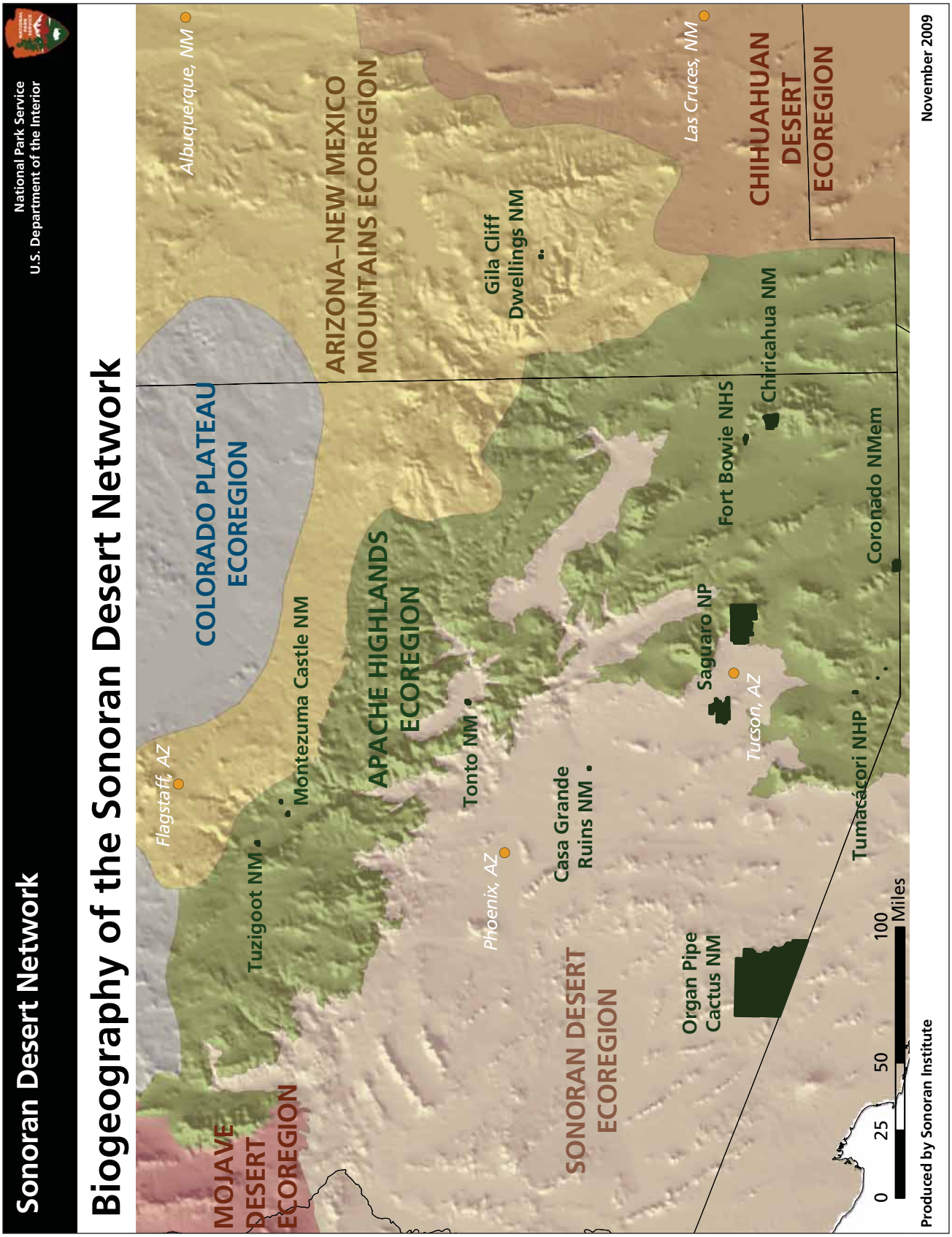


Figure 1.4.2. Biogeography of Gila Cliff Dwellings National Monument.

protocol, we did explore geomorphologic and landscape relationships with vegetation and dynamic soil monitoring parameters. The rugged country found within the park is typical of the Arizona–New Mexico Mountains ecoregion (TNC 1999) and, more generally, the basin-and-range topography of the Intermountain West (Scarborough 2000).

1.4.3 Local geology and soils

As with several other units of the Sonoran Desert Network, Gila Cliff Dwellings NM and the surrounding wilderness lie within an ancient caldera that collapsed following an enormous volcanic eruption (USFS 2003). The surrounding mesas are composed of rhyolite, andesite, basalt, and welded tuffs interbedded with Gila Conglomerate, while the floodplains and channels are composed of shallow alluvium from local deposition of these same materials. Soil information for Gila Cliff Dwellings NM is scant, as the park has never had a comprehensive soil survey due to a lack of funding for this core inventory. Soil properties have important consequences for vegetation composition, persistence, and productivity (McAullife 1999). Therefore, we explored relationships between in-situ soil characteristics and vegetation monitoring parameters on the monitoring site through a complementary effort (Nauman in review) that in no way approaches the coverage and detail of even a rudimentary soil survey.

1.4.4 Climate and hydrology

The climate of Gila Cliff Dwellings NM is typical of the Arizona–New Mexico Mountains ecoregion: highly variable, bimodal precipitation with a considerable range in daily and seasonal air temperature, and relatively high potential evapotranspiration rates (TNC 1999). Approximately half of the annual precipitation falls during summer thunderstorms, when maximum air temperatures often exceed 30°C and lead to violent (and often localized) rainstorms. The bulk of the remaining annual precipitation falls in relatively gentle events of broad extent, occasionally as snow (Figure 1.4.4). Winters are often cold relative to many other SODN parks.

Flooding near contact station at Gila Cliff Dwellings National Monument, Autumn 2007.

Annual precipitation during the five years preceding and including vegetation and soil sampling was only 82% of the 30-year normal (13.86"vs. 16.97"), with drier than normal periods during both winter and summer seasons (Figure 1.4.4). Maximum air temperatures were also consistently warmer during 2005–2009, with average monthly maximum temperatures ranging about 2–7°F (~1–3.75°C) higher than normal. Average overall and average minimum monthly temperatures were close to the 30-year normal (Figure 1.4.4).*

The Middle and West Forks of the Gila River drain 4,200 km^2 (~1,037,843 acres), at an average discharge of approximately five cubic meters per second (~177 cubic feet per second), as estimated from downstream stream gages (Sprouse et al. 2002), although stream flow is highly variable and tightly linked to upstream weather events. Flooding is common, particularly following rain or snow events, spring snowmelt peaks, and, to a lesser extent, intense localized summer thunderstorms.

1.4.5 Human habitation of the landscape

Human use of the Gila Cliff Dwellings NM landscape apparently has occurred for at least the past 2,000 years, although the park's iconic dwellings

*A potentially confounding factor is that the 30-year normal values are based on long-term measurements collected from a since-discontinued NOAA cooperative observer station located at Gila Hot Springs, whereas the 2005–2009 data were collected a few kilometers away, at a Remote Automated Weather Station (RAWS). Cooperative observer stations and RAWS have different instruments and siting requirements (Davey et al. 2007), making direct comparisons somewhat tenuous, particularly for air temperature. However, the scale of difference and close proximity of sites suggests that the differences in observed precipitation probably represent an actual drier-than-normal period from 2005 to 2009, although we caution against interpreting the differences in an absolute sense.

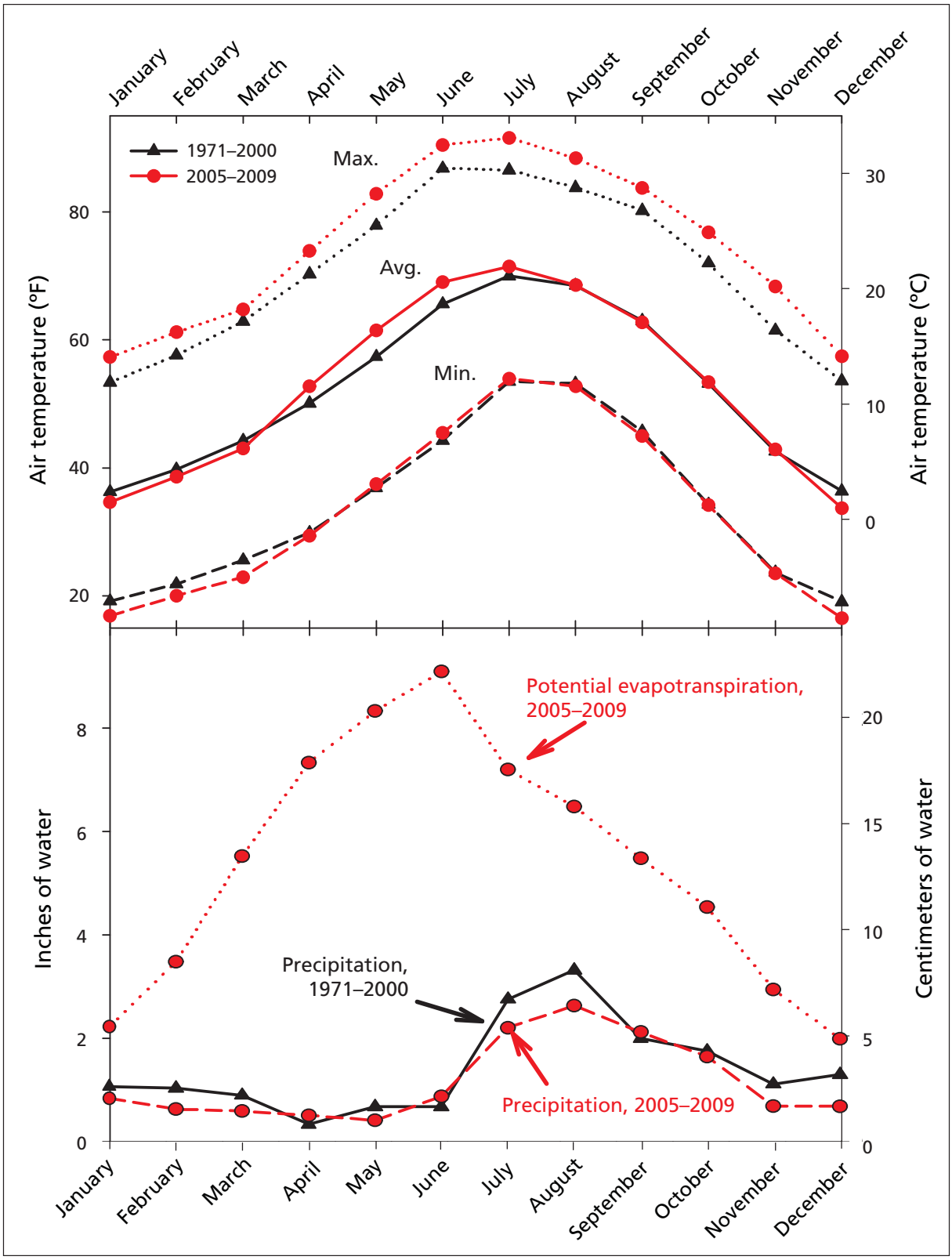


Figure 1.4.4. Climate data in the context of 30-year normal, Gila Cliff Dwellings NM, 2004–2009.

were probably only occupied for perhaps 50 years during the 13th century A.D. (see McKenna and Bradford 1989; Russell 1992 for overviews of cultural resources research). The unexcavated TJ Ruin is of perhaps greater archeological importance than the cliff dwellings, as it one of only a few intact sites known to exist from the Mimbres culture period (McKenna and Bradford 1989).

Protohistoric and historic use appears to have been dominated by the Chiricahua Apache (Anderson et al. 1986) during the 17th–19th centuries, indicating a key cultural link with other units of the SODN, principally Fort Bowie NHS and Chiricahua NM. During the historic period, homesteading, ranching, and eventually, guest ranching became dominant land uses in the area. Amateur archeology and sensationalized findings brought broad public attention to the cliff dwellings, such as the discovery of "proof" of a race of prehistoric dwarves, in the form of a diminutive mummified body that was later determined to be that of an infant (Russell 1992).

In addition to the cliff dwellings, contemporary and historic visitors were attracted to the magnificent wilderness, perennial waters of the Gila headwaters, hot springs, and mild climate of the region. Today, recreation is the primary human use of the Gila Cliff Dwellings landscape, with guest ranches, vacation cabins, and campgrounds distributed along the few roads and developed areas within the Gila Wilderness.

1.4.6 Brief overview of natural resource inventories

Under the Natural Resource Challenge, the NPS authorized and funded 12 basic natural resource inventories for all 270 parks deemed to have "significant" natural resources, including Gila Cliff Dwellings NM (NPS 2009). At time of writing, seven of these inventories had been completed at Gila Cliff Dwellings NM, three others were in progress, one was being updated, and the last was expected to be completed at some future date (Table 1.4.6). Coordinated at the national level, most of these inventories rely on existing information and deliver products ranging from electronic data sets to short reports. However, three inventories (species lists, species occurrence and distribution, and vegetation characterization) involve extensive fieldwork culminating in detailed reports. See NPS (2009) for additional information on the National Park Service Natural Resource Inventory Program.

Cliff dwellings, Gila Cliff Dwellings National Monument.

1.4.7 Other long-term monitoring and related research

In addition to terrestrial vegetation and soils monitoring, the Sonoran Desert Network conducts long-term monitoring on air quality, birds, climate, exotic invasive plants, groundwater, and aquatic and riparian resources associated with streams (Middle Fork of the Gila River) at Gila Cliff Dwellings NM. Details on these efforts are provided in NPS (2005) and on the Sonoran Desert Network website, http://science.nature.nps.gov/im/units/sodn/.

To date, Gila Cliff Dwellings NM has not been the focus of abundant natural resources research, possibly due to the park's remote location, small size, shifting administration, and emphasis on cultural resources. However, the New Mexico Game and Fish Department has monitored fish in the park annually since 1988 (Propst 2000).

Beyond SODN efforts, the only vegetation study of which we are aware is a collection, dating to the mid-1970s, conducted by a graduate student (S. Lambert) from the University of Texas at El Paso (UTEP). This project produced 204 specimens, currently located in the UTEP herbarium. No documentation from the original study has persisted, and the specimens are in generally poor shape. See Powell and others (2006) for additional details on this project.

Hayward and Hunt (1972) surveyed vertebrates in the area, with focus on amphibians and reptiles, as documented in an unpublished report to

Table 1.4.6. Status of natural resource inventories, Gila Cliff Dwellings NM, 2010.

Inventory	Description	Status
Air Quality Data	Baseline air quality data collected both on and off-park. *Products: http://www.nature.nps.gov/air/maps/AirAtlas/*	Complete
Air Quality Related Values	An evaluation of resources sensitive to air quality. *Products:* http://www.nature.nps.gov/air/Permits/ARIS/	Being updated
Base Cartographic Data	A compilation of basic electronic cartographic materials. *Products: http://science.nature.nps.gov/nrdata/*	Complete
Baseline Water Quality	Assessment of water chemistry in Middle and West Forks of Gila River. *Products:* http://www.nature.nps.gov/water/horizon.cfm	Complete
Climate	A basic assessment of nearby climate stations and instrumentation. *Products: http://www1.nrintra.nps.gov/NPClime/*	Complete
Geologic Resources	A synthesis of existing geologic data, resulting in a report and electronic map.	Map complete, report in progress (complete 2011)
Natural Resource Bibliography	An electronic catalog of natural resource-related information. *Products: http://science.nature.nps.gov/im/apps/nrbib/*	Complete
Soil Resources	Electronic geospatial data regarding basic soil properties. *Products: http://www.nature.nps.gov/geology/soils/*	Not scheduled
Species Lists	Documentation of the occurrence and distributions of >90% of the vertebrates & vascular plant species, based on prior research and fieldwork. *Products:* Powell et al. 2007	Complete
Species Occurrence and Distribution		
Vegetation Characterization	Description, classification, and mapping of vegetation communities, based on fieldwork.	In progress (complete 2011)
Water Body Location and Classification	Basic geographic data on hydrologic units.	In progress (no completion date given)

the Gila National Forest. Other research efforts have been sporadic, with limited effort devoted to birds (Zimmerman 1995), and bats and other mammals (Hayward 1965, as cited in Powell 2006), primarily to produce checklists for park visitors.

At time of writing (2010), network and park staff were working in conjunction with scientists at the Sonoran Institute to initiate a natural resource condition assessment for Gila Cliff Dwellings NM. This detailed assessment should identify additional information on resources and resource conditions relevant to terrestrial vegetation and soils of the park. See http://www.nature.nps.gov/water/ for additional information on this service-wide program.

1.5 Natural resource management issues

1.5.1 Invasive exotic plants

Biological invasions into new regions, whether accidental or deliberate, have increased at unprecedented rates in the past few hundred years (D'Antonio & Vitousek 1992). Once established, non-native plant species introductions often lead to changes in ecosystem processes that are self-maintaining and evolving, leading to functional as well as compositional change. Several studies have implicated environmental and climatic variables as potential drivers for sustaining or accelerating non-native plant dominance in semi-arid ecosystems (Shinneman and Baker 2009). In the American Southwest, historic and current land management activities, such as livestock grazing and fire suppression, are thought to have contributed to the susceptibility of arid lands to invasion and subsequent loss of native species and decreased biodiversity (Brown and Archer 1999).

Reduced species richness and biological soil cover are indicative of communities degraded by grazing, and these factors have been linked to invasion by non-native grasses in place of native species that are less able to adapt to such pressures (Shinneman and Baker 2009). In general,

the southwestern semi-desert grasslands, savannas, and riparian community types are at greatest risk of invasion, due to modified disturbance regimes involving fire and herbivory.

To our knowledge, invasive plants have never been extensively surveyed or mapped at Gila Cliff Dwellings NM, with the exception of ongoing monitoring of riparian vegetation by SODN, and the SODN vertebrate and vascular plant inventory (Powell et al. 2006), which detected 37 non-native species (Table 1.5.1) comprising 8.5% of the flora. The Gila National Forest includes portions of the Middle Fork of the Gila River in their annual surveys for invasive riparian tamarisk (*Tamarix* spp.; Steve Riley, personal communication). To date, tamarisk has not been detected within the park.

1.5.2 Potential impacts of visitation

Early visitors to Gila Cliff Dwellings NM often caused significant damage to park cultural resources by excavating for artifacts (pot-hunting) and by climbing in and on the fragile structures (Russell 1992). Both issues were largely addressed by the presence of onsite park staff and development of infrastructure, such as the contact station, paved access trail, and effective interpretive signage and programs. Despite these improvements, impacts to the cliff dwellings persist (albeit on a much reduced scale) and have led to repeated calls for a visitor impacts study, with focus on visitor carrying capacity (NPS 1987, Russell 1992, Steve Riley, personal communication).

Negative consequences for natural resources appear to be minor, due to the limited access and aforementioned infrastructure. Impacts are likely unintentional, as the park's remote location makes incidents of vandalism and poaching generally more rare than at parks located in closer proximity to large population centers (e.g., Saguaro NP). Still, dramatic increases in visitation since road improvements occurred in the 1960s (Figure 1.5.2), and the relatively concentrated use of USFS campgrounds and trails in the area, indicate the potential for visitor use impacts to park ecosystems.

1.5.3 Amphibians and other aquatic invertebrates

Perhaps the most dramatic and alarming natural resource issue at Gila Cliff Dwellings NM has been the rise of non-native aquatic species,

Table 1.5.1. Non-native plants detected at Gila Cliff Dwellings NM, 2010.

Species	Common name
Achillea millefolium	common yarrow
Bidens pilosa	hairy beggarticks
Lactuca serriola	prickly lettuce
Melampodium sericeum	rough blackfoot
Sonchus asper	spiny sowthistle
Taraxacum laevigatum	rock dandelion
Taraxacum officinale	common dandelion
Tragopogon dubius	yellow salsify
Tragopogon pratensis	Jack-go-to-bed-at-noon
Descurainia sophia	herb sophia
Sisymbrium altissimum	tall tumblemustard
Cerastium glomeratum	sticky chickweed
Chenopodium glaucum	oakleaf goosefoot
Ipomoea purpurea	tall morning-glory
Macroptilum gibbosifolium	variableleaf bushbean
Medicago lupulina	black medick
Melilotus alba	white sweetclover
Melilotus indica	sourclover
Melilotus officinalis	yellow sweetclover
Erodium cicutarium	redstem stork's bill
Marrubium vulgare	horehound
Agrostis gigantea	redtop
Bromus hordeaceus	soft brome
Bromus inermis	smooth brome
Bromus japonicus	Japanese brome
Bromus rubens	red brome
Bromus tectorum	cheatgrass
Echinochloa crus-galli	barnyardgrass
Eragrostis curvula	weeping lovegrass
Pennisetum ciliare	buffelgrass
Poa pratensis	Kentucky bluegrass
Polygonum convovulus	black bindweed
Polygonum persicaria	spotted ladysthumb
Rumex acetosella	common sheep sorrel
Rumex crispus	curly dock
Verbascum thapsus	common mullein
Urtica dioica	stinging nettle

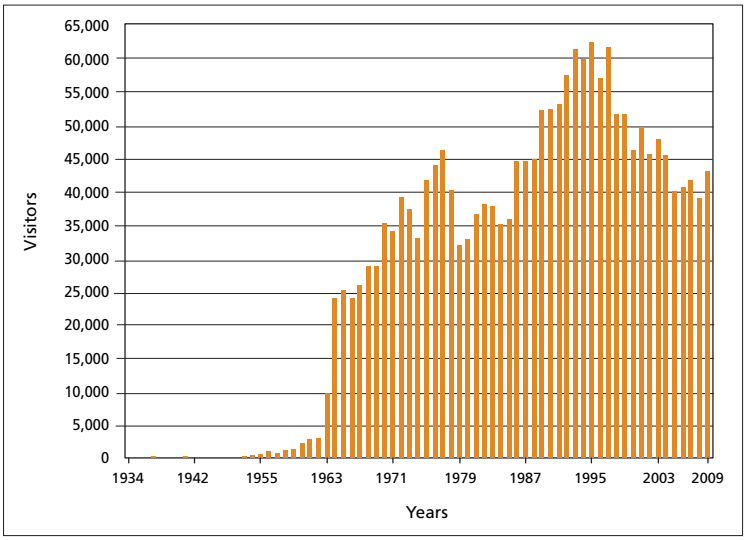


Figure 1.5.2. Visitation at Gila Cliff Dwellings NM, 1934–2009.

such as American bullfrog (*Lithobates catesbeiana*) and crayfish (*Orcontectes* spp.), and the consequent decline, and even extirpation, of many native aquatic vertebrates (Powell et al. 2006). Exhaustive field surveys conducted from 2001 to 2003, as part of the SODN biological inventory (Powell et al. 2006), failed to locate four species of amphibians that were historically common in the park: Mexican spadefoot (*Spea multiplicata*), Woodhouse's toad (*Anaxyrus woodhousii*), red-spotted toad (*Anaxyrus punctatus*), and Chiricahua leopard frog (*Lithobates chiricahuensis*) (Hayward and Hunt 1972).

Declines in native amphibian species have been widely observed throughout the American Southwest, and are also attributed to habitat alteration, extended drought, increased UV radiation, non-native fishes, and chytrid fungus. See Powell and others (2006) for a detailed overview of this issue, particularly as it pertains to Gila Cliff Dwellings NM. While this is a troubling resource concern at the park, it is unlikely to have strong linkages to terrestrial vegetation and soils.

1.5.4 Gila Cliff Dwellings NM as a reference site

Beyond the issues described in the previous sections, Gila Cliff Dwellings NM is remarkably free of major anthropogenic stressors. The park lies within a 300,000-acre designated wilderness area—one of the first such designated areas in the world. Mining, agriculture, and other forms of development are largely absent, beyond scattered vacation homes and public infrastructure to support outdoor recreation. Livestock grazing was retired in the 1950s, to support the recovery of elk herds (Russell 1992), and overall visitation (see Figure 1.5.2) is the second-lowest (to Fort Bowie NHS) in the Sonoran Desert Network (NPS 2010).

Consequently, we have viewed Gila Cliff Dwellings NM as a reference or control site for the generally more disturbed units of the network. Gila Cliff Dwellings NM shares many ecological similarities with Chiricahua NM, Fort Bowie NHS, and Coronado NMem—units that are currently affected by undocumented immigration traffic and the law-enforcement response, as well as trespass livestock, groundwater depletion, and exotic plant vectors (NPS 2005).

In addition, the park's situation (i.e., as a small cultural-resource park located along a key stretch of a major southwestern river) is shared with Montezuma Castle NM, Tuzigoot NM, and Tumacácori National Historical Park, which are strongly affected by upstream water regulation (dams, diversions, wastewater treatment) and active residential, agricultural, and industrial development within their immediate watersheds (NPS 2005). By contrast, Gila Cliff Dwellings NM's relatively pristine conditions and remote, protected setting provides a reference for understanding the consequences of these stressors on resources in kind, and may serve as a bellwether for assessing the effects of global climate change in the absence of other externalities.

American bullfrog (*Lithobates catesbeiana*).

2 Methods

2.1 Response design

The response design for this protocol employs permanent, 20 × 50-m sampling plots (Figure 2.1). The 50-m edges of the plot run parallel with the contours of the site. Vegetation sampling is done in conjunction with soil cover and stability measures along six transects within the plot. In the spaces between transects (subplots), within-plot frequency is estimated by noting the occurrence of any plant species or lifeform not observed on the adjacent transects. See Hubbard and others (in review) for details on plot configuration and collecting the measures.

2.1.1 Vegetation and soil cover: Line-point intercept

Line-point intercept is a common and efficient technique for measuring the vegetation cover of plants. Line-point intercept measures the number of "hits" of a given species out of the total number of points measured (Elzinga et al. 1998; Bonham 1989). Vegetation was recorded within three height categories along each of the six transects using the line-point intercept method, with points spaced every 0.5 m (240 points total). The three height categories were field (<0.5 m), subcanopy (0.5–2.0 m), and canopy (>2.0 m). Perennial vegetation was recorded to species and annual vegetation was recorded to lifeform, with the exception of a suite of annual non-native plants that were recorded to the species level. Soil cover (see Hubbard et al. in review, SOP #4) was recorded by substrate class (e.g., rock, gravel, litter), with biological soil crust cover (SOP #7) recorded to morphological group (e.g., light cyanobacteria, dark cyanobacteria, lichen, moss).

2.1.2 Vegetation frequency: Subplots

The area between any two adjacent transects formed the boundary of 10 × 20-m subplots that were used to estimate within-plot frequency of perennial plant species, exotic plants, and all lifeforms. The occurrence of any species/lifeform not measured on the adjacent line-point transect was recorded to determine a within-plot frequency of 0–5. Figure 2.1 explains the relationship between each subplot and its corresponding adjacent transect.

2.1.3 Soil aggregate stability

Surface soil aggregate stability was measured using a modified wet aggregate stability method (Herrick et al. 2005a). Within each plot, samples were collected at pre-determined points on either side of the six line-point intercept transects. A total of 48 uniformly sized (2–3 mm thick and 6–8 mm on each side) samples were tested per plot, in groups of 16. Each sample was placed on a screen and soaked in water for five minutes. After five minutes, the samples were slowly dipped up and down in the water, with the remaining amount of soil recorded as an index of the wet aggregate stability of the sample. Samples were scored from 1 to 6, with 6 being the most stable.

2.1.4 Soil and site characterization

Proximate soil and landform factors are known to influence vegetation and dynamic soil function parameters at local scales (McAuliffe 1999). To characterize the soil and landscape attributes of each plot, a suite of topoedaphic variables was collected through site diagrams, repeat photo points, and collection of soil cores. Landform, slope position, and parent material were recorded at each plot. Flow-length diagrams were used to depict surface-flow patterns and document the slopes (%) and lengths (m) of the hillslope within and immediately upslope of each plot. Permanent photo points were established at each plot corner to characterize general site physiognomy and as an aid to interpreting quantitative trend data in successive sampling periods. In addition, general site descriptions (including observed disturbances, such as fire) were collected for each plot.

2.2 Sampling design

2.2.1 Overview

All plots are sampled in July–August of the same year, then revisited at five-year intervals. If a major disturbance (e.g., fire, extended periods of temperature extremes, mass soil movement) occurs in the intervening years, we may collect additional plot data to characterize and account for the potential effects of these important stochastic events.

Terrestrial vegetation and soils plots were allocated by elevation classes (see Section 3.2.3, Hubbard et al. in review), with plots being equally allocated to two strata: 4,500–6,000' (Stratum 400),

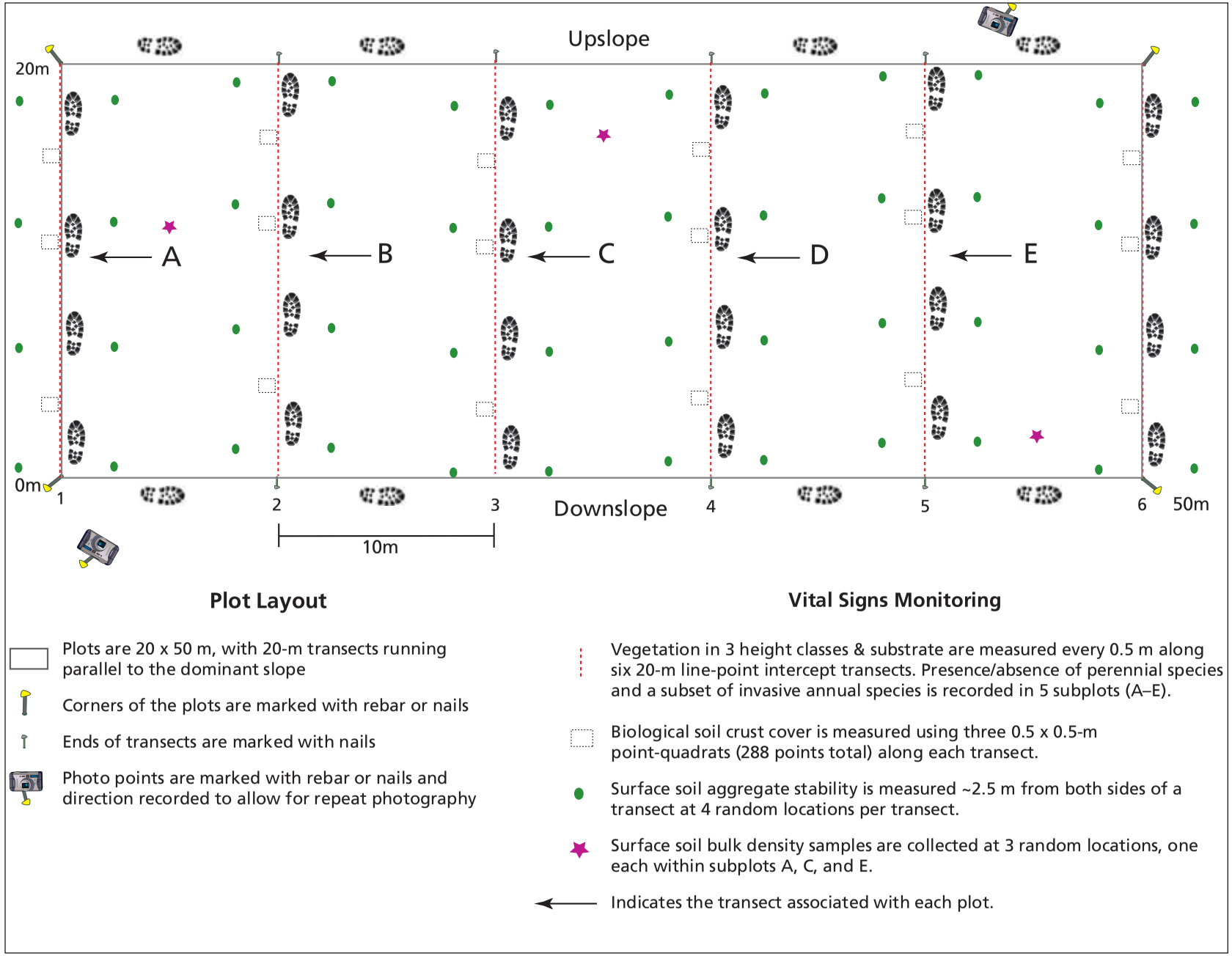


Figure 2.1. Terrestrial vegetation and soils monitoring plot design. See Hubbard and others (in review) for additional details on design and data collection.

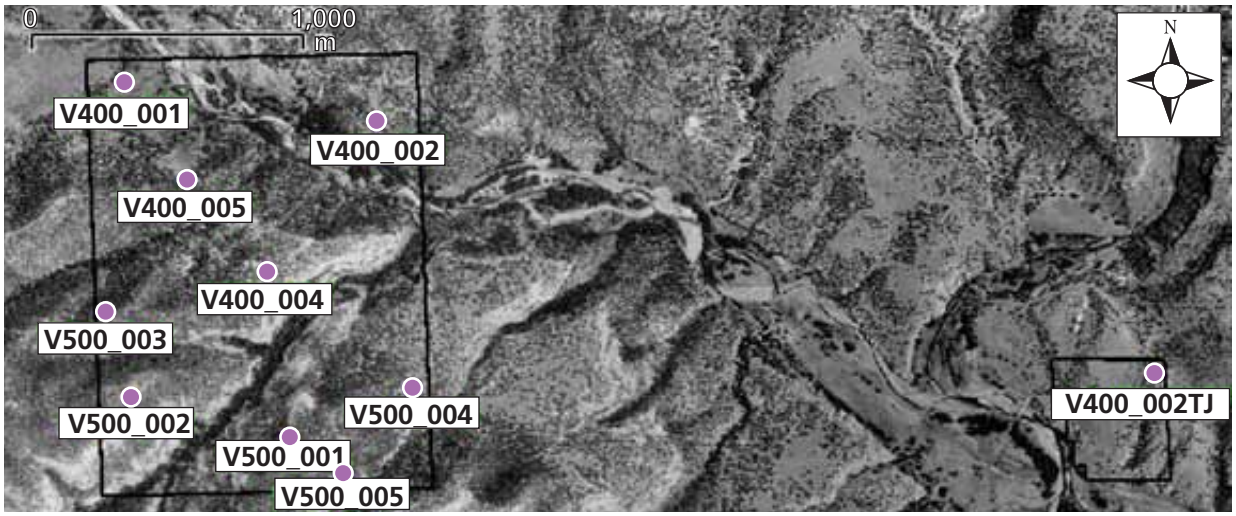


Figure 2.2.1. Allocation of monitoring plots, Gila Cliff Dwellings National Monument.

and >6,000' (Stratum 500) (Figure 2.2.1). For most network parks, soil rock fragments are also used to stratify permanent plot locations, with rock fragments serving as a coarse proxy for soil development and water-holding capacity. However, there are no baseline soils data for Gila Cliff Dwellings NM, and no soils inventory was scheduled or planned at time of writing (Pete Biggam, personal communication). In the absence of soils information, we chose to collect on-site soils data from each plot for possible post-stratification of our monitoring data (see Results and Discussion sections). Therefore, inference from the plots at Gila Cliff Dwellings NM is to all terrestrial areas of the park by elevation strata, except for the areas discussed in Section 2.2.3, below.

We allocated a total of 10 monitoring plots (5 per elevation class) in a spatially balanced arrangement (see Section 2.2.2), based on a priori expectations of required sample size to meet our criteria for statistical power and detectability (see Sections 2.2.5–2.2.6).

2.2.2 Spatial balance

The spatial sampling design for this protocol employs permanent, 20 × 50-m sampling plots, allocated through a Reversed Randomized Quadrant-Recursive Raster (RRQRR) spatially balanced design (Theobald et al. 2007), using the "spatially balanced sample" function in the STARMAP Spatial Sampling Toolbox in ArcGIS 9.0 (http://www.spatialecology.com/htools/index.php). This tool produces a design that is spatially well-balanced, probability-based, flexible, and simple (Theobald et al. 2007). Because it tries to maximize the spatial independence between plots, the spatially-balanced sampling design should provide more information per plot, thus increasing efficiency (Theobald et al. 2007).

Spatially balanced designs, such as RRQRR (for polygon data) and the Generalized Random Tessellation Stratified (GRTS; for points and lines) approach (Stevens and Olsen 2004), are increasingly being applied to ecosystem monitoring (e.g., Environmental Protection Agency Ecological Monitoring and Assessment Program) because they provide the advantages of a probabilistic design (Stehman 1999) and ensure spatial balance, regardless of overall sample size. RRQRR designs facilitate adding or removing sites in a spatially balanced manner if statistical power, financial considerations, or additional monitoring objectives warrant adjusting the sample size. This scaling ability is an important advantage, as (1) the number of plots per park cannot always be adequately estimated a priori (see Section 3.4.2, Hubbard et al. in review) and (2) future changes in technology, objectives, and budgets may necessitate increasing or decreasing sample sizes.

2.2.3 Sampling frame

The sampling frame for Gila Cliff Dwellings NM includes all terrestrial areas within park boundaries, except for the following (Figure 2.2.3):

- Slopes of ≥45° (for crew safety)
- Roads and buildings (including 100-m buffer)
- Trails washes, and streams (including 50-m buffer)

- Selected fragile cultural features (the cliff dwellings)

The total area excluded under these criteria was 197 acres (~79 ha), or 38% of the park area.

2.2.4 Management assessment points as the link between science and management

To achieve our core mission of resource protection, resource management and monitoring must be explicitly linked (Bingham et al. 2007). We advocate the use of management assessment points as a bridge between science and management. Management assessment points are "pre-selected points along a continuum of resource-indicator values where scientists and managers have agreed to stop and assess the status or trend of a resource relative to program goals, natural variation, or potential concerns" (Bennetts et al. 2007).

Management assessment points therefore aid interpretation of ecological information within a management context. They do not, however, define strict management or ecological thresholds, inevitably result in management actions, or reflect any legal or regulatory standard; they are only intended to serve as a potential early warning system allowing scientists and managers to pause, review the available information in detail, and consider options. Bennetts and others (2007) provided a detailed explanation of this concept and its application to monitoring and management of protected areas.

Although no management assessment points have been formally established for Gila Cliff Dwellings NM, we propose some assessment points here, based on the ecological literature and our knowledge of these ecosystems and park management goals. We intend for these assessment points to (1) initiate a discussion of potential indicators and assessment points—a conversation that will expand as the park completes a natural resource condition assessment (see Section 1.4.7) and commences additional park planning; and (2) provide a useful framework for evaluating terrestrial vegetation and soils data in a broader ecological and managerial context. Proposed assessment points are summarized in Table 3.3 and discussed in more detail in the Discussion section.

2.2.5 Statistical power to distinguish status from management assessment points

Estimating our statistical power to distinguish current conditions (i.e., status) from management assessment points (see previous section) is important for both protocol design (especially for determining adequate sample sizes) and data interpretation. Adequate sample size (number of plots) is estimated by (Herrick et al. 2005b):

$$n = \frac{(S)^2 (Z_\alpha + Z_\beta)^2}{(MDC)^2}$$

Where:

S = standard deviation of the sample,

Z_α = Z-coefficient for false change (Type I) error (set at 90%),

Z_β = Z-coefficient for missed-change (Type II) error (set at 10%), and

MDC = minimum detectable change from the assessment point (set at 5–20%).

Bonham (1989), Elzinga and others (1998), and Herrick and others (2005b) provide detailed discussions of statistical power to detect differences from a standard.

2.2.6 Statistical power to detect trends

Statistical power is also important for evaluating trends (change over time) in monitoring parameters. Adequate sample size (number of plots) for detecting a trend of a given size across a landscape with permanent plots is estimated from:

$$n = \frac{(S_{diff})^2 (Z_\alpha + Z_\beta)^2}{(MDC)^2}$$

Where:

S_{diff} = Standard deviation of the differences between paired samples,

Z_α = Z-coefficient for false change (Type I) error (set at 90%),

Z_β = Z-coefficient for missed-change (Type II) error (set at 10%), and

MDC = minimum detectable change size between time 1 and time 2 (set at 5–20%)

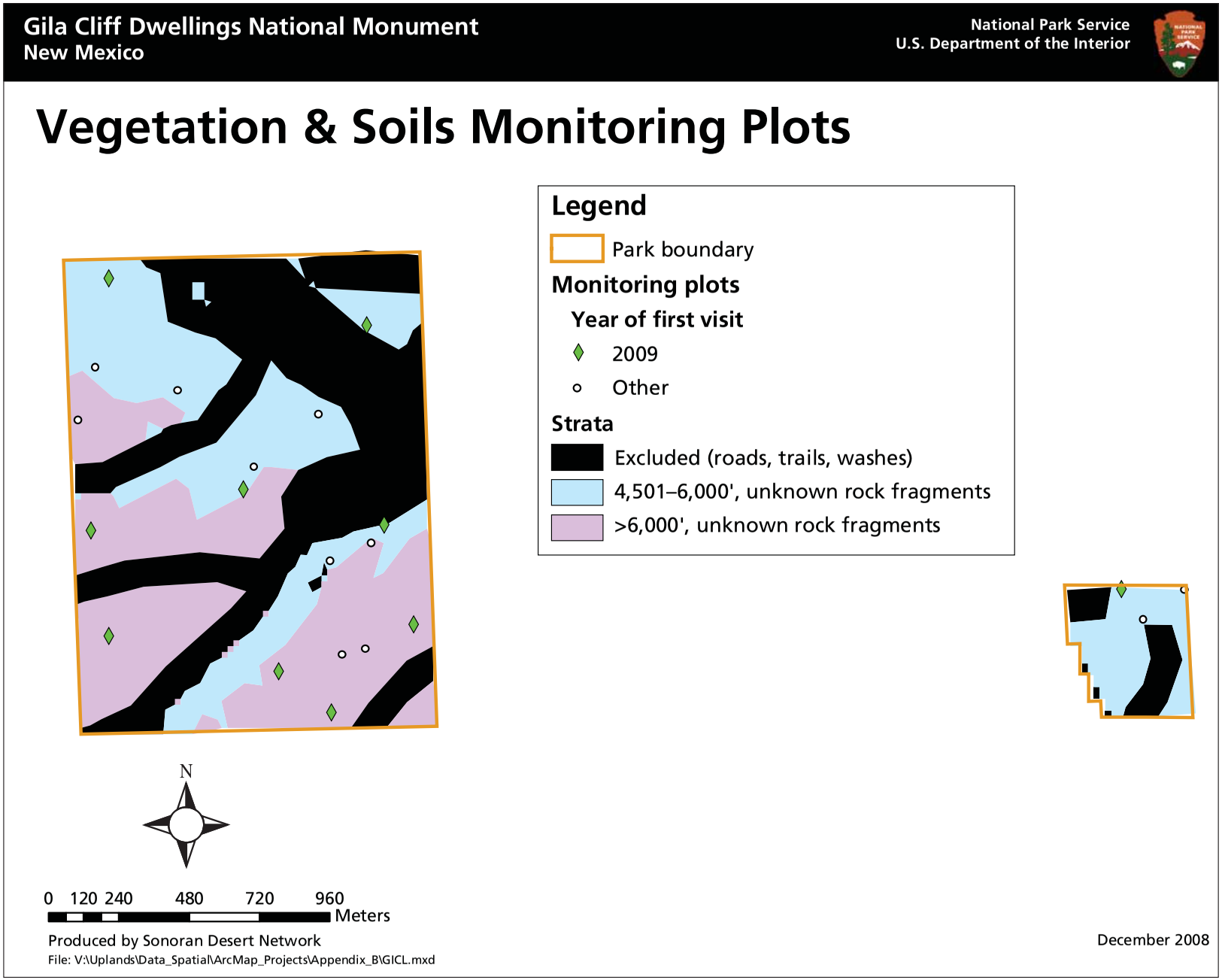


Figure 2.2.3. Sampling frame for terrestrial vegetation and soils monitoring, Gila Cliff Dwellings National Monument.

Because we only have one year of data for this report, we estimated "S_{diff}" using the following equation:

$$S_{diff} = (S_1)(\sqrt{(2(1-corr_{diff}))})$$

Where:

S_1 = Sample standard deviation among sampling units at first time period, and

$corr_{diff}$ = estimated correlation coefficient between time 1 and time 2, set at 0.75.

Bonham (1989), Elzinga and others (1998), and Herrick and others (2005b) provide detailed discussions of statistical power to detect trend.

2.2.7 Evaluation of strata

The terrestrial vegetation monitoring design apportions long-term monitoring sites to strata to improve the efficiency of parkwide estimation of monitoring parameters of interest. It is assumed that vegetation and dynamic soil functional attributes respond differently to environmental factors that can be clearly defined and are immutable over management and monitoring timescales (Bonham 1989).

To evaluate the efficiency and pertinence of our preselected elevation strata, we contrasted the similarity of the vegetation communities on each stratum using Analysis of Similarity (ANOSIM), non-metric multidimensional scaling (NMDS), and SIMPER, a permutation procedure that reveals which species contribute most to any between- and within-group dissimilarities. These non-parametric, multivariate community analysis techniques make few assumptions about the data, yielding a simple yet powerful analysis tool (Clarke and Warwick 2001).

Site-specific soils information (Nauman in review) was also used to better evaluate the utility of the sampling design in regard to elevation strata. BIOENV, a permutation procedure that uses Spearman correlation coefficients to find the "best" match between multivariate environmental (in this case, soils) variables and vegetation patterns across sites, was used to explore how the soils information might best explain the observed vegetation patterns. See Clarke and Warwick (2001) for a detailed explanation of this procedure. Evaluating these soils data may suggest more efficient strata for future terrestrial vegetation and soils information.

3 Results

3.1 Vegetation monitoring

3.1.1 New species

Our 2009 monitoring detected 11 species previously unknown at Gila Cliff Dwellings NM: one tree, three grasses, one cactus, and six forbs (Table 3.1.1). Voucher specimens were collected for accession into the park collection stored at the University of Arizona, and managed through an agreement with SODN and the NPS Western Archeological Conservation Center.

3.1.2 Cover and frequency of plant lifeforms

All major lifeforms were encountered on the monitoring plots, with the greatest cover and frequency occurring in the "field" elevation stratum (<0.5 m height; Figures 3.1.2a–b).

3.1.3 Cover and frequency of perennial plant species

Monitoring sites in the 400 stratum (4,500–6,000') were co-dominated by *Pinus ponderosa* (ponderosa pine), *Juniperus monosperma* (oneseed juniper), and *Pinus edulis* (twoneedle pinyon), with juvenile *Juniperus monosperma* prevalent in the subcanopy, as well (Appendix A, Tables A1–A2). By contrast, sites at >6,000' were dominated by dense *Pinus edulis* canopies, with *Juniperus osteosperma* (Utah juniper) as an important sub-dominant tree. Both species also comprised significant cover as juveniles in the subcanopy (Appendix A, Tables A1–A2). In all sites, the field layer was dominated by patchy stands of the perennial bunchgrass, *Bouteloua gracilis* (blue grama), in a diverse matrix of other perennial grasses and annual forbs (Appendix A, Table A1).

Several native perennial plant species were ubiquitous (widespread) throughout the park, as summarized in Table 3.1.3. Appendix A provides the cover (Appendix A, Tables A1–A3) and within-plot and landscape frequencies (Table A4) for all perennial plant species and plots.

3.1.4 Cover and frequency of exotic species

No exotic plant species were sampled on line-point transects. Two exotic forbs were detected on frequency subplots (Table 3.1.4): *Verbascum thapsus* (common mullein) and *Polygonum argyrocoleon* (silversheath knotweed). The latter had not been detected at the park prior to the current monitoring period (Powell et al. 2006).

Table 3.1.1. New plant species detected during terrestrial vegetation sampling at Gila Cliff Dwellings NM, 2009.

Species	Common name	Monitoring site(s)
Forbs/Herbs		
Erigeron flagellaris	trailing fleabane	GICL_Uplands_400_V002, 400_V002TJ, 400_V004, 500_V001, 500_V002, 500_V004, 500_V005
Polygonum argyrocoleon	silversheath knotweed	GICL_Uplands_500_V005
Veronica peregrina	neckweed	GICL_Uplands_400_V005
Graminoids		
Aristida schiedeana	single threeawn	GICL_Uplands_400_V001, 400_V004, 500_V004
Carex geophila	White Mountain sedge	GICL_Uplands_400_V001, 400_V002, 400_V005, 500_V001, 500_V003
Muhlenbergia pauciflora	New Mexico muhly	GICL_Uplands_500_V001
Subshrubs		
Brickellia californica	California brickellbush	GICL_Uplands_400_V002
Eriogonum jamesii	James' buckwheat	GICL_Uplands_500_V004
Krascheninnikovia lanata	n/a	GICL_Uplands_500_V005
Succulents		
Echinocereus coccineus	scarlet hedgehog cactus	GICL_Uplands_500_V004
Trees		
Pinus discolor	border pinyon	GICL_Uplands_500_V005

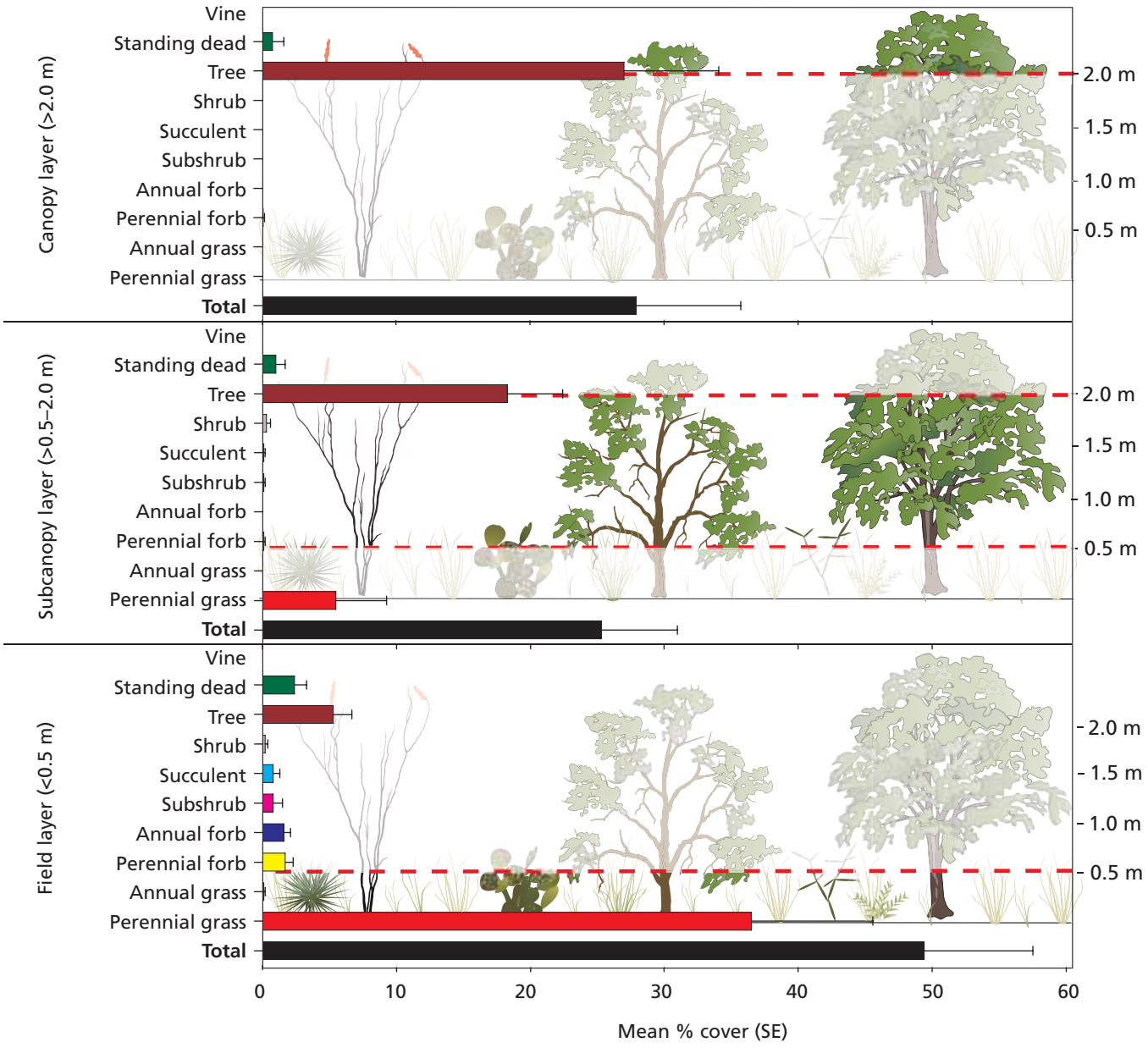


Figure 3.1.2a. Lifeform cover in terrestrial vegetation monitoring plots, 400 stratum (4,500–6,000' elevation), Gila Cliff Dwellings NM, 2009.

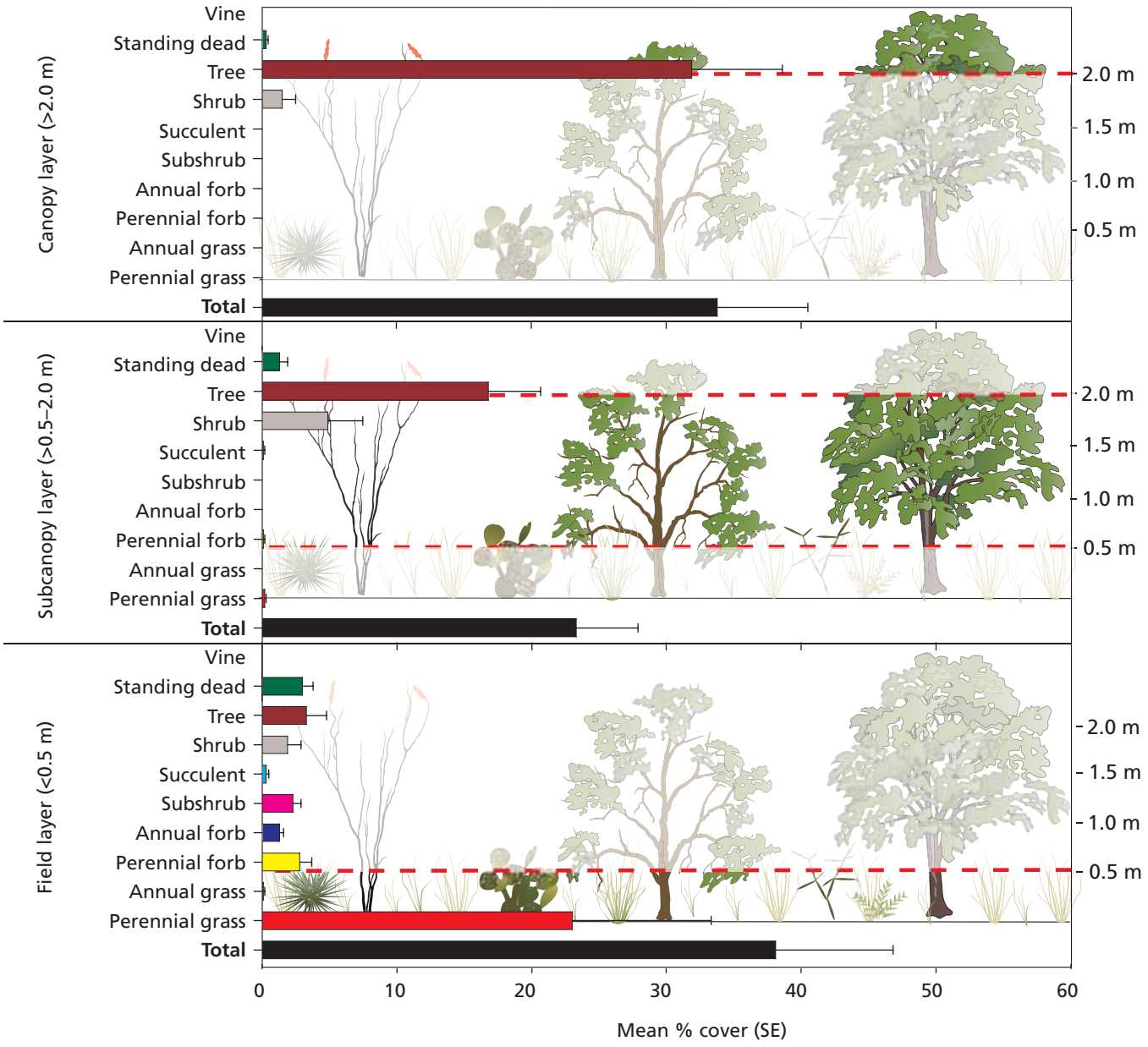


Figure 3.1.2b. Lifeform cover in terrestrial vegetation monitoring plots, 500 stratum (>6,000' elevation), Gila Cliff Dwellings NM, 2009.

Table 3.1.3. Ubiquitous native species observed on monitoring and test plots, Gila Cliff Dwellings NM, 2009.

Species	Common name	Life form	# field sites			Within-plot frequency (Mean ± SE)	
			# field sites (of 10)	400 stratum* (of 5)	500 stratum** (of 5)	400 stratum*	500 stratum**
Bouteloua gracilis	blue grama	Graminoid	9	5	4	80 ± 9%	80 ± 20%
Juniperus monosperma	oneseed juniper	Tree	9	5	4	68 ± 14%	40 ± 17%
Opuntia phaeacantha	pricklypear	Succulent	8	4	4	68 ± 19%	48 ± 16%
Pinus edulis	twoneedle pinyon	Tree	8	3	5	52 ± 22%	72 ± 15%
Quercus grisea	gray oak	Tree	8	4	4	80 ± 20%	40 ± 14%
Artemisia carruthii	Carruth's sagewort	Forb/Herb	7	3	5	40 ± 21%	48 ± 17%
Erigeron flagellaris	trailing fleabane	Forb/Herb	7	3	4	28 ± 12%	24 ± 8%
Bouteloua curtipendula	sideoats grama	Graminoid	7	4	3	48 ± 19%	48 ± 22%
Cercocarpus montanus	alderleaf mountain mahogany	Shrub	7	3	4	28 ± 15%	76 ± 19%
Sphaeralcea fendleri	Fendler's globemallow	Subshrub	7	4	3	32 ± 10%	12 ± 5%
Brickellia brachyphylla	plumed brickellbush	Subshrub	6	2	4	20 ± 16%	56 ± 17%
Yucca baccata	banana yucca	Succulent	6	3	3	24 ± 15%	44 ± 18%
Juniperus osteosperma	Utah juniper	Tree	6	1	5	4 ± 4%	72 ± 17%
Quercus gambelii	Gambel oak	Tree	6	4	2	80 ± 20%	40 ± 14%

*4,500–6,000'
**>6,000'

Table 3.1.4. Exotic plants detected on frequency subplots at upland vegetation monitoring sites, Gila Cliff Dwellings NM, 2009.

Species	Common name	Life form	Within-site frequency	Park frequency	Field sites
Verbascum thapsus	common mullein	Forb/Herb	20 ± 7.3%	4 (40%)	V400_01, V400_02, V400_05, V500_01
Polygonum argyrocoleon	silversheath knotweed	Forb/Herb	2 ± 1.4%	1 (10%)	V500_05

3.2 Soil monitoring results

3.2.1 Soil cover

Soil substrate cover was dominated by plant litter, duff (partially decomposed plant litter), and gravel. Only about 3% of the soil surface was bare soil without vegetative cover (Table 3.2.1). Plot-specific information is provided in Appendix A, Table A5.

3.2.2 Soil stability

All sites in the 400 stratum (4,500–6,000') had a surface soil aggregate stability rating of at least 2 (somewhat unstable), with a high degree of between-site variability (see Table 3.2.1, Appendix A, Table A5). Sites V400_02 and V400_05 had particularly unstable soil aggregates, whereas the others—including V400_02TJ, which contains important subsurface cultural resources—were relatively stable (Appendix A, Table A5).

Surface soil aggregate stability on sites above 6,000' in elevation were similarly variable, and generally less stable (see Table 3.2.1, Appendix A, Table A5) than sites below that elevation. Site V500_03 and, to a lesser extent, V500_05, were relatively unstable, with overall ratings of 1.78 ± 0.31 and 2.25 ± 0.34, respectively (Appendix A, Table A5.

For all sites at all elevations, samples collected under vegetation tended to have higher stability values than those collected in open spaces (see Table 3.2.1). Plot-specific information is given in Appendix A, Table A5.

3.3 Management assessment points

Relevant data were contrasted with the proposed management assessment points to assist in interpretation of the monitoring data (Table 3.3). Most indicators did not approach the management assessment point, but some individual plots had values that suggested some potential for site-specific issues (see Appendix A). The parkwide exception (across both elevation strata) was surface soil aggregate stability, an indicator of erosion hazard (Tables 3.2.1, 3.3). We estimate that our statistical power is sufficient to detect a change of slightly less than one level in stability, reflecting the high variability in this parameter across the park (Table 3.3).

The other management assessment point that was exceeded was the extent of exotic plant occurrence for sites in the 400 stratum, where exotic plants were detected on more than 50% of the monitoring sites (Tables 3.1.4, 3.3). Extent (landscape frequency) is a measure of exotic plant dispersal, an important issue at Gila Cliff Dwellings NM.

3.4 Evaluation of strata

3.4.1 ANOSIM results

Analysis of similarity (ANOSIM) results indicated significant differences between the overstory communities (canopy level, >2.0 m height) between strata (P = 4.8%, R = 0.272), as illustrated by NMDS (Figure 3.4.1a). SIMPER analysis revealed that *Pinus edulis, Juniperus osteosperma*, and *Pinus ponderosa* were most responsible for the canopy differences between the strata, with the former two species more associated with the 500 stratum, and the latter associated with the 400 stratum (Table 3.4.1a).

Results for subcanopy communities (0.5–2.0 m height) also indicate significant differences between elevation strata (P = 1.6%%, R = 0.268; Figure 3.4.1b, Table 3.4.1b). Species most associated with the 500 stratum included *Pinus edulis*, *Juniperus osteosperma*, and *Cercocarpus montana* (alderleaf mountain mahogany), whereas *Juniperus monosperma* and *Quercus grisea* (gray oak) were more associated with the 400 stratum (Table 3.4.1b).

No significant differences were detected for the understory communities (field level, <0.5 m height) (P = 29.4%, R = 0.052; Figure 3.4.1c).

3.4.2 Influence of local soils on monitoring plot composition

In his companion soil assessment, Nauman (in review) found large variations in most measured soil physical and chemical properties, and a surprising amount of soil organic carbon. However, only Topographic Wetness Index (TWI; Yang et al. 2007), an indicator of potential soil water availability based on topographic analysis of GIS layers, had a significant correlation (R^2 = 0.589, P = 3%) with any vegetation patterns—in this case, field-layer (<0.5 m) vegetation composition. None of the other soil or landform variables were correlated with vegetation patterns (P ≥11%).

Surface rock fragments ranged from 41 to 72% (Nauman in review), placing all plots in the same "very rocky" stratum (i.e., "403, "503") categories using our a priori sampling scheme (Hubbard et

Table 3.2.1. Parkwide dynamic soil function vital signs, Gila Cliff Dwellings NM 2009.

Decreasing erosion hazard ↓

Parameter	400 stratum*		500 stratum*		Parkwide	
	Mean ± SE	MDC, # plots	Mean ± SE	MDC, # plots	Mean ± SE	MDC, # plots
Soil substrate						
Bare soil (<2 mm), no overhead vegetative cover	2.2% ± 0.7	5%, 1	3.4% ± 1.2	5%, 2	2.8% ± 0.7	5%, 1
Bare soil (<2 mm), under vegetation	3.3% ± 1.3	5%, 2	7.6% ± 5.1	11%, 5	5.4% ± 2.6	6%, 10
Duff (partially decomposed organic matter)	13.3% ± 5.7	12%, 5	12.4% ± 5.6	12%, 5	12.9% ± 3.8	8%, 10
Litter (intact organic matter)	50.7% ± 5.1	11%, 5	38.3% ± 7.3	15%, 5	44.5% ± 4.7	10%, 10
Biological soil crust: cyanobacteria	---	---	0.3% ± 0.3	5%, 1	0.2% ± 0.2	5%, 1
Biological soil crust: moss	0.3% ± 0.2	5%, 1	0.8% ± 0.4	5%, 1	0.5% ± 0.2	5%, 1
Plant base	6.0% ± 2.3	5%, 5	4.9% ± 3.5	8%, 5	5.5% ± 2.0	5%, 7
Gravel (2–75 mm)	17.8% ± 5.0	11%, 5	24.0% ± 4.4	10%, 5	20.9% ± 3.3	7%, 10
Rock (76–600 mm)	1.4% ± 0.8	5%, 1	6.0% ± 2.7	6%, 5	3.7% ± 1.5	5%, 4
Lichen on rock	3.9% ± 2.4	5%, 5	1.2% ± 0.5	5%, 1	2.5% ± 1.3	5%, 3
Bedrock	1.2% ± 0.9	5%, 1	1.0% ± 0.8	5%, 1	1.1% ± 0.6	5%, 1
Surface soil aggregate stability						
All samples						
Average Soil Stability, categories from 1 (=very unstable) to 6 (=very stable)	3.16 ± 0.40	0.90, 5	2.71 ± 0.33	0.70, 5	2.93 ± 0.26	0.55, 10
% samples in "very stable" (=6) category	22.3% ± 6.8	13%, 5	16.6% ± 5.8	12%, 5	19.5% ± 4.4	9%, 10
Under vegetation						
Average Soil Stability, categories from 1 (=very unstable) to 6 (=very stable)	3.36 ± 0.46	1.00, 5	2.88 ± 0.50	1.10, 5	3.12 ± 0.33	0.70, 10
% samples in "very stable" (=6) category	24.8% ± 7.0	14%, 5	19.6% ± 7.1	15%, 5	22.2% ± 4.8	10%, 10
No vegetation cover						
Average Soil Stability, categories from 1 (=very unstable) to 6 (=very stable)	2.70 ± 0.41	0.80, 5	2.28 ± 0.28	0.60, 5	2.49 ± 0.25	0.55, 10
% samples in "very stable" (=6) category	14.0% ± 9.3	11%, 5	14.7% ± 6.6	14%, 5	11.9% ± 3.7	8%, 10

*4,500–6,000'
**>6,000'
Values are cover (%) unless otherwise indicated.

Table 3.3. Terrestrial vegetation and soils monitoring data in the context of proposed management assessment points, Gila Cliff Dwellings NM, 2009.

Issue	Management assessment point	Mean	SE	MDC	n=	Point met?	Recommendation
400 stratum (4,500–6,000')							
Erosion hazard	Bare ground (with no overhead vegetation) is >20%	2.2%	0.70%	5%	1	NO	Continue monitoring
	Average surface soil aggregate stability is <Class 3	**3.2**	**0.4**	**0.9**	**5**	**YES**	**Meet and consider**
	% grass & forb cover that are annuals is >33%	4.5%	1.0%	5%	1	NO	Continue monitoring
Site stability	Foliar cover of dead trees is >10%	0.1%	0.1%	5%	1	NO	Continue monitoring
	Foliar cover of dead shrubs is >10%	1.0%	0.7%	5%	1	NO	Continue monitoring
Fire hazard	Litter + duff cover is >80%	64.0%	6.40%	14%	5	NO	Continue monitoring
Exotic plant dispersal	**Extent of exotic plants is >50%**	**60%**	**n/a**	**n/a**	**n/a**	**YES**	**Meet and consider**
Exotic plant invasion	% of total plant cover that is exotic is >10% (field)	---	n/a	n/a	n/a	NO	Continue monitoring
	% of total plant cover that is exotic is >10% (subcanopy)	---	n/a	n/a	n/a	NO	Continue monitoring
	% of total plant cover that is exotic is >10% (canopy)	---	n/a	n/a	n/a	NO	Continue monitoring
500 stratum (>6,000')							
Erosion hazard	Bare ground (with no overhead vegetation) is >20%	3.4%	1.20%	5%	2	NO	Continue monitoring
	Average surface soil aggregate stability is <Class 3	**2.71**	**0.33**	**0.7**	**5**	**YES**	**Meet and consider**
	% grass & forb cover that are annuals is >33%	9.8%	6.5%	5%	3	NO	Continue monitoring
Site stability	Foliar cover of dead trees is >10%	0.3%	0.2%	5%	1	NO	Continue monitoring
	Foliar cover of dead shrubs is >10%	1.3%	0.6%	5%	1	NO	Continue monitoring
Fire hazard	Litter + duff cover is >80%	50.8%	10.5%	22%	5	NO	Continue monitoring
Exotic plant dispersal	Extent of exotic plants is >50%	10%	n/a	n/a	n/a	NO	Continue monitoring
Exotic plant invasion	% of total plant cover that is exotic is >10% (field)	---	n/a	n/a	n/a	NO	Continue monitoring
	% of total plant cover that is exotic is >10% (subcanopy)	---	n/a	n/a	n/a	NO	Continue monitoring
	% of total plant cover that is exotic is >10% (canopy)	---	n/a	n/a	n/a	NO	Continue monitoring

MDC = minimum detectable change (%)
n = number of plots to meet power assumptions under our criteria (see text).

Table 3.4.1. Results of SIMPER analysis of (a) canopy communities and (b) subcanopy communities indicating which species contribute most to the dissimilarity between strata.

A. Canopy (>2.0 m)

Scientific name	Common name	Average abundance		Average		Contributing %	Cumulative %
		4,500–6,000'	>6,000'	Dissimilarity	Dissimilarity/SD		
Pinus edulis	twoneedle pinyon	1.66	3.61	13.22	1.40	19.39%	19.39%
Juniperus osteosperma	Utah juniper	0.41	2.63	12.61	1.54	18.47%	37.87%
Pinus ponderosa	ponderosa pine	2.17	1.17	11.12	1.04	16.31%	54.17%
Juniperus monosperma	oneseed juniper	2.01	1.60	9.61	1.10	14.09%	68.27%
Quercus grisea	gray oak	1.10	0.60	4.76	1.54	6.98%	75.24%
Juniperus deppeana	alligator juniper	0.97	0.13	3.93	0.82	5.76%	81.00%
Cercocarpus montana	alderleaf mountain mahogany	0.00	0.89	3.89	0.83	5.70%	86.70%
Snag*		0.39	0.36	2.53	0.93	3.70%	90.40%
Overall dissimiarilty = 68.21%							

*standing dead tree or shrub

B. Subcanopy (0.5–2.0 m)

Scientific name	Common name	Average abundance		Average		Contributing %	Cumulative %
		4,500–6,000'	>6,000'	Dissimilarity	Dissimilarity/SD		
Juniperus osteosperma	Utah juniper	0.36	2.21	8.79	1.79	11.72%	11.72%
Pinus edulis	twoneedle pinyon	0.80	2.22	8.49	1.50	11.33%	2305.00%
Juniperus monosperma	oneseed juniper	2.06	1.38	8.11	1.65	10.82%	33.87%
Quercus grisea	gray oak	1.87	0.57	7.51	1.31	10.03%	43.89%
Cercocarpus montana	alderleaf mountain mahogany	0.22	1.36	5.49	1.34	7.33%	51.23%
Quercus gambelii	Gambel oak	0.53	0.49	3.88	0.77	5.18%	56.41%
Snag*		0.70	0.84	3.78	1.30	5.04%	61.45%
Garrya wrightii	Wright's silktassel	0.00	0.82	3.45	0.75	4.60%	66.05%
Bouteloua gracilis	blue grama	0.68	0.00	2.82	0.48	3.76%	69.80%
Bouteloua curtipendula	sideoats grama	0.47	0.13	2.29	0.61	3.05%	72.85%
Aristida schiedeana	single threeawn	0.41	0.00	2.21	0.48	2.94%	75.80%
Muhlenbergia spp.	muhly	0.36	0.00	1.97	0.48	2.63%	78.43%
Pinus ponderosa	ponderosa pine	0.29	0.13	1.89	0.63	2.53%	80.95%
Juniperus deppeana	alligator juniper	0.41	0.00	1.83	0.76	2.45%	83.40%
Rhus trilobata	skunkbush	0.00	0.31	1.68	0.72	2.24%	85.64%

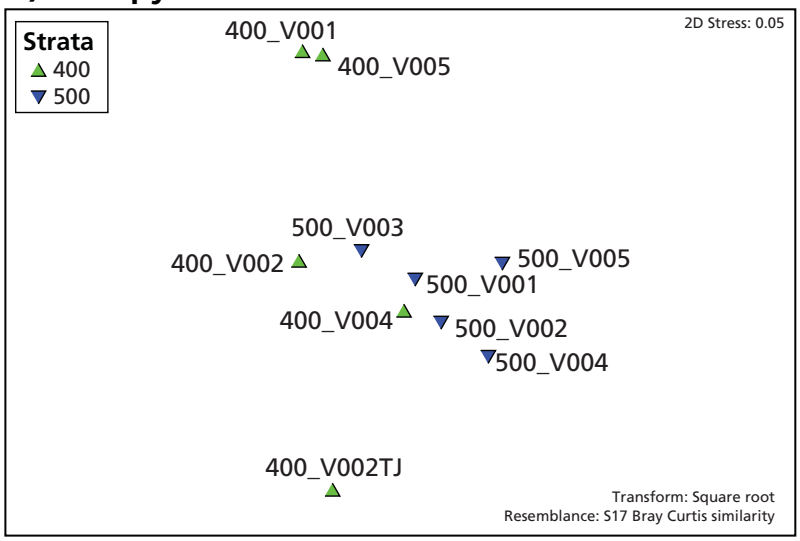
Table 3.4.1. Results of SIMPER analysis of (a) canopy communities and (b) subcanopy communities indicate which species contribute most to the dissimilarity between strata, cont.

Scientific name	Common name	Average abundance		Average		Contributing %	Cumulative %
		4,500–6,000'	>6,000'	Dissimilarity	Dissimilarity/SD		
Juniperus scopulorum	Rocky Mountain juniper	0.36	0.00	1.46	0.48	1.95%	87.59%
Bouteloua hirsuta	hairy grama	0.32	0.00	1.30	0.48	1.74%	89.33%
Abies lasiocarpa	balsam fir	0.22	0.00	1.14	0.48	1.52%	90.34%
Overall dissimiarilty = 74.93%							

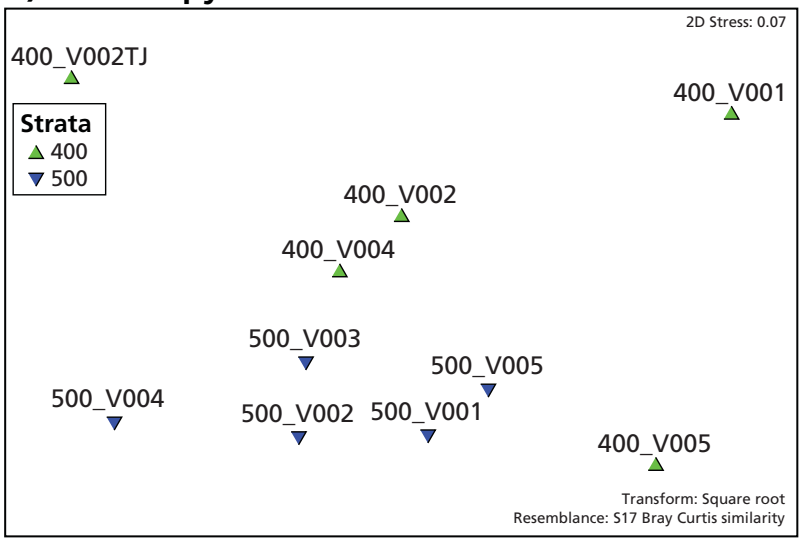
*standing dead tree or shrub

Figure 3.4.1. Non-metric multidimensional scaling indicates similarity of (a) canopy, (b) sub-canopy, and (c) field layer communities. The distance between any two points increases as their composition and structure differ.

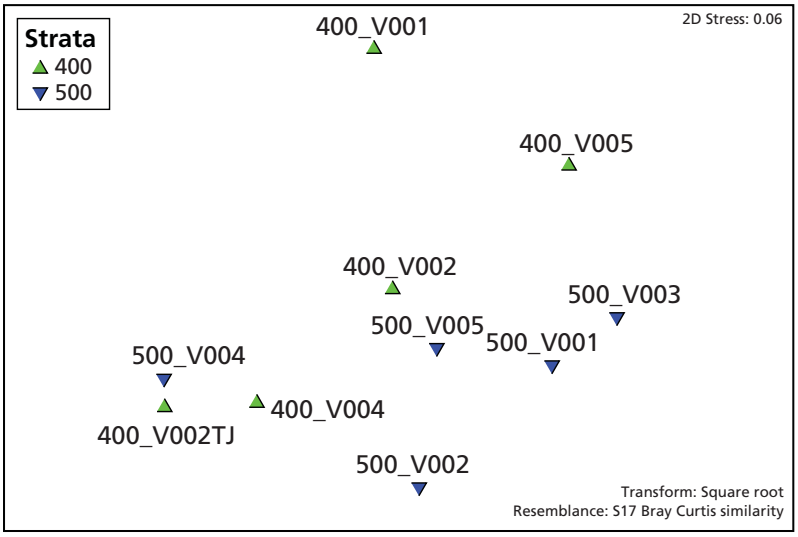
a) Canopy



b) Subcanopy



c) Field



al. in review).

3.5 Estimates of power and species detectability

3.5.1 Power to distinguish monitoring data from management assessment points

Our design permitted us to detect a 5% difference from the management assessment point for most parameters, with the exception of litter and duff cover (a measure of fire hazard), where high between-site variability resulted in the estimated ability to detect only a 14% (400 stratum) and 22% (500 stratum) change, with 90% power and a 10% chance of a false-change error (see Table 3.3).

3.5.2 Power to detect trends in plant lifeforms and common perennial species

Our proposed sampling design generally exceeded our expectations for statistical power to detect trends in plant lifeforms and common perennial species based on our design criteria (i.e., to detect a 10% absolute change in foliar cover with 90% power and 10% chance of a false-change error). Our data indicate that we will be able to detect a 5% change (absolute foliar cover) for nearly all detected perennial species and lifeforms (Appendix A, Tables A1–A3).

The only perennial species that failed to meet our criteria with five plots per stratum was *Bouteloua gracilis* (blue grama), for which we could only detect a 19% (400 stratum) and 23% (500 stratum) change based on our 2009 data. The variability of this species likely contributed to the failure to meet our initial design criteria for perennial grass lifeforms, as well, as we estimate that we can only detect a 17% (400 stratum) and 20% (500 stratum) change (Appendix A, Table A1).

As the strata evaluation indicated that "field" (<0.5 m) plant communities did not significantly differ (Section 3.4.1), all 10 plots can be grouped (4,500'+), increasing power such that we can detect a 14% and 15%, respectively, for *Bouteloua gracilis* and perennial grasses (Appendix A, Table A1).

Tree lifeforms in the canopy layers also failed to meet our design criteria, as we estimate that we could only reliably detect a 15% (400 stratum) and 14% (500 stratum) change based on five plots per stratum (Appendix A, Table A3).

3.5.3 Plant species detectability and power for trend in uncommon perennial species

Line-point intercepts on the 10 monitoring sites detected 70 perennial species, to which the frequency subplots added 46 perennial species. Of the 116 species detected, more than half were exclusive to plots in one elevation stratum or the other (31 exclusively in the 400 stratum, 36 in the 500 stratum). Species accumulation curves (Figure 3.4.5a–c) suggest that adding plots would increase perennial species detections, particularly in the 400 stratum (Figure 3.4.5b), although the slopes diminish with sampling effort.

Our design met or exceeded our sampling objectives for detecting trends in most uncommon perennial species (i.e., to detect at least a 10% change in within-plot frequency with 90% power and 10% chance of false-change error) for species encountered only in frequency subplots. Several species with relatively high within-plot frequencies and high variance had less power to detect change (Appendix A, Table A7). However, these more variable species were generally common enough to be detected along the line-point transect, which provides a far more precise estimate of cover and improved statistical power than does frequency (Appendix A, Tables A1–A3).

Figure 3.4.5a. Species area curves for cover and frequency data collected on terrestrial vegetation and soils plots, Gila Cliff Dwellings NM, 2009. Curves show cumulative numbers of species detected as plots are added. UGE = mean species accumulation curve with samples entered in random order (Ugland et al. 2003).

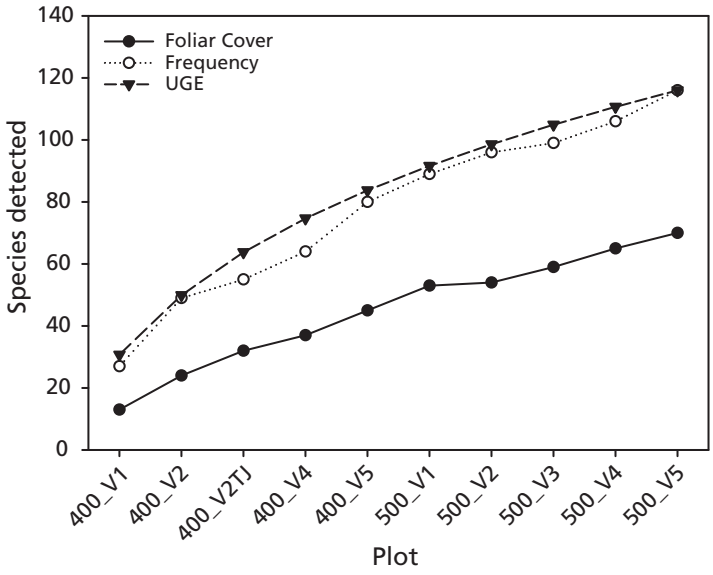


Figure 3.4.5b. Species area curves for cover and frequency data collected on terrestrial vegetation and soils plots, 400 stratum (4,500–6,000'), Gila Cliff Dwellings NM, 2009.

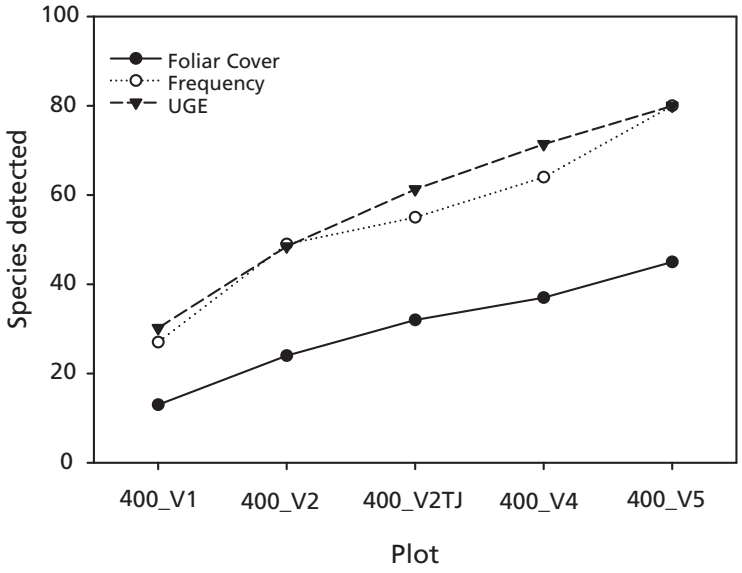
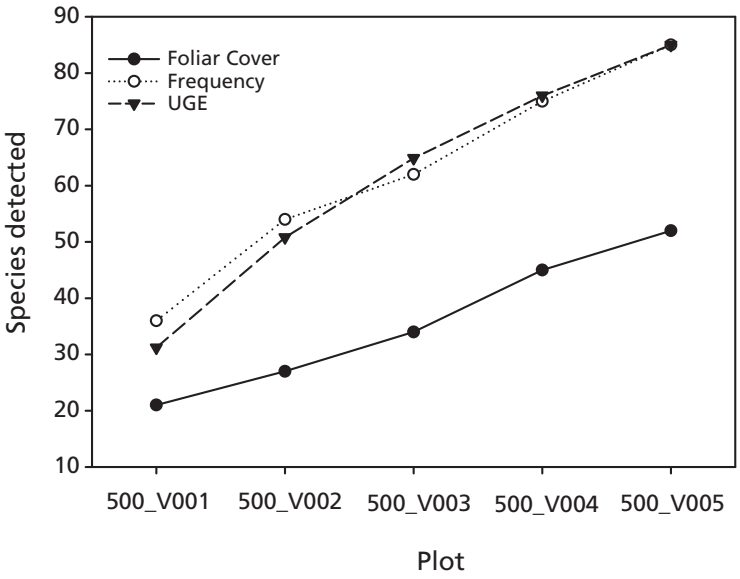


Figure 3.4.5c. Species area curves for cover and frequency data collected on terrestrial vegetation and soils plots, 500 stratum (>6,000'), Gila Cliff Dwellings NM, 2009.



4 Discussion

4.1 Contrasting habitats of mesa tops and canyons

The data in this report describe a mesa-and-canyon landscape in which local topography mediates plant water balances far more than elevation does. Lower-elevation sites (<6,000') occur along the three ephemeral canyons, where narrow walls limit potential evapotranspiration—the dominant constraint on plant growth in this semi-arid environment (see Figure 1.4.4b). Whereas mortality and damage from extended frost can limit productivity, these canyon sites are generally more favorable microclimates for plant growth.

By contrast, mesa tops are relatively flat, exposed, and rocky (Figure 4.1), and have a much greater daily photoperiod. The small gain in elevation (and, therefore, reduction of air temperature) cannot offset the reduced potential evapotranspiration afforded by canyon walls.

Unlike the "sky-island" model of topographic influence, in which elevation is positively correlated with precipitation and negatively correlated with air temperature and (therefore) potential evapotranspiration, the localized effects of topography at Gila Cliff Dwellings NM place the cooler, moister sites lower—rather than higher—on the landscape. This mesa-and-canyon pattern is also seen at many other locations in the Sonoran, Apache Highlands, and Arizona–New Mexico Mountains ecoregions, including Chiricahua NM and Bandelier NP.

Canyon vegetation communities are composed of two-phase tree savannas and open woodlands with relatively dense perennial grass growth between and beneath tree canopies. Tree canopies are generally clustered together and dominated by relatively tall *Pinus ponderosa*, with shorter *Juniperus monosprema*, *Juniperus deppeana* (alligator juniper), and *Pinus edulis* as important codominants. Shrubs are nearly absent.

Mesa-top sites are classic pinyon-juniper woodlands. Perennial grasses and shrubs are clustered in the microclimates beneath well-spaced and short-statured *Pinus edulis* and *Juniperus osteosperma* trees. Interspaces between tree canopies have sparse vegetative cover, and the proportion of bare soil, rock, and gravel is relatively high.

4.2 Exotic invasive plants

Exotic plant encroachment typically occurs in two phases: (1) colonization, the process by which a problematic species gradually disperses into suitable habitats, recruits into the system, and competes for resources with other members of the plant community; and (2) domination, the process by which the new species becomes common or even dominant in the plant community, often with negative consequences for ecosystem structure and function. Domination often occurs through asymmetrical competition, mediated through disturbance. It is important to note that this second phase often requires a specific set of ecological triggers or conditions that may never actually occur; this is why many exotic species are relatively innocuous under some environmental conditions. Determining which phase has occurred can have important implications for designing successful management strategies and effective monitoring designs.

Our data indicate that one exotic herb, common mullein (*Verbascum thapsus*), has completed the colonization phase, as it is widely distributed in upland portions (particularly below 6,000') of Gila Cliff Dwellings NM (see Table 3.1.3), suggesting that it is not dispersal-limited from suitable habitats within the park. Many sites that are likely to be colonized have been colonized. However,

Figure 4.1. Contrasting habitats and vegetation of dry, flat, and rocky mesa tops (foreground) and more protected canyons (background) along upper Cliff Dweller Canyon, Gila Cliff Dwellings NM. Denser riparian vegetation in the canyon bottom is sampled through the SODN Streams and Washes protocol, and was excluded from the current study.

Verbascum thapsus cover was sufficiently sparse that it was never encountered on the line-point transects, indicating it is likely not a major influence on vegetation at the park, let alone a dominant, negative influence on native flora. It appears that native species can effectively compete with this invasive exotic species under current conditions.

Our sampling also detected *Polygonum argyrocoleon* (silversheath knotweed), a non-native herb that had not been previously detected at the park. We found only one plant at one site (V500_05), so this species has clearly not effectively colonized the park at this time.

As neither of these species exhibit alleopathy or have traits that can have disproportionate impacts to ecosystem function at low abundances (e.g., such as those of *tamarix* sp., which can dramatically increase soil and soil water salinity; Hua Yin et al. 2009), it appears that their current impact on terrestrial ecosystems at Gila Cliff Dwellings NM is negligible. However, changing biotic and abiotic conditions may favor the expansion of these species in the future. We will continue to monitor the distribution and abundance of these and other non-native plants, and recommend continued vigilance and the development of a containment strategy that could be employed in the event of a future increase in these potentially problematic species.

4.3 Site stability and erosion

Site stability is the resistance of a site to localized wind and water erosion of soils, with tremendous consequences for park ecosystems and the protection of finite aboveground and subsurface cultural resources.

Soil factors mediate water relations for plants in semi-arid environments (McAullife 1990), thereby controlling patch-scale ecological composition and net primary productivity (Herrick et al. 2005a). As recovery of disturbed soils is particularly slow in dry and seasonally dry environments (Aber and Melillo 1991), avoiding erosion is of paramount importance to effective natural resource management in SODN parks, including Gila Cliff Dwellings NM.

Static and dynamic factors determine the vulnerability of a site to water erosion (Herrick et al. 2005a). Static factors are generally not affected by management actions; these include soil texture, depth, and parent material; slope; aspect; and climate (Herrick et al. 2005a). These factors can be combined to estimate site erosion potential (Davenport et al. 1998). As such, static factors establish the range of erosion potential, within which dynamic factors may be influenced by disturbance and management actions to determine actual erosion.

Dynamic factors affecting water erosion include soil disturbance, soil structure, total cover, and plant basal cover. The amount of total cover (soil cover and vegetation cover) is the single most important dynamic factor affecting water erosion (Herrick et al. 2005a). Most soil loss occurs in "unprotected" areas (i.e., uncovered bare soils; Davenport et al. 1998), whereas rock, gravel, vegetation, biological soil crusts, and even plant debris (litter and duff) can "armor" the soil, slowing the flow of water and permitting increased infiltration of water into the soil profile (Belnap et al. 2007).

Our data indicate that soils at Gila Cliff Dwellings NM are currently very well armored, with only 2.8 ± 0.7% (see Table 3.2.1) of the soil surface consisting of exposed, bare mineral soil. However, the majority of the resistant soil cover is composed of vegetation, leaf litter, and duff—materials that could be rapidly lost following wildfire or prolonged drought.

In addition, the stability of surface soil aggregates (an indicator of soil structure) was below our proposed management assessment point (see Table 3.3), indicating the potential for significant soil erosion if soil cover is lost.

Our data on the dynamic factors of water erosion indicate that while potential erosion is a concern, actual erosion is currently fairly moderate. However, three sites (V400_002, V500_001, V500_002) have evidence of sheet flows or major rill development—signs of water erosion. Damage at V500_002 was particularly significant, with more than 50% of the plot degraded. Fortunately, the TJ Ruin site was in relatively good condition, and is fairly resistant to future erosion based on our dynamic soil functional data (Appendix A, Table A5).

Although current soil loss appears to be moderate and localized, wildfire and prolonged drought could have serious negative impacts on critical soil resources at Gila Cliff Dwellings NM, due to inherent site instability.

4.4 Implications for terrestrial vegetation and soils monitoring

This effort entailed some of the first terrestrial vegetation and soils monitoring in the SODN. Therefore, much of our focus was on evaluating the efficacy of the sampling and response designs to support improvement of the protocol. We found the plot-sampling design to be efficient. Most plots were sampled within 2–4 hours, including tasks that will not need to be repeated in successive visits (initial plot layout, permanent marking and mapping, and collection of in situ soil and landscape parameters).

In particular, simultaneously fielding two large crews allowed us to effectively sample all of the monitoring plots in a short period of time, and is a model that we will employ in similar situations in other SODN parks.

Stratifying sampling sites by two elevation classes (4,500–6,000', >6,000') was an efficient approach for sampling canopy (>2 m stature) and subcanopy (0.5–2.0 m) vegetation. The approach effectively partitioned variation, providing excellent statistical power for status and trend detection that generally exceeded our design criteria. The design also captured and differentiated the two distinct terrestrial woodland and savanna vegetation types at the park, as described in Section 4.1.

Unfortunately, the elevation strata were less effective for sampling the field layer (<0.5 m stature), which did not differ greatly between strata. This is likely due to high within-stratum variability in vegetative cover of species such as *Bouteloua gracilis* (for which we failed to attain our statistical power criteria), and the high overlap of species occurrence across the two strata. As a result, stratifying the field layer is probably unnecessary, and the data can be grouped for analysis and interpretation. Increasing our power and precision for *Bouteloua gracilis* would require nine additional plots, necessitating a significant increase in cost and effort that is not warranted unless this topic is determined to be of particular interest for park managers.

In all other cases, our design and sample size (=10 plots) met or exceeded the statistical power thresholds for vegetation established in our monitoring objectives. Despite relatively high between-plot variation (a theme repeated throughout all of the soils results—see Nauman in review), we also met or exceeded our thresholds for substrate type and surface aggregate stability.

The lack of a priori soils information did not impact our design; nor did the soil physical and chemical properties explain the vegetation patterns we observed. As a result, we see no compelling reason to reallocate our plots to new strata based on the soil results.

We detected one-third (116 of 348) of the documented flora of the park (Powell et al. 2006), and added 10 new species to park lists. This was a reasonable result, considering that we grouped all annual grasses and forbs, and did not sample within the riparian zones of the park (those areas are sampled in the SODN Washes and Seeps/Springs/Tinajas protocols).

After comparing these results with our monitoring objectives, we conclude that the sampling design is appropriate, and will maintain the same approach for future monitoring. Monitoring will next occur in Gila Cliff Dwellings NM in 2014.

4.5 Are terrestrial vegetation and soils within the range of natural variability?

Within the context of the network's vital signs for species composition, community structure, and dynamic soil function, we conclude that terrestrial vegetation and soils at Gila Cliff Dwellings NM are well within the range of natural variability. Current park conditions contrast very favorably with those described in local and regional accounts (though we recognize the limitations of historical data).

Gila Cliff Dwellings NM is relatively free of anthropogenic stressors, as is reflected in the overall good condition of terrestrial vegetation and soils at the park. As a result, the park is an excellent reference site for evaluating other units with similar ecology and/or park settings, and for investigating the signal of potential climate change effects from the noise of other stressors.

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Appendix A. Supplemental Data

Tables begin on next page.

Table A1a. Within-plot cover values (%) for species measured in the "field" (<0.5 m stature) layer of the 400 stratum (4,500–6,000'), terrestrial vegetation and soils plots, Gila Cliff Dwellings NM, 2009.

	Individual plot measures					Across-plot measures					
Species	**V400_01**	**V400_02**	**V400_02TJ**	**V400_04**	**V400_05**	**AVG**	**SD**	**SE**	**Sdiff**	**MDC**	**n=**
Forbs/Herbs											
Artemisia carruthii	0.0%	0.0%	0.0%	2.10%	1.30%	0.70%	1.00%	0.40%	0.70%	5%	1
Artemisia dracunculus	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Artemisia ludoviciana	0.0%	0.0%	0.0%	0.0%	0.4%	0.1%	0.2%	0.1%	0.1%	5%	1
Bidens bigelovii	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.00%	0.00%	0.0%	5%	0
Commelina dianthifolia	0.0%	0.0%	1.3%	0.0%	0.0%	0.3%	0.6%	0.3%	0.4%	5%	1
Desmodium grahamii	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Echeandia flavescens	0.0%	0.4%	0.0%	0.0%	0.0%	0.1%	0.20%	0.10%	0.1%	5%	1
Erigeron flagellaris	0.0%	0.0%	0.4%	0.0%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
Hackelia floribunda	0.0%	0.0%	0.0%	0.4%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
Hedeoma nana	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.00%	0.00%	0.0%	5%	0
Lithospermum multiflorum	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Lotus wrightii	0.0%	0.0%	0.0%	0.0%	1.7%	0.3%	0.7%	0.3%	0.5%	5%	1
Psoralidium tenuiflorum	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.00%	0.00%	0.0%	5%	0
Thalictrum fendleri	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Tradescantia pinetorum	0.0%	0.4%	0.0%	0.0%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
Graminoids											
Aristida	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.00%	0.00%	0.0%	5%	0
Aristida purpurea	0.4%	0.0%	0.4%	0.0%	0.0%	0.2%	0.2%	0.1%	0.2%	5%	1
Aristida schiedeana	14.2%	0.0%	0.0%	0.0%	0.0%	2.8%	6.3%	2.8%	4.5%	6%	5
Aristida ternipes	0.0%	0.0%	0.0%	2.1%	0.0%	0.4%	0.90%	0.40%	0.7%	5%	1
Bouteloua curtipendula	0.0%	3.3%	3.8%	0.0%	0.8%	1.6%	1.8%	0.8%	1.3%	5%	1
Bouteloua gracilis	0.8%	6.7%	41.7%	35.4%	0.0%	16.9%	20.0%	9.0%	14.2%	19%	5
Bouteloua hirsuta	0.8%	0.0%	6.3%	0.0%	0.0%	1.4%	2.70%	1.20%	1.9%	5%	2
Carex geophila	0.8%	1.3%	0.0%	0.0%	0.4%	0.5%	0.5%	0.2%	0.4%	5%	1
Elymus elymoides	0.0%	0.0%	0.4%	0.4%	0.4%	0.3%	0.2%	0.1%	0.2%	5%	1
Lycurus setosus	10.0%	0.0%	0.0%	1.7%	0.0%	2.3%	4.30%	1.90%	3.1%	5%	4
Muhlenbergia pauciflora	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0

Table A1a. Within-plot cover values (%) for species measured in the "field" (<0.5 m stature) layer of the 400 stratum (4,500–6,000'), terrestrial vegetation and soils plots, Gila Cliff Dwellings NM, 2009, cont.

	Individual plot measures					Across-plot measures					
Species	**V400_01**	**V400_02**	**V400_02TJ**	**V400_04**	**V400_05**	**AVG**	**SD**	**SE**	**Sdiff**	**MDC**	**n=**
Graminoids, cont.											
Muhlenbergia polycaulis	28.3%	0.0%	0.0%	0.0%	5.8%	6.8%	12.3%	5.5%	8.7%	12%	5
Piptochaetium fimbriatum	0.0%	0.0%	2.5%	1.3%	0.0%	0.8%	1.10%	0.50%	0.8%	5%	1
Poa fendleriana	0.0%	1.7%	0.0%	0.0%	8.8%	2.1%	3.8%	1.7%	2.7%	5%	3
Sporobolus cryptandrus	0.0%	0.0%	0.0%	0.8%	1.3%	0.4%	0.6%	0.3%	0.4%	5%	1
Subshrubs											
Ageratina herbacea	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.00%	0.00%	0.0%	5%	0
Brickellia brachyphylla	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Brickellia floribunda	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Dalea candida	0.0%	0.0%	0.0%	0.0%	0.4%	0.1%	0.20%	0.10%	0.1%	5%	1
Geranium caespitosum	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Menodora scabra	0.0%	0.0%	1.3%	0.0%	0.0%	0.3%	0.6%	0.3%	0.4%	5%	1
Viguiera dentata	0.0%	0.0%	2.1%	0.0%	0.0%	0.4%	0.90%	0.40%	0.7%	5%	1
Shrubs											
Artemisia	0.0%	0.0%	0.0%	0.0%	0.8%	0.2%	0.4%	0.2%	0.3%	5%	1
Calliandra humilis	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Cercocarpus montanus	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.00%	0.00%	0.0%	5%	0
Garrya wrightii	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Succulents											
Opuntia phaeacantha	0.0%	0.0%	0.0%	1.3%	0.0%	0.3%	0.6%	0.3%	0.4%	5%	1
Yucca baccata	0.0%	0.0%	2.1%	0.8%	0.0%	0.6%	0.90%	0.40%	0.6%	5%	1
Trees											
Abies lasiocarpa	0.0%	0.0%	0.0%	0.0%	0.8%	0.2%	0.4%	0.2%	0.3%	5%	1
Juniperus deppeana	0.0%	1.3%	0.0%	0.8%	0.0%	0.4%	0.6%	0.3%	0.4%	5%	1
Juniperus monosperma	0.0%	3.3%	3.3%	1.3%	0.0%	1.6%	1.70%	0.80%	1.2%	5%	1
Juniperus osteosperma	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Pinus edulis	0.0%	2.1%	0.0%	0.4%	0.0%	0.5%	0.9%	0.4%	0.6%	5%	1
Pinus ponderosa	0.4%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1

Table A1a. Within-plot cover values (%) for species measured in the "field" (<0.5 m stature) layer of the 400 stratum (4,500–6,000'), terrestrial vegetation and soils plots, Gila Cliff Dwellings NM, 2009, cont.

	Individual plot measures					Across-plot measures					
Species	**V400_01**	**V400_02**	**V400_02TJ**	**V400_04**	**V400_05**	**AVG**	**SD**	**SE**	**Sdiff**	**MDC**	**n=**
Trees, cont.											
Quercus gambelii	0.0%	0.0%	0.0%	0.0%	4.6%	0.9%	2.00%	0.90%	1.4%	5%	1
Quercus grisea	1.7%	1.7%	0.0%	1.3%	3.8%	1.7%	1.4%	0.6%	1.0%	5%	1
Vine											
Phaseolus angustissimus	0.4%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
N/A											
Galium	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.00%	0.00%	0.0%	5%	0
Hedeoma	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Lesquerella	0.0%	0.0%	0.0%	0.4%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
Totals by lifeform											
Annual Forb	1.3%	0.8%	3.8%	0.8%	1.3%	1.6%	1.20%	0.50%	0.9%	5%	1
Annual Grass	0.0%	0.0%	0.4%	0.0%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
Perennial Forb	0.0%	0.8%	1.7%	2.5%	3.3%	1.7%	1.3%	0.6%	0.9%	5%	1
Perennial Grass	55.4%	12.9%	55.0%	41.7%	17.5%	36.5%	20.30%	9.10%	14.3%	19%	5
Subshrub	0.0%	0.0%	3.3%	0.0%	0.4%	0.8%	1.5%	0.7%	1.0%	5%	1
Shrub	0.0%	0.0%	0.0%	0.0%	0.8%	0.2%	0.4%	0.2%	0.3%	5%	1
Succulent	0.0%	0.0%	2.1%	2.1%	0.0%	0.8%	1.10%	0.50%	0.8%	5%	1
Tree	2.1%	8.3%	3.3%	3.8%	9.2%	5.3%	3.2%	1.4%	2.3%	5%	2
Snag	4.2%	2.9%	0.0%	0.4%	4.6%	2.4%	2.1%	0.9%	1.5%	5%	1
Vine	0.4%	0.0%	0.0%	0.0%	0.0%	0.1%	0.20%	0.10%	0.1%	5%	1
Total	63.3%	25.8%	69.6%	51.3%	37.1%	49.4%	18.1%	8.1%	12.8%	17%	5

MDC = minimum detectable change (% cover)
n = required number of plots for power criteria (see text).
Bolded species are new to park lists.
Highlighted species and lifeforms failed to meet our 10% change criteria.

Table A1b. Within-plot cover values (%) for species measured in the "field" (<0.5 m stature) layer of the 500 stratum (>6,000'), terrestrial vegetation and soils plots, Gila Cliff Dwellings NM, 2009.

	Individual plot measures					Across-plot measures					
Species	**V500_01**	**V500_02**	**V500_03**	**V500_04**	**V500_05**	**AVG**	**SD**	**SE**	**Sdiff**	**MDC**	**n=**
Forbs/Herbs											
Artemisia carruthii	3.30%	0.00%	1.30%	0.00%	2.10%	1.30%	1.40%	0.60%	1.00%	5%	1
Artemisia dracunculus	0.40%	0.00%	0.00%	0.00%	0.00%	0.10%	0.20%	0.10%	0.10%	5%	1
Artemisia ludoviciana	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5%	0
Bidens bigelovii	0.00%	0.00%	0.00%	0.40%	0.00%	0.10%	0.20%	0.10%	0.10%	5%	1
Commelina dianthifolia	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5%	0
Desmodium grahamii	0.00%	0.00%	0.00%	0.00%	0.40%	0.10%	0.20%	0.10%	0.10%	5%	1
Echeandia flavescens	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5%	0
Erigeron flagellaris	0.00%	0.00%	0.00%	1.70%	0.00%	0.30%	0.70%	0.30%	0.50%	5%	1
Hackelia floribunda	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5%	0
Hedeoma nana	0.00%	0.00%	0.00%	0.00%	0.40%	0.10%	0.20%	0.10%	0.10%	5%	1
Lithospermum multiflorum	0.00%	0.00%	0.40%	0.00%	0.00%	0.10%	0.20%	0.10%	0.10%	5%	1
Lotus wrightii	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5%	0
Psoralidium tenuiflorum	0.00%	0.00%	0.00%	0.00%	2.90%	0.60%	1.30%	0.60%	0.90%	5%	1
Thalictrum fendleri	0.00%	0.00%	0.40%	0.00%	0.00%	0.10%	0.20%	0.10%	0.10%	5%	1
Tradescantia pinetorum	0.00%	0.40%	0.00%	0.00%	0.00%	0.10%	0.20%	0.10%	0.10%	5%	1
Graminoids											
Aristida	0.00%	0.00%	0.00%	1.70%	0.00%	0.30%	0.70%	0.30%	0.50%	5%	1
Aristida purpurea	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5%	0
Aristida schiedeana	0.00%	0.00%	0.00%	0.40%	0.00%	0.10%	0.20%	0.10%	0.10%	5%	1
Aristida ternipes	0.00%	0.00%	0.00%	0.40%	0.00%	0.10%	0.20%	0.10%	0.10%	5%	1
Bouteloua curtipendula	0.00%	9.20%	0.00%	0.40%	2.90%	2.50%	3.90%	1.80%	2.80%	5%	3
Bouteloua gracilis	2.10%	1.70%	0.00%	56.30%	4.60%	12.90%	24.30%	10.90%	17.20%	23%	5
Bouteloua hirsuta	0.00%	0.00%	0.00%	2.90%	0.00%	0.60%	1.30%	0.60%	0.90%	5%	1
Carex geophila	0.00%	0.00%	0.40%	0.00%	0.00%	0.10%	0.20%	0.10%	0.10%	5%	1
Elymus elymoides	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5%	0
Lycurus setosus	0.00%	2.10%	0.00%	0.80%	0.80%	0.80%	0.90%	0.40%	0.60%	5%	1
Muhlenbergia pauciflora	0.40%	0.00%	0.00%	0.00%	0.00%	0.10%	0.20%	0.10%	0.10%	5%	1
Muhlenbergia polycaulis	1.70%	0.00%	0.00%	0.00%	0.00%	0.30%	0.70%	0.30%	0.50%	5%	1

Table A1b. Within-plot cover values (%) for species measured in the "field" (<0.5 m stature) layer of the 500 stratum (>6,000'), terrestrial vegetation and soils plots, Gila Cliff Dwellings NM, 2009, cont.

	Individual plot measures					Across-plot measures					
Species	**V500_01**	**V500_02**	**V500_03**	**V500_04**	**V500_05**	**AVG**	**SD**	**SE**	**Sdiff**	**MDC**	**n=**
Graminoids, cont.											
Piptochaetium fimbriatum	0.00%	0.00%	0.00%	0.40%	0.00%	0.10%	0.20%	0.10%	0.10%	5%	1
Poa fendleriana	16.30%	0.00%	9.60%	0.00%	0.00%	5.20%	7.50%	3.30%	5.30%	5%	10
Sporobolus cryptandrus	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5%	0
Subshrubs											
Ageratina herbacea	0.40%	0.00%	0.00%	0.00%	0.00%	0.10%	0.20%	0.10%	0.10%	5%	1
Brickellia brachyphylla	2.40%	0.40%	3.30%	0.00%	2.10%	1.60%	1.40%	0.60%	1.00%	5%	1
Brickellia floribunda	0.00%	0.00%	0.00%	0.80%	0.00%	0.20%	0.40%	0.20%	0.30%	5%	1
Dalea candida	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5%	0
Geranium caespitosum	0.00%	0.00%	0.40%	0.00%	0.00%	0.10%	0.20%	0.10%	0.10%	5%	1
Menodora scabra	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5%	0
Viguiera dentata	0.00%	0.00%	0.40%	0.00%	0.80%	0.30%	0.40%	0.20%	0.30%	5%	1
Shrubs											
Artemisia	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5%	0
Calliandra humilis	0.00%	0.00%	0.00%	0.40%	0.00%	0.10%	0.20%	0.10%	0.10%	5%	1
Cercocarpus montanus	1.70%	2.90%	0.00%	0.00%	0.80%	1.10%	1.20%	0.60%	0.90%	5%	1
Garrya wrightii	1.30%	2.50%	0.00%	0.00%	0.00%	0.80%	1.10%	0.50%	0.80%	5%	1
Succulents											
Opuntia phaeacantha	0.00%	0.40%	0.00%	0.00%	0.00%	0.10%	0.20%	0.10%	0.10%	5%	1
Yucca baccata	0.00%	0.80%	0.40%	0.00%	0.00%	0.30%	0.40%	0.20%	0.30%	5%	1
Trees											
Abies lasiocarpa	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5%	0
Juniperus deppeana	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5%	0
Juniperus monosperma	0.40%	0.40%	0.80%	0.40%	0.00%	0.40%	0.30%	0.10%	0.20%	5%	1
Juniperus osteosperma	1.30%	0.00%	0.40%	0.80%	2.50%	1.00%	1.00%	0.40%	0.70%	5%	1
Pinus edulis	4.20%	0.00%	0.00%	0.00%	1.30%	1.10%	1.80%	0.80%	1.30%	5%	1
Pinus ponderosa	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5%	0
Quercus gambelii	1.70%	0.00%	0.40%	0.00%	0.00%	0.40%	0.70%	0.30%	0.50%	5%	1
Quercus grisea	1.30%	0.00%	0.00%	0.00%	0.80%	0.40%	0.60%	0.30%	0.40%	5%	1

Table A1b. Within-plot cover values (%) for species measured in the "field" (<0.5 m stature) layer of the 500 stratum (>6,000'), terrestrial vegetation and soils plots, Gila Cliff Dwellings NM, 2009, cont.

	Individual plot measures					Across-plot measures					
Species	**V500_01**	**V500_02**	**V500_03**	**V500_04**	**V500_05**	**AVG**	**SD**	**SE**	**Sdiff**	**MDC**	**n=**
Vine											
Phaseolus angustissimus	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5%	0
N/A											
Galium	0.40%	0.00%	0.00%	0.00%	0.00%	0.10%	0.20%	0.10%	0.10%	5%	1
Hedeoma	0.80%	0.00%	0.00%	0.00%	0.00%	0.20%	0.40%	0.20%	0.30%	5%	1
Lesquerella	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5%	0
Totals by lifeform											
Annual Forb	2.50%	1.30%	0.80%	0.80%	1.30%	1.30%	0.70%	0.30%	0.50%	5%	1
Annual Grass	0.00%	0.00%	0.00%	0.00%	0.40%	0.10%	0.20%	0.10%	0.10%	5%	1
Perennial Forb	3.80%	0.40%	2.10%	2.10%	5.80%	2.80%	2.00%	0.90%	1.40%	5%	1
Perennial Grass	20.40%	12.90%	10.00%	63.30%	8.30%	23.00%	23.00%	10.30%	16.30%	22%	5
Subshrub	2.80%	0.40%	4.20%	0.80%	2.90%	2.20%	1.60%	0.70%	1.10%	5%	1
Shrub	2.90%	5.40%	0.00%	0.40%	0.80%	1.90%	2.30%	1.00%	1.60%	5%	1
Succulent	0.00%	1.30%	0.40%	0.00%	0.00%	0.30%	0.50%	0.20%	0.40%	5%	1
Tree	8.80%	0.40%	1.70%	1.30%	4.60%	3.30%	3.40%	1.50%	2.40%	5%	2
Snag	4.20%	1.70%	4.20%	0.40%	4.60%	3.00%	1.80%	0.80%	1.30%	5%	1
Vine	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5%	0
Total	45.30%	23.80%	23.30%	69.20%	28.80%	38.10%	19.50%	8.70%	13.80%	20%	5

MDC = minimum detectable change (% cover)
n = required number of plots for power criteria (see text).
Bolded species are new to park lists.
Highlighted species and lifeforms failed to meet our 10% change criteria.

Table A1c. Within-plot cover values (%) for species measured in the "field" (<0.5 m stature) layer of all strata (10 plots), terrestrial vegetation and soils plots, Gila Cliff Dwellings NM, 2009.

Species	AVG	SD	SE	Sdiff	MDC	n=
Forbs/Herbs						
Artemisia carruthii	1.00%	1.20%	0.38%	0.80%	5%	1
Artemisia dracunculus	0.00%	0.13%	0.04%	0.10%	5%	1
Artemisia ludoviciana	0.00%	0.13%	0.04%	0.10%	5%	1
Bidens bigelovii	0.00%	0.13%	0.04%	0.10%	5%	1
Commelina dianthifolia	0.10%	0.40%	0.13%	0.30%	5%	1
Desmodium grahamii	0.00%	0.13%	0.04%	0.10%	5%	1
Echeandia flavescens	0.00%	0.13%	0.04%	0.10%	5%	1
Erigeron flagellaris	0.20%	0.53%	0.17%	0.40%	5%	1
Hackelia floribunda	0.00%	0.13%	0.04%	0.10%	5%	1
Hedeoma nana	0.00%	0.13%	0.04%	0.10%	5%	1
Lithospermum multiflorum	0.00%	0.13%	0.04%	0.10%	5%	1
Lotus wrightii	0.20%	0.53%	0.17%	0.40%	5%	1
Psoralidium tenuiflorum	0.30%	0.92%	0.29%	0.70%	5%	1
Thalictrum fendleri	0.00%	0.13%	0.04%	0.10%	5%	1
Tradescantia pinetorum	0.10%	0.18%	0.06%	0.10%	5%	1
Graminoids						
Aristida	0.20%	0.53%	0.17%	0.40%	5%	1
Aristida purpurea	0.10%	0.18%	0.06%	0.10%	5%	1
Aristida schiedeana	1.50%	4.47%	1.41%	3.20%	5%	4
Aristida ternipes	0.30%	0.66%	0.21%	0.50%	5%	1
Bouteloua curtipendula	2.00%	2.92%	0.92%	2.10%	5%	2
Bouteloua gracilis	14.90%	21.09%	6.67%	14.90%	10%	19
Bouteloua hirsuta	1.00%	2.06%	0.65%	1.50%	5%	1
Carex geophila	0.30%	0.44%	0.14%	0.30%	5%	1
Elymus elymoides	0.10%	0.20%	0.06%	0.10%	5%	1
Lycurus setosus	1.50%	3.07%	0.97%	2.20%	5%	2
Muhlenbergia pauciflora	0.00%	0.13%	0.04%	0.10%	5%	1
Muhlenbergia polycaulis	3.60%	8.89%	2.81%	6.30%	5%	14
Piptochaetium fimbriatum	0.40%	0.83%	0.26%	0.60%	5%	1
Poa fendleriana	3.60%	5.81%	1.84%	4.10%	5%	6
Sporobolus cryptandrus	0.20%	0.45%	0.14%	0.30%	5%	1
Subshrubs						
Ageratina herbacea	0.00%	0.13%	0.04%	0.10%	5%	1
Brickellia brachyphylla	0.80%	1.27%	0.40%	0.90%	5%	1
Brickellia floribunda	0.10%	0.26%	0.08%	0.20%	5%	1
Dalea candida	0.00%	0.13%	0.04%	0.10%	5%	1
Geranium caespitosum	0.00%	0.13%	0.04%	0.10%	5%	1
Menodora scabra	0.10%	0.40%	0.13%	0.30%	5%	1
Viguiera dentata	0.30%	0.67%	0.21%	0.50%	5%	1

Table A1c. Within-plot cover values (%) for species measured in the "field" (<0.5 m stature) layer of all strata, terrestrial vegetation and soils plots, Gila Cliff Dwellings NM, 2009, cont.

Species	AVG	SD	SE	Sdiff	MDC	n=
Shrubs						
Artemisia	0.10%	0.26%	0.08%	0.20%	5%	1
Calliandra humilis	0.00%	0.13%	0.04%	0.10%	5%	1
Cercocarpus montanus	0.50%	1.00%	0.32%	0.70%	5%	1
Garrya wrightii	0.40%	0.84%	0.27%	0.60%	5%	1
Succulents						
Opuntia phaeacantha	0.20%	0.40%	0.13%	0.30%	5%	1
Yucca baccata	0.40%	0.68%	0.22%	0.50%	5%	1
Trees						
Abies lasiocarpa	0.10%	0.26%	0.08%	0.20%	5%	1
Juniperus deppeana	0.20%	0.45%	0.14%	0.30%	5%	1
Juniperus monosperma	1.00%	1.29%	0.41%	0.90%	5%	1
Juniperus osteosperma	0.50%	0.83%	0.26%	0.60%	5%	1
Pinus edulis	0.80%	1.38%	0.44%	1.00%	5%	1
Pinus ponderosa	0.00%	0.13%	0.04%	0.10%	5%	1
Quercus gambelii	0.70%	1.47%	0.47%	1.00%	5%	1
Quercus grisea	1.00%	1.18%	0.37%	0.80%	5%	1
Vine						
Phaseolus angustissimus	0.00%	0.13%	0.04%	0.10%	5%	1
N/A						
Galium	0.00%	0.13%	0.04%	0.10%	5%	1
Hedeoma	0.10%	0.26%	0.08%	0.20%	5%	1
Lesquerella	0.00%	0.13%	0.04%	0.10%	5%	1
Totals by lifeform						
Annual Forb	1.50%	0.95%	0.30%	0.70%	5%	1
Annual Grass	0.10%	0.18%	0.06%	0.10%	5%	1
Perennial Forb	2.30%	1.74%	0.55%	1.20%	5%	1
Perennial Grass	29.80%	21.65%	6.85%	15.30%	15%	9
Subshrub	1.50%	1.62%	0.51%	1.10%	5%	1
Shrub	1.00%	1.78%	0.56%	1.30%	5%	1
Succulent	0.60%	0.88%	0.28%	0.60%	5%	1
Tree	4.30%	3.29%	1.04%	2.30%	5%	2
Snag	2.70%	1.90%	0.60%	1.30%	5%	1
Vine	0.00%	0.13%	0.04%	0.10%	5%	1
Total	43.70%	18.75%	5.93%	13.30%	13%	9

MDC = minimum detectable change (% cover)
n = required number of plots for power criteria (see text).
Bolded species are new to park lists.
Highlighted species and lifeforms failed to meet our 10% change criteria.

Table A2a. Within-plot cover values (%) for species measured in the subcanopy (0.5–2.0 m stature) layer of the 400 stratum (4,500–6,000'), terrestrial vegetation and soils plots, Gila Cliff Dwellings NM, 2009.

	Individual plot measures					Across-plot measures					
Species	**V400_01**	**V400_02**	**V400_02TJ**	**V400_04**	**V400_05**	**AVG**	**SD**	**SE**	**Sdiff**	**MDC**	**n=**
Forbs/Herbs											
Hackelia floribunda	0.0%	0.0%	0.0%	0.4%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
Packera neomexicana	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Graminoids											
Aristida schiedeana	4.2%	0.0%	0.0%	0.0%	0.0%	0.8%	1.9%	0.8%	1.3%	5%	1
Bouteloua curtipendula	0.0%	0.0%	5.4%	0.0%	0.0%	1.1%	2.4%	1.1%	1.7%	5%	2
Bouteloua gracilis	0.0%	0.0%	11.7%	0.0%	0.0%	2.3%	5.2%	2.3%	3.7%	5%	5
Bouteloua hirsuta	0.0%	0.0%	2.5%	0.0%	0.0%	0.5%	1.1%	0.5%	0.8%	5%	1
Muhlenbergia polycaulis	3.3%	0.0%	0.0%	0.0%	0.0%	0.7%	1.5%	0.7%	1.1%	5%	1
Sporobolus cryptandrus	0.4%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
Subshrub											
Viguiera dentata	0.0%	0.0%	0.4%	0.0%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
Shrubs											
Cercocarpus montanus	0.0%	0.0%	0.0%	0.0%	1.3%	0.3%	0.6%	0.3%	0.4%	5%	1
Fendlera wrightii	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Garrya wrightii	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Rhus trilobata	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Succulent											
Yucca baccata	0.0%	0.0%	0.4%	0.0%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
Trees											
Abies lasiocarpa	0.0%	0.0%	0.0%	0.0%	1.3%	0.3%	0.6%	0.3%	0.4%	5%	1
Fraxinus velutina	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Juniperus deppeana	0.0%	0.8%	0.0%	1.3%	0.0%	0.4%	0.6%	0.3%	0.4%	5%	1
Juniperus monosperma	0.0%	8.8%	22.5%	6.7%	0.0%	7.6%	9.2%	4.1%	6.5%	9%	5
Juniperus osteosperma	0.0%	0.0%	0.0%	3.3%	0.0%	0.7%	1.5%	0.7%	1.1%	5%	1
Juniperus scopulorum	0.0%	3.3%	0.0%	0.0%	0.0%	0.7%	1.5%	0.7%	1.1%	5%	1
Pinus discolor	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Pinus edulis	0.0%	9.6%	0.0%	0.8%	0.0%	2.1%	4.2%	1.9%	3.0%	5%	4

Table A2a. Within-plot cover values (%) for species measured in the subcanopy (0.5–2.0 m stature) layer of the 400 stratum (4,500–6,000'), terrestrial vegetation and soils plots, Gila Cliff Dwellings NM, 2009, cont.

	Individual plot measures					Across-plot measures					
Species	**V400_01**	**V400_02**	**V400_02TJ**	**V400_04**	**V400_05**	**AVG**	**SD**	**SE**	**Sdiff**	**MDC**	**n=**
Trees, cont.											
Pinus ponderosa	2.1%	0.0%	0.0%	0.0%	0.0%	0.4%	0.9%	0.4%	0.7%	5%	1
Ptelea trifoliata	0.0%	0.4%	0.0%	0.0%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
Quercus gambelii	0.0%	0.0%	0.0%	0.0%	7.1%	1.4%	3.2%	1.4%	2.2%	5%	2
Quercus grisea	3.3%	7.5%	0.0%	2.9%	9.6%	4.7%	3.8%	1.7%	2.7%	5%	3
Vine											
Lonicera albiflora	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Totals by lifeform											
Perennial Forb	0.0%	0.0%	0.0%	0.4%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
Perennial Grass	7.9%	0.0%	19.6%	0.0%	0.0%	5.5%	8.6%	3.8%	6.1%	8%	5
Subshrub	0.0%	0.0%	0.4%	0.0%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
Shrub	0.0%	0.0%	0.0%	0.0%	1.3%	0.3%	0.6%	0.3%	0.4%	5%	1
Succulent	0.0%	0.0%	0.4%	0.0%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
Tree	5.4%	30.4%	22.5%	15.0%	17.9%	18.3%	9.2%	4.1%	6.5%	9%	5
Snag	0.0%	3.8%	0.0%	0.4%	0.8%	1.0%	1.6%	0.7%	1.1%	5%	1
Total	13.3%	34.2%	42.9%	15.8%	20.0%	25.3%	12.7%	5.7%	9.0%	12%	5

MDC = minimum detectable change (% cover)
n = required number of plots for power criteria (see text).
Bolded species are new to park lists.

Table A2b. Within-plot cover values (%) for species measured in the subcanopy (0.5–2.0 m stature) layer, 500 stratum (>6,000'), terrestrial vegetation and soils plots, Gila Cliff Dwellings NM, 2009.

	Individual plot measures					Across-plot measures					
Species	**V500_01**	**V500_02**	**V500_03**	**V500_04**	**V500_05**	**AVG**	**SD**	**SE**	**Sdiff**	**MDC**	**n=**
Forbs/Herbs											
Hackelia floribunda	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Packera neomexicana	0.0%	0.0%	0.0%	0.0%	0.4%	0.1%	0.2%	0.1%	0.1%	5%	1
Graminoids											
Aristida schiedeana	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Bouteloua curtipendula	0.0%	0.4%	0.0%	0.0%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
Bouteloua gracilis	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Bouteloua hirsuta	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Muhlenbergia polycaulis	0.4%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
Sporobolus cryptandrus	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Subshrub											
Viguiera dentata	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Shrubs											
Cercocarpus montanus	2.9%	8.3%	0.4%	0.0%	2.5%	2.8%	3.3%	1.5%	2.4%	5%	2
Fendlera wrightii	0.0%	0.0%	0.0%	0.4%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
Garrya wrightii	2.5%	6.3%	0.0%	0.0%	0.0%	1.8%	2.7%	1.2%	1.9%	5%	2
Rhus trilobata	0.0%	0.0%	0.0%	0.8%	0.4%	0.3%	0.4%	0.2%	0.3%	5%	1
Succulent											
Yucca baccata	0.0%	0.0%	0.4%	0.0%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
Trees											
Abies lasiocarpa	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Fraxinus velutina	0.0%	0.0%	0.4%	0.0%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
Juniperus deppeana	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Juniperus monosperma	0.8%	3.8%	5.0%	3.3%	0.0%	2.6%	2.1%	0.9%	1.5%	5%	1
Juniperus osteosperma	1.7%	3.3%	4.2%	5.0%	13.3%	5.5%	4.5%	2.0%	3.2%	5%	4
Juniperus scopulorum	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Pinus discolor	0.0%	0.0%	0.0%	0.0%	0.4%	0.1%	0.2%	0.1%	0.1%	5%	1
Pinus edulis	11.7%	6.3%	2.1%	0.0%	14.2%	6.8%	6.1%	2.7%	4.3%	6%	5
Pinus ponderosa	0.0%	0.0%	0.4%	0.0%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1

Table A2b. Within-plot cover values (%) for species measured in the subcanopy (0.5–2.0 m stature) layer, 500 stratum (>6,000'), terrestrial vegetation and soils plots, Gila Cliff Dwellings NM, 2009, cont.

	Individual plot measures					Across-plot measures					
Species	**V500_01**	**V500_02**	**V500_03**	**V500_04**	**V500_05**	**AVG**	**SD**	**SE**	**Sdiff**	**MDC**	**n=**
Trees, cont.											
Ptelea trifoliata	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Quercus gambelii	3.3%	0.0%	0.4%	0.0%	0.0%	0.8%	1.5%	0.7%	1.0%	5%	1
Quercus grisea	1.3%	0.0%	0.0%	0.0%	2.9%	0.8%	1.3%	0.6%	0.9%	5%	1
Vine											
Lonicera albiflora	0.4%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
Totals by lifeform											
Perennial Forb	0.0%	0.0%	0.0%	0.0%	0.4%	0.1%	0.2%	0.1%	0.1%	5%	1
Perennial Grass	0.4%	0.4%	0.0%	0.0%	0.0%	0.2%	0.2%	0.1%	0.2%	5%	1
Subshrub	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Shrub	5.4%	14.6%	0.4%	1.3%	2.9%	4.9%	5.7%	2.6%	4.1%	6%	4
Succulent	0.0%	0.0%	0.4%	0.0%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
Tree	18.8%	13.3%	12.5%	8.3%	30.8%	16.8%	8.7%	3.9%	6.2%	9%	4
Snag	2.9%	0.0%	2.5%	0.0%	0.8%	1.3%	1.4%	0.6%	1.0%	5%	1
Total	27.5%	28.3%	15.8%	9.6%	35.0%	23.3%	10.3%	4.6%	7.3%	10%	5

MDC = minimum detectable change (% cover)
n = required number of plots for power criteria (see text).
Bolded species are new to park lists.

Table A2c. Within-plot cover values (%) for species measured in the subcanopy (0.5–2.0 m stature) layer, all strata (10 plots), terrestrial vegetation and soils plots, Gila Cliff Dwellings NM, 2009.

Species	AVG	SD	SE	Sdiff	MDC	n=
Forbs/Herbs						
Hackelia floribunda	0.0%	0.1%	0.1%	0.1%	5%	1
Packera neomexicana	0.0%	0.1%	0.1%	0.1%	5%	1
Graminoids						
Aristida schiedeana	0.4%	1.3%	0.6%	0.9%	5%	1
Bouteloua curtipendula	0.6%	1.7%	0.8%	1.2%	5%	1
Bouteloua gracilis	1.2%	3.7%	1.6%	2.6%	5%	3
Bouteloua hirsuta	0.3%	0.8%	0.4%	0.6%	5%	1
Muhlenbergia polycaulis	0.4%	1.0%	0.5%	0.7%	5%	1
Sporobolus cryptandrus	0.0%	0.1%	0.1%	0.1%	5%	1
Subshrub						
Viguiera dentata	0.0%	0.1%	0.1%	0.1%	5%	1
Shrubs						
Cercocarpus montanus	1.5%	2.6%	1.2%	1.9%	5%	2
Fendlera wrightii	0.0%	0.1%	0.1%	0.1%	5%	1
Garrya wrightii	0.9%	2.0%	0.9%	1.4%	5%	1
Rhus trilobata	0.1%	0.3%	0.1%	0.2%	5%	1
Succulent						
Yucca baccata	0.1%	0.2%	0.1%	0.1%	5%	1
Trees						
Abies lasiocarpa	0.1%	0.4%	0.2%	0.3%	5%	1
Fraxinus velutina	0.0%	0.1%	0.1%	0.1%	5%	1
Juniperus deppeana	0.2%	0.5%	0.2%	0.3%	5%	1
Juniperus monosperma	5.1%	6.8%	3.1%	4.8%	5%	8
Juniperus osteosperma	3.1%	4.1%	1.8%	2.9%	5%	3
Juniperus scopulorum	0.3%	1.1%	0.5%	0.7%	5%	1
Pinus discolor	0.0%	0.1%	0.1%	0.1%	5%	1
Pinus edulis	4.5%	5.5%	2.5%	3.9%	5%	6
Pinus ponderosa	0.3%	0.7%	0.3%	0.5%	5%	1
Ptelea trifoliata	0.0%	0.1%	0.1%	0.1%	5%	1
Quercus gambelii	1.1%	2.4%	1.1%	1.7%	5%	1
Quercus grisea	2.8%	3.4%	1.5%	2.4%	5%	2
Vine						
Lonicera albiflora	0.0%	0.1%	0.1%	0.1%	5%	1
Totals by lifeform						
Perennial Forb	0.1%	0.2%	0.1%	0.1%	5%	1
Perennial Grass	2.8%	6.4%	2.9%	4.5%	5%	7
Subshrub	0.0%	0.1%	0.1%	0.1%	5%	1
Shrub	2.6%	4.6%	2.0%	3.2%	5%	4
Succulent	0.1%	0.2%	0.1%	0.1%	5%	1
Tree	17.5%	8.5%	3.8%	6.0%	6%	9
Snag	1.1%	1.4%	0.6%	1.0%	5%	1
Total	24.3%	11.0%	4.9%	7.8%	8%	9

MDC = minimum detectable change (% cover). n = required number of plots for power criteria (see text). Bolded species are new to park lists.

Table A3a. Within-plot cover values (%) for species measured in the canopy (>2.0 m stature) layer, 400 stratum (4,500–6,000'), terrestrial vegetation and soils plots, Gila Cliff Dwellings NM, 2009.

	Individual plot measures					Across-plot measures					
Species	**V400_01**	**V400_02**	**V400_02TJ**	**V400_04**	**V400_05**	**AVG**	**SD**	**SE**	**Sdiff**	**MDC**	**n=**
Forbs/Herbs											
Hackelia floribunda	0.0%	0.0%	0.0%	0.4%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
Shrubs											
Cercocarpus montanus	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Garrya wrightii	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Trees											
Fraxinus velutina	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Juniperus deppeana	0.0%	4.2%	0.0%	7.9%	0.0%	2.4%	3.6%	1.6%	2.5%	5%	3
Juniperus monosperma	0.0%	7.1%	25.8%	5.4%	0.0%	7.7%	10.6%	4.8%	7.5%	10%	5
Juniperus osteosperma	0.0%	0.0%	0.0%	4.2%	0.0%	0.8%	1.9%	0.8%	1.3%	5%	1
Pinus discolor	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Pinus edulis	0.0%	17.1%	0.4%	12.5%	0.0%	6.0%	8.2%	3.7%	5.8%	8%	5
Pinus ponderosa	11.3%	15.8%	0.0%	0.0%	12.5%	7.9%	7.4%	3.3%	5.2%	7%	5
Pseudotsuga menziesii	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Quercus gambelii	0.0%	0.0%	0.0%	0.0%	0.8%	0.2%	0.4%	0.2%	0.3%	5%	1
Quercus grisea	0.4%	7.1%	0.0%	1.7%	0.8%	2.0%	2.9%	1.3%	2.1%	5%	2
Vines											
Lonicera albiflora	0.0%	0.4%	0.0%	0.0%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
Totals by lifeform											
Forb/Herb	0.0%	0.0%	0.0%	0.4%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
Shrub	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Tree	11.7%	51.3%	26.3%	31.7%	14.2%	27.0%	15.9%	7.1%	11.2%	15%	5
Snag	0.0%	3.8%	0.0%	0.0%	0.0%	0.8%	1.7%	0.8%	1.2%	5%	1
Vine	0.0%	0.4%	0.0%	0.0%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
Total	11.7%	55.4%	26.3%	32.1%	14.2%	27.9%	17.5%	7.8%	12.4%	17%	5

MDC = minimum detectable change (% cover)
n = required number of plots for power criteria (see text).
Bolded species are new to park lists.
Highlighted lifeforms failed to meet our 10% change criteria.

Table A3b. Within-plot cover values (%) for species measured in the canopy (>2.0 m stature) layer, 500 stratum (>6,000'), terrestrial vegetation and soils plots, Gila Cliff Dwellings NM, 2009.

	Individual plot measures					Across-plot measures					
Species	**V500_01**	**V500_02**	**V500_03**	**V500_04**	**V500_05**	**AVG**	**SD**	**SE**	**Sdiff**	**MDC**	**n=**
Forbs/Herbs											
Hackelia floribunda	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Shrubs											
Cercocarpus montanus	0.8%	5.4%	0.8%	0.0%	0.0%	1.4%	2.3%	1.0%	1.6%	5%	1
Garrya wrightii	0.4%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
Trees											
Fraxinus velutina	0.0%	0.0%	1.3%	0.0%	0.0%	0.3%	0.6%	0.3%	0.4%	5%	1
Juniperus deppeana	0.4%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.1%	0.1%	5%	1
Juniperus monosperma	4.2%	4.2%	5.4%	2.5%	0.0%	3.3%	2.1%	0.9%	1.5%	5%	1
Juniperus osteosperma	7.1%	6.3%	2.5%	6.3%	15.4%	7.5%	4.8%	2.1%	3.4%	5%	4
Pinus discolor	0.0%	0.0%	0.0%	0.0%	0.4%	0.1%	0.2%	0.1%	0.1%	5%	1
Pinus edulis	25.0%	12.5%	15.0%	1.7%	18.8%	14.6%	8.6%	3.9%	6.1%	8%	5
Pinus ponderosa	2.9%	0.0%	17.1%	0.0%	0.0%	4.0%	7.4%	3.3%	5.2%	7%	5
Pseudotsuga menziesii	0.0%	0.0%	5.4%	0.0%	0.0%	1.1%	2.4%	1.1%	1.7%	5%	2
Quercus gambelii	0.8%	0.0%	0.0%	0.0%	0.0%	0.2%	0.4%	0.2%	0.3%	5%	1
Quercus grisea	2.5%	0.0%	0.0%	0.0%	2.1%	0.9%	1.3%	0.6%	0.9%	5%	1
Vines											
Lonicera albiflora	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Totals by lifeform											
Forb/Herb	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Shrub	1.3%	5.4%	0.8%	0.0%	0.0%	1.5%	2.3%	1.0%	1.6%	5%	1
Tree	42.9%	22.9%	46.7%	10.4%	36.7%	31.9%	15.0%	6.7%	10.6%	14%	5
Snag	0.8%	0.8%	0.0%	0.0%	0.0%	0.3%	0.5%	0.2%	0.3%	5%	1
Vine	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5%	0
Total	45.0%	29.2%	47.5%	10.4%	36.7%	33.8%	14.9%	6.7%	10.5%	14%	5

MDC = minimum detectable change (% cover)
n = required number of plots for power criteria (see text).
Bolded species are new to park lists.
Highlighted lifeforms failed to meet our 10% change criteria.

Table A3c. Within-plot cover values (%) for species measured in the canopy (>2.0 m stature) layer, all strata (10 plots), terrestrial vegetation and soils plots, Gila Cliff Dwellings NM, 2009.

Species	AVG	SD	SE	Sdiff	MDC	n=
Forbs/Herbs						
Hackelia floribunda	0.00%	0.10%	0.00%	0.10%	5%	1
Shrubs						
Cercocarpus montanus	0.70%	1.70%	0.50%	1.20%	5%	1
Garrya wrightii	0.00%	0.10%	0.00%	0.10%	5%	1
Trees						
Fraxinus velutina	0.10%	0.40%	0.10%	0.30%	5%	1
Juniperus deppeana	1.30%	2.70%	0.80%	1.90%	5%	2
Juniperus monosperma	5.50%	7.60%	2.40%	5.40%	5%	10
Juniperus osteosperma	4.20%	4.90%	1.50%	3.50%	5%	5
Pinus discolor	0.00%	0.10%	0.00%	0.10%	5%	1
Pinus edulis	10.30%	9.10%	2.90%	6.50%	6%	10
Pinus ponderosa	6.00%	7.30%	2.30%	5.20%	5%	10
Pseudotsuga menziesii	0.50%	1.70%	0.50%	1.20%	5%	1
Quercus gambelii	0.20%	0.40%	0.10%	0.20%	5%	1
Quercus grisea	1.50%	2.20%	0.70%	1.50%	5%	1
Vines						
Lonicera albiflora	0.00%	0.10%	0.00%	0.10%	5%	1
Totals by lifeform						
Forb/Herb	0.00%	0.10%	0.00%	0.10%	5%	1
Shrub	0.80%	1.70%	0.50%	1.20%	5%	1
Tree	29.50%	14.80%	4.70%	10.50%	10%	10
Snag	0.50%	1.20%	0.40%	0.80%	5%	1
Vine	0.00%	0.10%	0.00%	0.10%	5%	1
Total	30.80%	15.60%	4.90%	11.10%	11%	9

MDC = minimum detectable change (% cover)
n = required number of plots for power criteria (see text).
Bolded species are new to park lists.
Highlighted lifeforms failed to meet our 10% change criteria.

Table A4a. Within-plot and landscape frequency (%) for all plots and species sampled on monitoring plots in the 400 stratum (4,500–6,000'), Gila Cliff Dwellings NM, 2009.

		Within-plot frequency (0–5)					Within-plot frequency (%)		
Species	Nativity	V400_01	V400_02	V400_02TJ	V400_04	V400_05	Mean	SE	Landscape frequency
Forbs/Herbs									
Achillea millefolium	Native	0	0	0	0	2	8%	8.0%	1 (20%)
Antennaria parvifolia	Native	0	0	0	0	1	4%	4.0%	1 (20%)
Artemisia carruthii	Native	4	0	0	5	1	40%	21.0%	3 (60%)
Artemisia dracunculus	Native	0	2	0	0	1	12%	8.0%	2 (40%)
Artemisia ludoviciana	Native	1	1	1	0	3	24%	9.8%	4 (80%)
Asclepias tuberosa	Native	1	0	0	0	1	8%	4.9%	2 (40%)
Astragalus	N/A	0	0	0	1	0	4%	4.0%	1 (20%)
Bidens bigelovii	Native	0	0	0	0	0	0%	0.0%	--
Boerhavia purpurascens	Native	0	0	0	0	0	0%	0.0%	--
Chamaesyce	N/A	0	0	2	0	0	8%	8.0%	1 (20%)
Commelina dianthifolia	Native	0	1	4	0	0	20%	15.5%	2 (40%)
Cryptantha	N/A	0	0	0	0	0	0%	0.0%	--
Dalea	N/A	3	0	0	0	0	12%	12.0%	1 (20%)
Desmodium	N/A	3	0	0	0	0	12%	12.0%	1 (20%)
Desmodium grahamii	Native	0	0	0	0	0	0%	0.0%	--
Dryopteris filix-mas	Native	0	1	0	0	0	4%	4.0%	1 (20%)
Echeandia flavescens	Native	0	2	0	0	1	12%	8.0%	2 (40%)
Erigeron divergens	Native	0	0	0	0	0	0%	0.0%	--
Erigeron flagellaris	Native	0	2	2	3	0	28%	12.0%	3 (60%)
Erigeron oreophilus	Native	0	0	0	0	0	0%	0.0%	--
Glandularia bipinnatifida	Native	0	0	0	0	0	0%	0.0%	--
Hackelia floribunda	Native	0	0	0	1	0	4%	4.0%	1 (20%)
Hedeoma nana	Native	0	0	0	0	0	0%	0.0%	--
Houstonia wrightii	Native	0	1	0	0	0	4%	4.0%	1 (20%)
Ipomoea	N/A	0	0	0	0	1	4%	4.0%	1 (20%)
Linanthus nuttallii	Native	0	0	0	0	1	4%	4.0%	1 (20%)
Lithospermum multiflorum	Native	0	2	0	0	1	12%	8.0%	2 (40%)
Lotus wrightii	Native	3	0	0	0	4	28%	17.4%	2 (40%)
Lupinus hillii	Native	0	0	0	0	4	16%	16.0%	1 (20%)
Machaeranthera bigelovii	Native	0	0	0	1	0	4%	4.0%	1 (20%)
Oenothera caespitosa	Native	0	0	0	0	3	12%	12.0%	1 (20%)
Packera neomexicana	Native	0	0	0	0	0	0%	0.0%	--
Polygonum argyrocoleon	Non-Native	0	0	0	0	0	0%	0.0%	--
Pseudocymopterus montanus	Native	0	0	0	0	0	0%	0.0%	--
Pseudognaphalium canescens	Native	0	0	0	0	0	0%	0.0%	--
Psoralidium tenuiflorum	Native	0	0	0	0	0	0%	0.0%	--
Solidago wrightii	Native	0	0	0	0	1	4%	4.0%	1 (20%)
Thalictrum fendleri	Native	0	0	0	0	0	0%	0.0%	--

Table A4a. Within-plot and landscape frequency (%) for all plots and species sampled on monitoring plots in the 400 stratum (4,500–6,000'), Gila Cliff Dwellings NM, 2009, cont.

Species	Nativity	Within-plot frequency (0–5)					Within-plot frequency (%)		Landscape frequency
		V400_01	V400_02	V400_02TJ	V400_04	V400_05	Mean	SE	
Forbs/Herbs, cont.									
Tradescantia pinetorum	Native	0	1	0	2	0	12%	8.0%	2 (40%)
Tragia ramosa	Native	0	0	0	0	0	0%	0.0%	--
Verbascum thapsus	Non-Native	2	4	0	0	3	36%	16.0%	3 (60%)
Veronica peregrina	Native	0	0	0	0	1	4%	4.0%	1 (20%)
Graminoids									
Aristida purpurea	Native	2	1	2	0	0	20%	8.9%	3 (60%)
Aristida schiedeana	Native	5	0	0	1	0	24%	19.4%	2 (40%)
Aristida ternipes	Native	0	0	0	3	0	12%	12.0%	1 (20%)
Bouteloua curtipendula	Native	0	5	4	1	2	48%	18.5%	4 (80%)
Bouteloua gracilis	Native	3	4	5	5	3	80%	8.9%	5 (100%)
Bouteloua hirsuta	Native	3	0	4	1	0	32%	16.2%	3 (60%)
Bromus	N/A	0	0	0	1	0	4%	4.0%	1 (20%)
Carex geophila	Native	3	4	0	0	2	36%	16.0%	3 (60%)
Elymus elymoides	Native	2	0	2	2	1	28%	8.0%	4 (80%)
Koeleria macrantha	Native	0	0	0	0	1	4%	4.0%	1 (20%)
Lycurus setosus	Native	5	0	0	4	0	36%	22.3%	2 (40%)
Muhlenbergia pauciflora	Native	0	0	0	0	0	0%	0.0%	--
Muhlenbergia polycaulis	Native	5	0	0	0	4	36%	22.3%	2 (40%)
Piptochaetium fimbriatum	Native	0	0	3	2	0	20%	12.6%	2 (40%)
Poa fendleriana	Native	0	5	0	1	5	44%	23.2%	3 (60%)
Schizachyrium cirratum	Native	0	1	0	0	1	8%	4.9%	2 (40%)
Sporobolus cryptandrus	Native	3	0	0	1	2	24%	11.7%	3 (60%)
Shrubs									
Artemisia	N/A	0	0	0	0	1	4%	4.0%	1 (20%)
Baccharis pteronioides	Native	0	0	0	0	0	0%	0.0%	--
Calliandra humilis	Native	4	0	1	4	4	52%	17.4%	4 (80%)
Cercocarpus montanus	Native	0	1	0	4	2	28%	15.0%	3 (60%)
Ericameria nauseosa	Native	1	0	0	0	0	4%	4.0%	1 (20%)
Fendlera wrightii	Native	0	0	0	0	0	0%	0.0%	--
Garrya wrightii	Native	0	0	0	0	0	0%	0.0%	--
Rhus aromatica	Native	0	0	0	0	1	4%	4.0%	1 (20%)
Rhus trilobata	Native	0	0	0	0	1	4%	4.0%	1 (20%)
Robinia neomexicana	Native	3	0	0	0	0	12%	12.0%	1 (20%)
Subshrubs									
Ageratina herbacea	Native	0	0	0	0	0	0%	0.0%	--
Brickellia brachyphylla	Native	0	4	0	1	0	20%	15.5%	2 (40%)
Brickellia californica	Native	0	1	0	0	0	4%	4.0%	1 (20%)
Brickellia floribunda	Native	0	0	0	0	0	0%	0.0%	--

Table A4a. Within-plot and landscape frequency (%) for all plots and species sampled on monitoring plots in the 400 stratum (4,500–6,000'), Gila Cliff Dwellings NM, 2009, cont.

Species	Nativity	Within-plot frequency (0–5)					Within-plot frequency (%)		Landscape frequency
		V400_01	V400_02	V400_02TJ	V400_04	V400_05	Mean	SE	
Subshrubs, cont.									
Brickellia rusbyi	Native	1	0	0	0	0	4%	4.0%	1 (20%)
Chaetopappa ericoides	Native	0	0	0	0	0	0%	0.0%	--
Dalea albiflora	Native	0	3	0	0	0	12%	12.0%	1 (20%)
Dalea candida	Native	0	0	0	0	1	4%	4.0%	1 (20%)
Desmodium grahamii	Native	0	0	0	0	0	0%	0.0%	--
Eriogonum alatum	Native	0	1	0	0	2	12%	8.0%	2 (40%)
Eriogonum jamesii	Native	0	0	0	0	0	0%	0.0%	--
Geranium caespitosum	Native	0	0	0	0	0	0%	0.0%	--
Gutierrezia microcephala	Native	0	2	0	0	0	8%	8.0%	1 (20%)
Gutierrezia sarothrae	Native	0	0	0	0	0	0%	0.0%	--
Krascheninnikovia lanata	Native	0	0	0	0	0	0%	0.0%	--
Menodora scabra	Native	0	0	5	0	0	20%	20.0%	1 (20%)
Phoradendron juniperinum	Native	0	0	0	0	0	0%	0.0%	--
Polygala obscura	Native	0	0	0	0	0	0%	0.0%	--
Solanum elaeagnifolium	Native	0	0	1	0	0	4%	4.0%	1 (20%)
Sphaeralcea fendleri	Native	2	0	1	3	2	32%	10.2%	4 (80%)
Toxicodendron pubescens	Native	0	0	0	0	0	0%	0.0%	--
Viguiera dentata	Native	0	0	3	0	0	12%	12.0%	1 (20%)
Succulents									
Echinocereus coccineus	Native	0	0	0	0	0	0%	0.0%	--
Echinocereus fendleri	Native	0	0	0	2	0	8%	8.0%	1 (20%)
Echinocereus triglochidiatus	Native	0	2	0	0	0	8%	8.0%	1 (20%)
Escobaria vivipara	Native	0	0	0	1	0	4%	4.0%	1 (20%)
Opuntia phaeacantha	Native	3	4	5	5	0	68%	18.5%	4 (80%)
Opuntia spinosior	Native	0	0	0	1	0	4%	4.0%	1 (20%)
Yucca baccata	Native	0	0	4	1	1	24%	14.7%	3 (60%)
Trees									
Abies lasiocarpa	Native	0	0	0	0	2	8%	8.0%	1 (20%)
Fraxinus velutina	Native	0	0	0	0	0	0%	0.0%	--
Juniperus deppeana	Native	0	3	0	1	0	16%	11.7%	2 (40%)
Juniperus monosperma	Native	1	4	5	4	3	68%	13.6%	5 (100%)
Juniperus osteosperma	Native	0	0	0	1	0	4%	4.0%	1 (20%)
Juniperus scopulorum	Native	0	1	0	0	0	4%	4.0%	1 (20%)
Pinus discolor	Native	0	0	0	0	0	0%	0.0%	--
Pinus edulis	Native	0	5	4	4	0	52%	21.5%	3 (60%)
Pinus ponderosa	Native	5	4	0	0	5	56%	23.2%	3 (60%)
Pseudotsuga menziesii	Native	0	0	0	0	0	0%	0.0%	--
Ptelea trifoliata	Native	0	1	0	0	0	4%	4.0%	1 (20%)

Table A4a. Within-plot and landscape frequency (%) for all plots and species sampled on monitoring plots in the 400 stratum (4,500–6,000'), Gila Cliff Dwellings NM, 2009, cont.

Species	Nativity	Within-plot frequency (0–5)					Within-plot frequency (%)		Landscape frequency
		V400_01	V400_02	V400_02TJ	V400_04	V400_05	Mean	SE	
Trees, cont.									
Quercus gambelii	Native	1	2	0	3	5	44%	17.2%	4 (80%)
Quercus grisea	Native	5	5	0	5	5	80%	20.0%	4 (80%)
Vines									
Lonicera albiflora	Native	0	0	0	0	0	0%	0.0%	--
Phaseolus	Native	0	0	0	0	3	12%	12.0%	1 (20%)
Phaseolus angustissimus	Native	5	0	0	0	0	20%	20.0%	1 (20%)
Rhynchosia senna	Native	0	0	0	0	0	0%	0.0%	--
Vitis arizonica	Native	0	0	0	0	1	4%	4.0%	1 (20%)

Bolded species are new to park lists.

Table A4b. Within-plot and landscape frequency (%) for all plots and species sampled on monitoring plots in the 500 stratum (>6,000'), Gila Cliff Dwellings NM, 2009.

		Within-plot frequency (0–5)					Within-plot frequency (%)		
Species	Nativity	V500_01	V500_02	V500_03	V500_04	V500_05	Mean	SE	Landscape frequency
Forbs/Herbs									
Achillea millefolium	Native	2	0	4	0	0	24%	16.0%	2 (40%)
Antennaria parvifolia	Native	0	0	0	0	0	0%	0.0%	--
Artemisia carruthii	Native	3	1	3	0	5	48%	17.4%	4 (80%)
Artemisia dracunculus	Native	1	0	0	0	1	8%	4.9%	2 (40%)
Artemisia ludoviciana	Native	0	1	0	0	0	4%	4.0%	1 (20%)
Asclepias tuberosa	Native	0	0	0	0	0	0%	0.0%	--
Astragalus	N/A	0	0	1	0	0	4%	4.0%	1 (20%)
Bidens bigelovii	Native	0	0	0	1	0	4%	4.0%	1 (20%)
Boerhavia purpurascens	Native	0	1	0	0	0	4%	4.0%	1 (20%)
Chamaesyce	N/A	0	0	0	0	0	0%	0.0%	--
Commelina dianthifolia	Native	0	1	0	0	1	8%	4.9%	2 (40%)
Cryptantha	N/A	2	0	0	1	0	12%	8.0%	2 (40%)
Dalea	N/A	0	0	0	0	0	0%	0.0%	--
Desmodium	N/A	0	0	0	0	0	0%	0.0%	--
Desmodium grahamii	Native	0	0	0	0	2	8%	8.0%	1 (20%)
Dryopteris filix-mas	Native	1	0	0	0	0	4%	4.0%	1 (20%)
Echeandia flavescens	Native	2	0	1	0	0	12%	8.0%	2 (40%)
Erigeron divergens	Native	0	1	0	1	0	8%	4.9%	2 (40%)
Erigeron flagellaris	Native	1	1	0	2	2	24%	7.5%	4 (80%)
Erigeron oreophilus	Native	0	1	0	0	0	4%	4.0%	1 (20%)
Glandularia bipinnatifida	Native	0	0	1	0	0	4%	4.0%	1 (20%)
Hackelia floribunda	Native	0	0	0	0	0	0%	0.0%	--
Hedeoma nana	Native	0	3	0	0	5	32%	20.6%	2 (40%)
Houstonia wrightii	Native	0	0	0	0	0	0%	0.0%	--
Ipomoea	N/A	0	0	0	0	0	0%	0.0%	--
Linanthus nuttallii	Native	0	0	0	0	0	0%	0.0%	--
Lithospermum multiflorum	Native	2	0	5	0	0	28%	19.6%	2 (40%)
Lotus wrightii	Native	0	0	1	1	0	8%	4.9%	2 (40%)
Lupinus hillii	Native	0	0	0	0	0	0%	0.0%	--
Machaeranthera bigelovii	Native	1	2	0	0	2	20%	8.9%	3 (60%)
Oenothera caespitosa	Native	1	0	0	0	0	4%	4.0%	1 (20%)
Packera neomexicana	Native	0	0	0	0	1	4%	4.0%	1 (20%)
Polygonum argyrocoleon	Non-Native	0	0	0	0	1	4%	4.0%	1 (20%)
Pseudocymopterus montanus	Native	0	0	1	0	0	4%	4.0%	1 (20%)
Pseudognaphalium canescens	Native	0	0	0	1	1	8%	4.9%	2 (40%)
Psoralidium tenuiflorum	Native	0	0	0	0	3	12%	12.0%	1 (20%)
Solidago wrightii	Native	1	0	0	0	0	4%	4.0%	1 (20%)
Thalictrum fendleri	Native	3	0	5	0	0	32%	20.6%	2 (40%)
Tradescantia pinetorum	Native	0	5	3	0	2	40%	19.0%	3 (60%)

Table A4b. Within-plot and landscape frequency (%) for all plots and species sampled on monitoring plots in the 500 stratum (>6,000'), Gila Cliff Dwellings NM, 2009, cont.

Species	Nativity	Within-plot frequency (0–5)					Within-plot frequency (%)		Landscape frequency
		V500_01	V500_02	V500_03	V500_04	V500_05	Mean	SE	
Forbs/Herbs, cont.									
Tragia ramosa	Native	0	0	0	0	2	8%	8.0%	1 (20%)
Verbascum thapsus	Non-Native	1	0	0	0	0	4%	4.0%	1 (20%)
Veronica peregrina	Native	0	0	0	0	0	0%	0.0%	--
Graminoids									
Aristida purpurea	Native	0	0	0	0	0	0%	0.0%	--
Aristida schiedeana	Native	0	0	0	1	0	4%	4.0%	1 (20%)
Aristida ternipes	Native	0	0	0	5	0	20%	20.0%	1 (20%)
Bouteloua curtipendula	Native	0	5	0	2	5	48%	22.4%	3 (60%)
Bouteloua gracilis	Native	5	5	0	5	5	80%	20.0%	4 (80%)
Bouteloua hirsuta	Native	0	0	0	3	0	12%	12.0%	1 (20%)
Bromus	N/A	0	0	0	0	0	0%	0.0%	--
Carex geophila	Native	1	0	2	0	0	12%	8.0%	2 (40%)
Elymus elymoides	Native	0	0	0	0	0	0%	0.0%	--
Koeleria macrantha	Native	0	0	0	0	0	0%	0.0%	--
Lycurus setosus	Native	0	2	0	3	5	40%	19.0%	3 (60%)
Muhlenbergia pauciflora	Native	1	0	0	0	0	4%	4.0%	1 (20%)
Muhlenbergia polycaulis	Native	4	3	0	0	2	36%	16.0%	3 (60%)
Piptochaetium fimbriatum	Native	0	0	0	2	0	8%	8.0%	1 (20%)
Poa fendleriana	Native	5	0	5	0	0	40%	24.5%	2 (40%)
Schizachyrium cirratum	Native	0	0	0	0	0	0%	0.0%	--
Sporobolus cryptandrus	Native	0	1	0	0	0	4%	4.0%	1 (20%)
Shrubs									
Artemisia	N/A	0	0	0	0	0	0%	0.0%	--
Baccharis pteronioides	Native	0	0	0	0	1	4%	4.0%	1 (20%)
Calliandra humilis	Native	0	0	0	4	0	16%	16.0%	1 (20%)
Cercocarpus montanus	Native	5	5	5	0	4	76%	19.4%	4 (80%)
Ericameria nauseosa	Native	0	0	0	0	0	0%	0.0%	--
Fendlera wrightii	Native	0	0	0	2	0	8%	8.0%	1 (20%)
Garrya wrightii	Native	2	5	0	0	0	28%	19.6%	2 (40%)
Rhus aromatica	Native	0	0	0	0	0	0%	0.0%	--
Rhus trilobata	Native	3	0	1	1	0	20%	11.0%	3 (60%)
Robinia neomexicana	Native	0	0	3	0	0	12%	12.0%	1 (20%)
Subshrubs									
Ageratina herbacea	Native	4	0	5	0	0	36%	22.3%	2 (40%)
Brickellia brachyphylla	Native	3	2	5	0	4	56%	17.2%	4 (80%)
Brickellia californica	Native	0	0	0	0	0	0%	0.0%	--
Brickellia floribunda	Native	0	0	0	1	0	4%	4.0%	1 (20%)
Brickellia rusbyi	Native	0	0	0	0	0	0%	0.0%	--
Chaetopappa ericoides	Native	0	1	0	0	0	4%	4.0%	1 (20%)

Table A4b. Within-plot and landscape frequency (%) for all plots and species sampled on monitoring plots in the 500 stratum (>6,000'), Gila Cliff Dwellings NM, 2009, cont.

Species	Nativity	Within-plot frequency (0–5)					Within-plot frequency (%)		Landscape frequency
		V500_01	V500_02	V500_03	V500_04	V500_05	Mean	SE	
Subshrubs, cont.									
Dalea albiflora	Native	0	0	0	0	0	0%	0.0%	--
Dalea candida	Native	0	0	0	0	0	0%	0.0%	--
Desmodium grahamii	Native	0	0	0	0	2	8%	8.0%	1 (20%)
Eriogonum alatum	Native	0	0	2	0	0	8%	8.0%	1 (20%)
Eriogonum jamesii	Native	0	0	0	3	0	12%	12.0%	1 (20%)
Geranium caespitosum	Native	1	0	3	0	0	16%	11.7%	2 (40%)
Gutierrezia microcephala	Native	0	0	0	0	0	0%	0.0%	--
Gutierrezia sarothrae	Native	0	1	0	0	0	4%	4.0%	1 (20%)
Krascheninnikovia lanata	Native	0	0	0	0	1	4%	4.0%	1 (20%)
Menodora scabra	Native	0	0	0	2	0	8%	8.0%	1 (20%)
Phoradendron juniperinum	Native	0	0	0	1	0	4%	4.0%	1 (20%)
Polygala obscura	Native	0	0	0	0	2	8%	8.0%	1 (20%)
Solanum elaeagnifolium	Native	0	0	0	0	0	0%	0.0%	--
Sphaeralcea fendleri	Native	1	1	0	1	0	12%	4.9%	3 (60%)
Toxicodendron pubescens	Native	1	0	0	0	0	4%	4.0%	1 (20%)
Viguiera dentata	Native	0	4	0	0	5	36%	22.3%	2 (40%)
Succulents									
Echinocereus coccineus	Native	0	0	0	1	0	4%	4.0%	1 (20%)
Echinocereus fendleri	Native	0	0	0	0	0	0%	0.0%	--
Echinocereus triglochidiatus	Native	0	0	0	0	0	0%	0.0%	--
Escobaria vivipara	Native	0	0	0	0	0	0%	0.0%	--
Opuntia phaeacantha	Native	0	4	4	1	3	48%	16.2%	4 (80%)
Opuntia spinosior	Native	0	1	0	0	1	8%	4.9%	2 (40%)
Yucca baccata	Native	0	4	3	0	4	44%	18.3%	3 (60%)
Trees									
Abies lasiocarpa	Native	1	0	0	0	0	4%	4.0%	1 (20%)
Fraxinus velutina	Native	1	0	4	0	0	20%	15.5%	2 (40%)
Juniperus deppeana	Native	3	0	0	0	0	12%	12.0%	1 (20%)
Juniperus monosperma	Native	2	1	5	2	0	40%	16.7%	4 (80%)
Juniperus osteosperma	Native	5	5	2	1	5	72%	17.4%	5 (100%)
Juniperus scopulorum	Native	0	0	0	0	0	0%	0.0%	--
Pinus discolor	Native	0	0	0	0	1	4%	4.0%	1 (20%)
Pinus edulis	Native	5	3	4	1	5	72%	15.0%	5 (100%)
Pinus ponderosa	Native	2	0	5	0	0	28%	19.6%	2 (40%)
Pseudotsuga menziesii	Native	0	0	5	0	0	20%	20.0%	1 (20%)
Ptelea trifoliata	Native	0	0	3	0	0	12%	12.0%	1 (20%)
Quercus gambelii	Native	4	0	5	0	0	36%	22.3%	2 (40%)
Quercus grisea	Native	4	0	2	1	3	40%	14.1%	4 (80%)

Table A4b. Within-plot and landscape frequency (%) for all plots and species sampled on monitoring plots in the 500 stratum (>6,000'), Gila Cliff Dwellings NM, 2009, cont.

Species	Nativity	Within-plot frequency (0–5)					Within-plot frequency (%)		Landscape frequency
		V500_01	V500_02	V500_03	V500_04	V500_05	Mean	SE	
Vines									
Lonicera albiflora	Native	3	0	4	0	1	32%	16.2%	3 (60%)
Phaseolus	Native	0	2	0	0	0	8%	8.0%	1 (20%)
Phaseolus angustissimus	Native	0	0	0	0	0	0%	0.0%	--
Rhynchosia senna	Native	0	2	0	0	0	8%	8.0%	1 (20%)
Vitis arizonica	Native	0	0	0	0	0	0%	0.0%	--

Species in BOLD are new to park lists.

Table A4c. Within-plot and landscape frequency (%) for all plots and species sampled on monitoring plots in all strata (10 plots), Gila Cliff Dwellings NM, 2009.

Species	Nativity	Within-plot frequency (%)		Landscape frequency
		Mean	SE	
Forbs/Herbs				
Achillea millefolium	Native	16%	8.60%	3 (30%)
Antennaria parvifolia	Native	2%	1.40%	1 (10%)
Artemisia carruthii	Native	44%	12.00%	7 (70%)
Artemisia dracunculus	Native	10%	3.70%	4 (40%)
Artemisia ludoviciana	Native	14%	4.80%	5 (50%)
Asclepias tuberosa	Native	4%	2.00%	2 (20%)
Astragalus	N/A	4%	2.30%	2 (20%)
Bidens bigelovii	Native	2%	2.00%	1 (10%)
Boerhavia purpurascens	Native	2%	2.00%	1 (10%)
Chamaesyce	N/A	4%	2.90%	1 (10%)
Commelina dianthifolia	Native	14%	6.00%	4 (40%)
Cryptantha	N/A	6%	4.20%	2 (20%)
Dalea	N/A	6%	4.30%	1 (10%)
Desmodium	N/A	6%	4.30%	1 (10%)
Desmodium grahamii	Native	4%	4.00%	1 (10%)
Dryopteris filix-mas	Native	4%	2.30%	2 (20%)
Echeandia flavescens	Native	12%	4.80%	4 (40%)
Erigeron divergens	Native	4%	2.60%	2 (20%)
Erigeron flagellaris	Native	26%	6.10%	7 (70%)
Erigeron oreophilus	Native	2%	2.00%	1 (10%)
Glandularia bipinnatifida	Native	2%	2.00%	1 (10%)
Hackelia floribunda	Native	2%	1.40%	1 (10%)
Hedeoma nana	Native	16%	10.90%	2 (20%)
Houstonia wrightii	Native	2%	1.40%	1 (10%)
Ipomoea	N/A	2%	1.40%	1 (10%)
Linanthus nuttallii	Native	2%	1.40%	1 (10%)
Lithospermum multiflorum	Native	20%	10.20%	4 (40%)
Lotus wrightii	Native	18%	7.00%	4 (40%)
Lupinus hillii	Native	8%	5.80%	1 (10%)
Machaeranthera bigelovii	Native	12%	5.20%	4 (40%)
Oenothera caespitosa	Native	8%	4.60%	2 (20%)
Packera neomexicana	Native	2%	2.00%	1 (10%)
Polygonum argyrocoleon	Non-Native	2%	2.00%	1 (10%)
Pseudocymopterus montanus	Native	2%	2.00%	1 (10%)
Pseudognaphalium canescens	Native	4%	2.60%	2 (20%)
Psoralidium tenuiflorum	Native	6%	6.00%	1 (10%)
Solidago wrightii	Native	4%	2.30%	2 (20%)
Thalictrum fendleri	Native	16%	10.90%	2 (20%)
Tradescantia pinetorum	Native	26%	10.70%	5 (50%)
Tragia ramosa	Native	4%	4.00%	1 (10%)

Table A4c. Within-plot and landscape frequency (%) for all plots and species sampled on monitoring plots in all strata (10 plots), Gila Cliff Dwellings NM, 2009, cont.

Species	Nativity	Within-plot frequency (%)		Landscape frequency
		Mean	SE	
Forbs/Herbs, cont.				
Verbascum thapsus	Non-Native	20%	7.30%	4 (40%)
Veronica peregrina	Native	2%	1.40%	1 (10%)
Graminoids				
Aristida purpurea	Native	10%	4.10%	3 (30%)
Aristida schiedeana	Native	14%	7.30%	3 (30%)
Aristida ternipes	Native	16%	10.50%	2 (20%)
Bouteloua curtipendula	Native	48%	13.40%	9 (90%)
Bouteloua gracilis	Native	80%	13.60%	9 (90%)
Bouteloua hirsuta	Native	22%	8.50%	4 (40%)
Bromus	N/A	2%	1.40%	1 (10%)
Carex geophila	Native	24%	7.60%	5 (50%)
Elymus elymoides	Native	14%	4.80%	4 (40%)
Koeleria macrantha	Native	2%	1.40%	1 (10%)
Lycurus setosus	Native	38%	12.40%	5 (50%)
Muhlenbergia pauciflora	Native	2%	2.00%	1 (10%)
Muhlenbergia polycaulis	Native	36%	11.30%	3 (30%)
Piptochaetium fimbriatum	Native	14%	6.00%	3 (30%)
Poa fendleriana	Native	42%	14.60%	5 950%)
Schizachyrium cirratum	Native	4%	2.00%	2 (20%)
Sporobolus cryptandrus	Native	14%	5.20%	4 (40%)
Shrubs				
Artemisia	N/A	2%	1.40%	1 (10%)
Baccharis pteronioides	Native	2%	2.00%	1 (10%)
Calliandra humilis	Native	34%	11.10%	5 (50%)
Cercocarpus montanus	Native	52%	14.20%	7 (70%)
Ericameria nauseosa	Native	2%	1.40%	1 (10%)
Fendlera wrightii	Native	4%	4.00%	1 (10%)
Garrya wrightii	Native	14%	10.20%	2 (20%)
Rhus aromatica	Native	2%	1.40%	1 (10%)
Rhus trilobata	Native	12%	6.00%	4 (40%)
Robinia neomexicana	Native	12%	7.00%	2 (20%)
Subshrubs				
Ageratina herbacea	Native	18%	11.90%	2 (20%)
Brickellia brachyphylla	Native	38%	11.90%	6 (60%)
Brickellia californica	Native	2%	1.40%	1 (10%)
Brickellia floribunda	Native	2%	2.00%	1 (10%)
Brickellia rusbyi	Native	2%	1.40%	1 (10%)
Chaetopappa ericoides	Native	2%	2.00%	1 (10%)
Dalea albiflora	Native	6%	4.30%	1 (10%)
Dalea candida	Native	2%	1.40%	1 (10%)
Desmodium grahamii	Native	4%	4.00%	1 (10%)

Table A4c. Within-plot and landscape frequency (%) for all plots and species sampled on monitoring plots in all strata (10 plots), Gila Cliff Dwellings NM, 2009, cont.

Species	Nativity	Within-plot frequency (%)		Landscape frequency
		Mean	SE	
Subshrubs, cont.				
Eriogonum alatum	Native	10%	4.80%	3 (30%)
Eriogonum jamesii	Native	6%	6.00%	1 (10%)
Geranium caespitosum	Native	8%	6.00%	2 (20%)
Gutierrezia microcephala	Native	4%	2.90%	1 (10%)
Gutierrezia sarothrae	Native	2%	2.00%	1 (10%)
Krascheninnikovia lanata	Native	2%	2.00%	1 (10%)
Menodora scabra	Native	14%	7.90%	2 (20%)
Phoradendron juniperinum	Native	2%	2.00%	1 (10%)
Polygala obscura	Native	4%	4.00%	1 (10%)
Solanum elaeagnifolium	Native	2%	1.40%	1 (10%)
Sphaeralcea fendleri	Native	22%	5.40%	7 (70%)
Toxicodendron pubescens	Native	2%	2.00%	1 (10%)
Viguiera dentata	Native	24%	12.10%	3 (30%)
Succulents				
Echinocereus coccineus	Native	2%	2.00%	1 (10%)
Echinocereus fendleri	Native	4%	2.90%	1 (10%)
Echinocereus triglochidiatus	Native	4%	2.90%	1 (10%)
Escobaria vivipara	Native	2%	1.40%	1 (10%)
Opuntia phaeacantha	Native	58%	12.00%	8 (80%)
Opuntia spinosior	Native	6%	2.80%	3 (30%)
Yucca baccata	Native	34%	11.20%	6 (60%)
Trees				
Abies lasiocarpa	Native	6%	3.40%	2 (20%)
Fraxinus velutina	Native	10%	7.90%	2 (20%)
Juniperus deppeana	Native	14%	7.00%	3 (30%)
Juniperus monosperma	Native	54%	11.40%	9 (90%)
Juniperus osteosperma	Native	38%	13.80%	6 (60%)
Juniperus scopulorum	Native	2%	1.40%	1 (10%)
Pinus discolor	Native	2%	2.00%	1 (10%)
Pinus edulis	Native	62%	12.90%	8 (80%)
Pinus ponderosa	Native	42%	13.30%	5 (50%)
Pseudotsuga menziesii	Native	10%	9.90%	1 (10%)
Ptelea trifoliata	Native	8%	6.00%	2 (20%)
Quercus gambelii	Native	40%	12.80%	6 (60%)
Quercus grisea	Native	60%	12.50%	8 (80%)
Vines				
Lonicera albiflora	Native	16%	9.20%	3 (30%)
Phaseolus	Native	10%	5.60%	2 (20%)
Phaseolus angustissimus	Native	10%	7.20%	1 (10%)
Rhynchosia senna	Native	4%	4.00%	1 (10%)
Vitis arizonica	Native	2%	1.40%	1 (10%)

Bolded species are new to park lists.

Table A5a. Soil substrate and surface aggregate stability by monitoring plot, 400 stratum (4,500–6,000'), Gila Cliff Dwellings NM, 2009.

Decreasing erosion hazard ↓

Parameter	Individual plot measures					Across-plot measures				
	V400_01	V400_02	V400_02TJ	V400_04	V400_05	AVG	SD	Sdiff	MDC	Plot
Substrate										
Bare soil (<2 mm), no overhead cover	2.5%	0.4%	0.8%	2.9%	4.2%	2.17%	1.54%	1.09%	5%	0.4
Bare soil (<2 mm), under vegetation	0.8%	0.4%	2.9%	7.1%	5.0%	3.25%	2.82%	1.99%	5%	1.4
Duff (partially decomposed organic matter)	4.2%	32.9%	17.5%	0.8%	11.3%	13.33%	12.70%	8.98%	12%	4.8
Litter (intact organic matter)	69.6%	47.1%	42.1%	42.1%	52.5%	50.67%	11.42%	8.07%	11%	4.6
Cyanobacteria	0.0%	0.0%	0.0%	0.0%	0.0%	0.00%	0.00%	0.00%	5%	0.0
Moss	0.0%	0.8%	0.0%	0.4%	0.0%	0.25%	0.37%	0.26%	5%	0.0
Plant base	5.8%	2.1%	9.6%	12.5%	0.4%	6.08%	5.04%	3.56%	5%	4.3
Gravel (2–75 mm)	16.7%	1.3%	26.3%	30.0%	14.6%	17.75%	11.24%	7.95%	11%	4.5
Rock (76–600 mm)	0.4%	0.4%	0.4%	1.3%	4.6%	1.42%	1.81%	1.28%	5%	0.6
Lichen on rock	0.0%	13.3%	0.4%	2.9%	2.9%	3.92%	5.44%	3.84%	5%	5.0
Bedrock	0.0%	1.3%	0.0%	0.0%	4.6%	1.17%	1.99%	1.40%	5%	0.7
Litter + duff	73.8%	80.0%	59.6%	42.9%	63.8%	64.00%	14.28%	10.09%	14%	4.4
Surface Soil Aggregate Stability										
Overall										
Average Soil Stability	4.49	2.14	3.24	3.39	2.52	3.16	0.905279	0.64	0.90	4.31
SE	0.28	0.46	0.32	0.38	0.36	-	-	-	-	-
% samples "very stable" (=6)	43%	23%	23%	23%	0%	19.47%	13.67%	9.66%	13.00%	4.71
n	37	22	43	31	29	-	-	-	-	-
Under vegetation										
Average Soil Stability	4.76	2.25	3.33	3.95	2.50	3.12	1.050423	0.74	1.00	4.70
SE	0.40	0.56	0.41	0.41	0.52	-	-	-	-	-
% samples "very stable" (=6)	43%	25%	29%	27%	0%	22.20%	15.04%	10.63%	14.00%	4.92
n	21	16	31	22	14	205	104	-	-	-
No vegetation cover										
Average Soil Stability	4.13	1.83	3.00	2.00	2.53	2.49	0.7786	0.55	0.80	4.04
SE	0.38	0.83	0.48	0.67	0.51	-	-	-	-	-
% samples "very stable" (=6)	25%	17%	17%	11%	0%	11.90%	11.80%	8.34%	11.00%	4.90
n	16	6	12	9	15	136	58	-	-	-

n = number of samples collected per plot.

Table A5b. Soil substrate and surface aggregate stability by monitoring plot, 500 stratum (>6,000'), Gila Cliff Dwellings NM, 2009.

	Individual plot measures					Across-plot measures				
Parameter	V500_01	V500_02	V500_03	V500_04	V500_05	AVG	SD	Sdiff	MDC	Plot
Substrate										
Bare soil (<2 mm), no overhead cover	3.3%	0.4%	2.5%	7.9%	2.9%	3.42%	2.75%	1.95%	5%	1.3
Bare soil (<2 mm), under vegetation	5.8%	0.0%	1.7%	27.5%	2.9%	7.58%	11.34%	8.02%	11%	4.5
Duff (partially decomposed organic matter)	13.8%	0.0%	32.5%	5.0%	10.8%	12.42%	12.42%	8.78%	12%	4.6
Litter (intact organic matter)	43.8%	44.2%	44.6%	9.6%	49.6%	38.33%	16.24%	11.49%	15%	5.0
Cyanobacteria	0.0%	0.0%	0.0%	1.7%	0.0%	0.33%	0.75%	0.53%	5%	0.1
Moss	0.8%	0.0%	0.4%	2.5%	0.4%	0.83%	0.98%	0.69%	5%	0.2
Plant base	3.3%	1.7%	0.0%	18.8%	0.8%	4.92%	7.83%	5.54%	8%	4.1
Gravel (2–75 mm)	16.3%	37.9%	12.9%	26.3%	26.7%	24.00%	9.86%	6.97%	10%	4.1
Rock (76–600 mm)	6.3%	15.8%	3.3%	0.0%	4.6%	6.00%	5.96%	4.21%	6%	4.2
Lichen on rock	2.5%	0.0%	2.1%	0.8%	0.4%	1.17%	1.08%	0.76%	5%	0.2
Bedrock	4.2%	0.0%	0.0%	0.0%	0.8%	1.00%	1.81%	1.28%	5%	0.6
Litter + duff	57.5%	44.2%	77.1%	14.6%	60.4%	50.75%	23.37%	16.52%	22%	4.8
Surface Soil Aggregate Stability										
Overall										
Average Soil Stability	2.89	3.76	1.78	2.87	2.25	2.71	0.74783	0.53	0.70	4.87
SE	0.37	0.30	0.31	0.20	0.34	-	-	-	-	-
% samples "very stable" (=6)	**27%**	**33%**	**8%**	**3%**	**13%**	16.56%	12.93%	9.15%	12.00%	4.95
n	37	45	27	38	32	-	-	-	-	-
Under vegetation										
Average Soil Stability	2.23	4.74	1.86	3.07	2.52	2.88	1.127843	0.80	1.10	4.48
SE	0.57	0.28	0.49	0.24	0.45	-	-	-	-	-
% samples "very stable" (=6)	**15%**	**46%**	**14%**	**4%**	**19%**	19.60%	15.81%	11.18%	15.00%	4.73
n	13	26	14	27	21	-	-	-	-	-
No vegetation cover										
Average Soil Stability	3.25	2.36	1.69	2.36	1.73	2.28	0.633301	0.45	0.60	4.75
SE	0.46	0.43	0.38	0.28	0.49	-	-	-	-	-
% samples "very stable" (=6)	**33%**	**16%**	**0%**	**0%**	**0%**	9.80%	14.70%	10.40%	14.00%	4.70
n	24	19	13	11	11	-	-	-	-	-

Decreasing erosion hazard ↓

n = number of samples collected per plot.

Red font indicates values beyond management assessment points (Table 3.3).

Table A5c. Soil substrate and surface aggregate stability by monitoring plot, all strata (10 plots).

Decreasing erosion hazard

Parameter	AVG	SD	Sdiff	MDC	Plot
Substrate					
Bare soil (<2 mm), no overhead cover	2.79%	2.21%	1.56%	5%	0.8
Bare soil (<2 mm), under vegetation	5.42%	8.12%	5.74%	6%	7.8
Duff (partially decomposed organic matter)	12.88%	11.85%	8.38%	8%	9.4
Litter (intact organic matter)	44.50%	14.75%	10.43%	10%	9.3
Cyanobacteria	0.17%	0.53%	0.37%	5%	0.0
Moss	0.54%	0.76%	0.54%	5%	0.1
Plant base	5.50%	6.24%	4.41%	5%	6.6
Gravel (2–75 mm)	20.88%	10.50%	7.42%	7%	9.6
Rock (76–600 mm)	3.71%	4.80%	3.39%	5%	3.9
Lichen on rock	2.54%	3.97%	2.81%	5%	2.7
Bedrock	1.08%	1.79%	1.27%	5%	0.5
Litter + duff	57.38%	19.54%	13.82%	13%	9.6
Surface Soil Aggregate Stability					
Overall					
Average Soil Stability	2.93	0.817341	0.58	0.55	9.41
SE	-	-	-	-	-
% samples "very stable" (=6)	19.47%	13.67%	9.66%	9.00%	9.83
n	-	-	-	-	-
Under vegetation					
Average Soil Stability	3.12	1.050423	0.74	0.70	9.60
SE	-	-	-	-	-
% samples "very stable" (=6)	22.20%	15.04%	10.63%	10.00%	9.64
n	-	-	-	-	-
No vegetation cover					
Average Soil Stability	2.49	0.7786	0.55	0.55	8.54
SE	-	-	-	-	-
% samples "very stable" (=6)	11.90%	11.80%	8.34%	8.00%	9.27
n	-	-	-	-	-

n = number of samples collected per plot.

Red font indicates values beyond management assessment points (Table 3.3).

Table A6. Plot-specific 2009 monitoring data in the context of proposed management assessment points.

	400 stratum (4,500–6,000')					500 stratum (>6,000')				
Management assessment point	**V400_01**	**V400_02**	**V400_02TJ**	**V400_04**	**V400_05**	**V500_01**	**V500_02**	**V500_03**	**V500_04**	**V500_05**
Bare ground > 30%	0.4%	0.0%	0.0%	0.4%	0.8%	0.4%	0.8%	0.4%	0.4%	0.4%
% surface samples in "very stable" class < 20%	33.0%	23.0%	33.0%	**18.0%**	69.0%	34.0%	**17.0%**	30.0%	40.0%	38.0%
Foliar cover of perennial grasses < 25%	33.0%	43.0%	39.0%	35.0%	48.0%	**15.0%**	40.0%	43.0%	52.0%	43.0%
Foliar cover of annual:total grasses > 30%	23.0%	**40.0%**	24.0%	**45.0%**	25.0%	**75.0%**	**37.0%**	27.0%	21.0%	30.0%
Shrub foliar cover >35% (field)	1.3%	0.4%	0.4%	3.3%	1.7%	2.9%	1.3%	8.3%	1.3%	0.8%
Shrub foliar cover >35% (subcanopy)	1.3%	0.0%	0.8%	7.1%	0.0%	1.3%	0.0%	15.8%	5.8%	1.3%
Mesquite (*Prosopis* sp.) > 20% (field)	0%	6%	0%	4%	6%	0%	5%	0%	0%	12%
Mesquite (*Prosopis* sp.) > 20% (subcanopy)	0%	3%	0%	0%	3%	0%	1%	0%	0%	10%
Extent of exotic plants > 20%	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Foliar cover of exotic:native plants > 1:5 (field)	0.01	0.10	0.03	0.00	0.04	0.01	0.08	0.01	0.04	0.05
Foliar cover of exotic:native plants > 1:5 (subcanopy)	0.02	0.20	0.01	0.03	0.00	0.00	0.27	0.00	0.12	0.04
Foliar cover of exotic:native plants > 1:5 (canopy)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Red font indicates values that are beyond management assessment points (Table 3.3).

Table A7a. Within-plot frequency (%) for species sampled on frequency subplots in the 400 stratum (4,500–6,000'), Gila Cliff Dwellings NM, 2009.

		Within-plot frequency (0–5)					Within-plot frequency (%)					
Species	**Nativity**	**V400_01**	**V400_02**	**V400_02TJ**	**V400_04**	**V400_05**	**Mean**	**SE**	**SD**	**Sdiff**	**MDC**	**n=**
Forbs/Herbs												
Achillea millefolium	Native	0	0	0	0	2	8%	8.0%	17.9%	12.6%	17%	5
Antennaria parvifolia	Native	0	0	0	0	1	4%	4.0%	8.9%	6.3%	9%	5
Asclepias tuberosa	Native	1	0	0	0	1	8%	4.9%	11.0%	7.7%	11%	5
Astragalus	N/A	0	0	0	1	0	4%	4.0%	8.9%	6.3%	9%	5
Boerhavia purpurascens	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Chamaesyce	N/A	0	0	2	0	0	8%	8.0%	17.9%	12.6%	17%	5
Cryptantha	N/A	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Dryopteris filix-mas	Native	0	1	0	0	0	4%	4.0%	8.9%	6.3%	9%	5
Erigeron divergens	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Erigeron oreophilus	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Glandularia bipinnatifida	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Hedeoma nana	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Houstonia wrightii	Native	0	1	0	0	0	4%	4.0%	8.9%	6.3%	9%	5
Ipomoea	N/A	0	0	0	0	1	4%	4.0%	8.9%	6.3%	9%	5
Linanthus nuttallii	Native	0	0	0	0	1	4%	4.0%	8.9%	6.3%	9%	5
Lupinus hillii	Native	0	0	0	0	4	16%	16.0%	35.8%	25.3%	34%	5
Machaeranthera bigelovii	Native	1	0	0	1	0	8%	4.9%	11.0%	7.7%	9%	7
Oenothera caespitosa	Native	0	0	0	0	3	12%	12.0%	26.8%	19.0%	25%	5
Polygonum argyrocoleon	Non-Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Pseudocymopterus montanus	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Pseudognaphalium canescens	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Solidago wrightii	Native	0	0	0	0	1	4%	4.0%	8.9%	6.3%	9%	5
Tragia ramosa	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Verbascum thapsus	Non-Native	2	4	0	0	3	36%	16.0%	35.8%	25.3%	34%	5
Veronica peregrina	Native	0	0	0	0	1	4%	4.0%	8.9%	6.3%	9%	5

Table A7a. Within-plot frequency (%) for species sampled on frequency subplots in the 400 stratum (4,500–6,000'), Gila Cliff Dwellings NM, 2009, cont.

		Within-plot frequency (0–5)					Within-plot frequency (%)					
Species	**Nativity**	**V400_01**	**V400_02**	**V400_02TJ**	**V400_04**	**V400_05**	**Mean**	**SE**	**SD**	**Sdiff**	**MDC**	**n=**
Graminoids												
Bromus	N/A	0	0	0	1	0	4%	4.0%	8.9%	6.3%	9%	5
Eragrostis barrelieri	Non-Native	0	0	0	0	1	4%	4.0%	8.9%	6.3%	9%	5
Koeleria macrantha	Native	0	0	0	0	1	4%	4.0%	8.9%	6.3%	9%	5
Schizachyrium cirratum	Native	0	1	0	0	1	8%	4.9%	11.0%	7.7%	11%	5
Shrubs												
Baccharis pteronioides	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Ericameria nauseosa	Native	1	0	0	0	0	4%	4.0%	8.9%	6.3%	9%	5
Rhus aromatica	Native	0	0	0	0	1	4%	4.0%	8.9%	6.3%	9%	5
Robinia neomexicana	Native	3	0	0	0	0	12%	12.0%	26.8%	19.0%	25%	5
Subshrubs												
Brickellia californica	Native	0	1	0	0	0	4%	4.0%	8.9%	6.3%	9%	5
Brickellia rusbyi	Native	1	0	0	0	0	4%	4.0%	8.9%	6.3%	9%	5
Chaetopappa ericoides	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Dalea albiflora	Native	0	3	0	0	0	12%	12.0%	26.8%	19.0%	25%	5
Desmodium gramineum	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Eriogonum alatum	Native	0	1	0	0	2	12%	8.0%	17.9%	12.6%	17%	5
Eriogonum jamesii	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Gutierrezia microcephala	Native	0	2	0	0	0	8%	8.0%	17.9%	12.6%	17%	5
Gutierrezia sarothrae	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Krascheninnikovia lanata	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Phoradendron juniperinum	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Polygala obscura	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Solanum elaeagnifolium	Native	0	0	1	0	0	4%	4.0%	8.9%	6.3%	9%	5
Sphaeralcea fendleri	Native	2	0	1	3	2	32%	10.2%	22.8%	16.1%	22%	5
Toxicodendron pubescens	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--

Table A7a. Within-plot frequency (%) for species sampled on frequency subplots in the 400 stratum (4,500–6,000′), Gila Cliff Dwellings NM, 2009, cont.

		Within-plot frequency (0–5)					Within-plot frequency (%)					
Species	**Nativity**	**V400_01**	**V400_02**	**V400_02TJ**	**V400_04**	**V400_05**	**Mean**	**SE**	**SD**	**Sdiff**	**MDC**	**n=**
Succulents												
Echinocereus coccineus	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Echinocereus fendleri	Native	0	0	0	2	0	8%	8.0%	17.9%	12.6%	17%	5
Echinocereus triglochidiatus	Native	0	2	0	0	0	8%	8.0%	17.9%	12.6%	17%	5
Escobaria vivipara	Native	0	0	0	1	0	4%	4.0%	8.9%	6.3%	9%	5
Opuntia spinosior	Native	0	0	0	1	0	4%	4.0%	8.9%	6.3%	9%	5
Vines												
Phaseolus	Native	0	0	0	0	3	12%	12.0%	26.8%	19.0%	25%	5
Phaseolus angustissimus	Native	5	0	0	0	0	20%	20.0%	44.7%	31.6%	42%	5
Rhynchosia senna	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Vitis arizonica	Native	0	0	0	0	1	4%	4.0%	8.9%	6.3%	9%	5

Bolded species are new to park lists.
Highlighted values do not meet our 10% change criteria.

Table A7b. Within-plot frequency (%) for species sampled on frequency subplots in the 500 stratum (>6,000'), Gila Cliff Dwellings NM, 2009.

Species	Nativity	Within-plot frequency (0–5)					Within-plot frequency (%)					
		V500_01	V500_02	V500_03	V500_04	V500_05	Mean	SE	SD	Sdiff	MDC	n=
Forbs/Herbs												
Achillea millefolium	Native	2	0	4	0	0	24%	16.0%	35.8%	25.3%	34%	5
Antennaria parvifolia	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Asclepias tuberosa	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Astragalus	N/A	0	0	1	0	0	4%	4.0%	8.9%	6.3%	9%	5
Boerhavia purpurascens	Native	0	1	0	0	0	4%	4.0%	8.9%	6.3%	9%	5
Chamaesyce	N/A	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Cryptantha	N/A	2	0	0	1	0	12%	8.0%	17.9%	12.6%	17%	5
Dryopteris filix-mas	Native	1	0	0	0	0	4%	4.0%	8.9%	6.3%	9%	5
Erigeron divergens	Native	0	1	0	1	0	8%	4.9%	11.0%	7.7%	11%	5
Erigeron oreophilus	Native	0	1	0	0	0	4%	4.0%	8.9%	6.3%	9%	5
Glandularia bipinnatifida	Native	0	0	1	0	0	4%	4.0%	8.9%	6.3%	9%	5
Hedeoma nana	Native	0	0	0	0	1	4%	4.0%	8.9%	6.3%	9%	5
Houstonia wrightii	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Ipomoea	N/A	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Linanthus nuttallii	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Lupinus hillii	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Machaeranthera bigelovii	Native	1	2	0	0	2	20%	8.9%	20.0%	14.1%	19%	5
Oenothera caespitosa	Native	1	0	0	0	0	4%	4.0%	8.9%	6.3%	9%	5
Polygonum argyrocoleon	Non-Native	0	0	0	0	1	4%	4.0%	8.9%	6.3%	9%	5
Pseudocymopterus montanus	Native	0	0	1	0	0	4%	4.0%	8.9%	6.3%	9%	5
Pseudognaphalium canescens	Native	0	0	0	1	1	8%	4.9%	11.0%	7.7%	11%	5
Solidago wrightii	Native	1	0	0	0	0	4%	4.0%	8.9%	6.3%	9%	5
Tragia ramosa	Native	0	0	0	0	2	8%	8.0%	17.9%	12.6%	17%	5
Verbascum thapsus	Non-Native	1	0	0	0	0	4%	4.0%	8.9%	6.3%	9%	5
Veronica peregrina	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--

Table A7b. Within-plot frequency (%) for species sampled on frequency subplots in the 500 stratum (>6,000'), Gila Cliff Dwellings NM, 2009, cont.

		Within-plot frequency (0–5)					Within-plot frequency (%)					
Species	**Nativity**	**V500_01**	**V500_02**	**V500_03**	**V500_04**	**V500_05**	**Mean**	**SE**	**SD**	**Sdiff**	**MDC**	**n=**
Graminoids												
Bromus	N/A	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Eragrostis barrelieri	Non-Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Koeleria macrantha	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Schizachyrium cirratum	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Shrubs												
Baccharis pteronioides	Native	0	0	0	0	1	4%	4.0%	8.9%	6.3%	9%	5
Ericameria nauseosa	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Rhus aromatica	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Robinia neomexicana	Native	0	0	3	0	0	12%	12.0%	26.8%	19.0%	25%	5
Subshrubs												
Brickellia californica	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Brickellia rusbyi	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Chaetopappa ericoides	Native	0	1	0	0	0	4%	4.0%	8.9%	6.3%	9%	5
Dalea albiflora	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Desmodium gramineum	Native	0	0	0	0	2	8%	8.0%	17.9%	12.6%	17%	5
Eriogonum alatum	Native	0	0	2	0	0	8%	8.0%	17.9%	12.6%	17%	5
Eriogonum jamesii	Native	0	0	0	3	0	12%	12.0%	26.8%	19.0%	25%	5
Gutierrezia microcephala	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Gutierrezia sarothrae	Native	0	1	0	0	0	4%	4.0%	8.9%	6.3%	9%	5
Krascheninnikovia lanata	Native	0	0	0	0	1	4%	4.0%	8.9%	6.3%	9%	5
Phoradendron juniperinum	Native	0	0	0	1	0	4%	4.0%	8.9%	6.3%	9%	5
Polygala obscura	Native	0	0	0	0	2	8%	8.0%	17.9%	12.6%	17%	5
Solanum elaeagnifolium	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Sphaeralcea fendleri	Native	1	1	0	1	0	12%	4.9%	11.0%	7.7%	11%	5
Toxicodendron pubescens	Native	1	0	0	0	0	4%	4.0%	8.9%	6.3%	9%	5

Table A7b. Within-plot frequency (%) for species sampled on frequency subplots in the 500 stratum (>6,000'), Gila Cliff Dwellings NM, 2009, cont.

		Within-plot frequency (0–5)					Within-plot frequency (%)					
Species	**Nativity**	**V500_01**	**V500_02**	**V500_03**	**V500_04**	**V500_05**	**Mean**	**SE**	**SD**	**Sdiff**	**MDC**	**n=**
Succulents												
Echinocereus coccineus	Native	0	0	0	1	0	4%	4.0%	8.9%	6.3%	9%	5
Echinocereus fendleri	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Echinocereus triglochidiatus	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Escobaria vivipara	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Opuntia spinosior	Native	0	1	0	0	1	8%	4.9%	11.0%	7.7%	11%	5
Vines												
Phaseolus	Native	0	2	0	0	0	8%	8.0%	17.9%	12.6%	17%	5
Phaseolus angustissimus	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--
Rhynchosia senna	Native	0	2	0	0	0	8%	8.0%	17.9%	12.6%	17%	5
Vitis arizonica	Native	0	0	0	0	0	0%	0.0%	0.0%	0.0%	10%	--

Bolded species are new to park lists.
Highlighted values do not meet our 10% change criteria.

Table A7c. Within-plot and landscape frequency (%) for species sampled on frequency subplots in all strata (10 plots), Gila Cliff Dwellings NM, 2009.

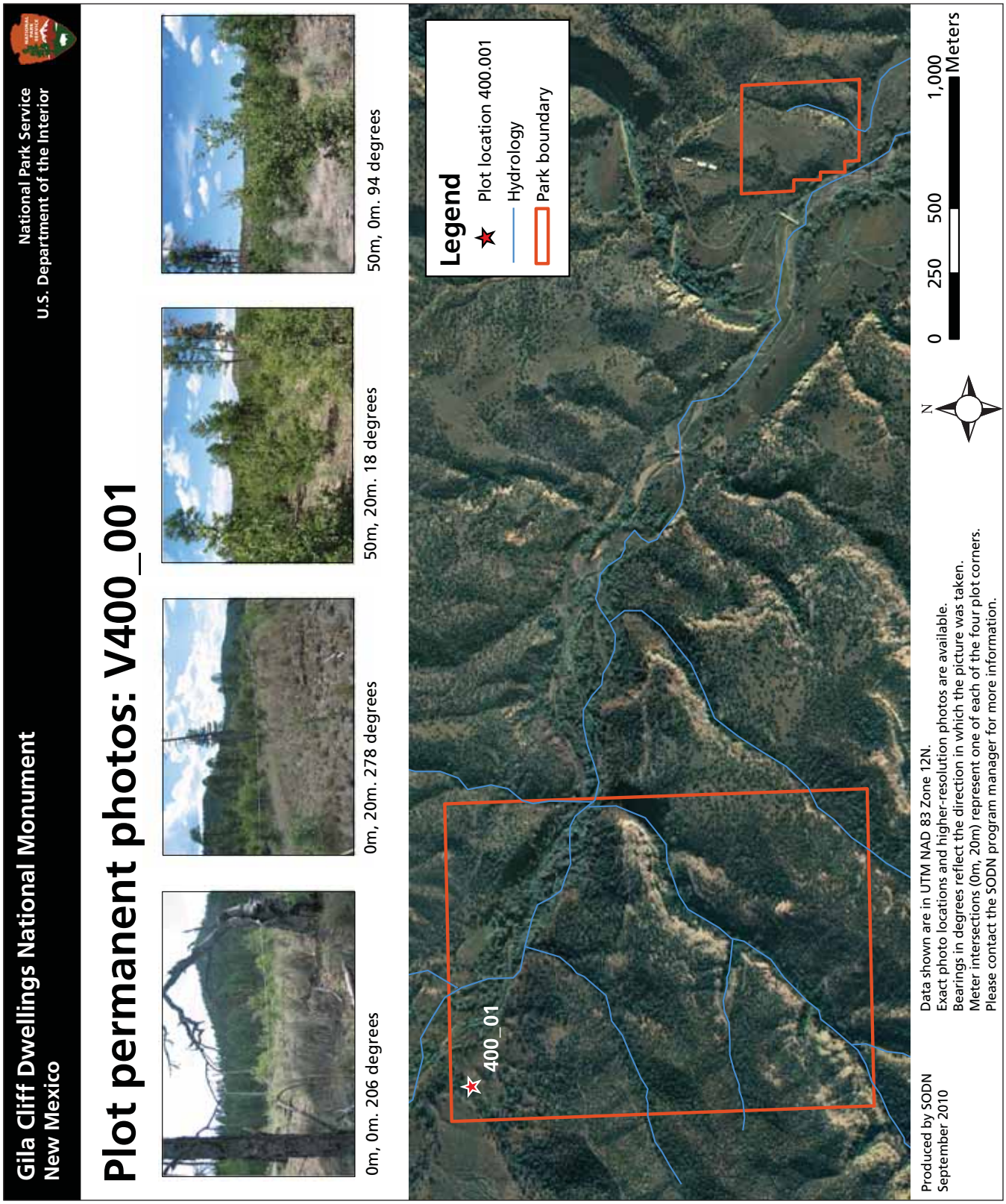
Species	Nativity	Within-plot frequency (%)		Landscape frequency
		Mean	SE	
Forbs/Herbs				
Achillea millefolium	Native	16%	11.70%	3 (30%)
Antennaria parvifolia	Native	2%	7.70%	1 (10%)
Asclepias tuberosa	Native	4%	7.70%	2 (20%)
Astragalus	N/A	4%	10.10%	2 (20%)
Boerhavia purpurascens	Native	2%	7.70%	1 (10%)
Chamaesyce	N/A	4%	8.20%	1 (10%)
Cryptantha	N/A	6%	8.40%	2 (20%)
Dryopteris filix-mas	Native	4%	10.10%	2 (20%)
Erigeron divergens	Native	4%	7.70%	2 (20%)
Erigeron oreophilus	Native	2%	7.70%	1 (10%)
Glandularia bipinnatifida	Native	2%	7.70%	1 (10%)
Hedeoma nana	Native	2%	7.70%	1 (10%)
Houstonia wrightii	Native	2%	7.70%	1 (10%)
Ipomoea	N/A	2%	7.70%	1 (10%)
Linanthus nuttallii	Native	2%	7.70%	1 (10%)
Lupinus hillii	Native	8%	9.10%	1 (10%)
Machaeranthera bigelovii	Native	14%	12.60%	4 (40%)
Oenothera caespitosa	Native	8%	10.70%	2 (20%)
Polygonum argyrocoleon	Non-Native	2%	7.70%	1 (10%)
Pseudocymopterus montanus	Native	2%	7.70%	1 (10%)
Pseudognaphalium canescens	Native	4%	7.70%	2 (20%)
Solidago wrightii	Native	4%	10.10%	2 (20%)
Tragia ramosa	Native	4%	8.40%	1 (10%)
Verbascum thapsus	Non-Native	20%	11.10%	4 (40%)
Veronica peregrina	Native	2%	7.70%	1 (10%)
Graminoids				
Bromus	N/A	2%	7.70%	1 (10%)
Eragrostis barrelieri	Non-Native	2%	7.70%	1 (10%)
Koeleria macrantha	Native	2%	7.70%	1 (10%)
Schizachyrium cirratum	Native	4%	7.70%	2 (20%)
Shrubs				
Baccharis pteronioides	Native	2%	7.70%	1 (10%)
Ericameria nauseosa	Native	2%	7.70%	1 (10%)
Rhus aromatica	Native	2%	7.70%	1 (10%)
Robinia neomexicana	Native	12%	11.50%	2 (20%)
Subshrubs				
Brickellia californica	Native	2%	7.70%	1 (10%)
Brickellia rusbyi	Native	2%	7.70%	1 (10%)
Chaetopappa ericoides	Native	2%	7.70%	1 (10%)
Dalea albiflora	Native	6%	8.70%	1 (10%)
Desmodium gramineum	Native	4%	8.40%	1 (10%)

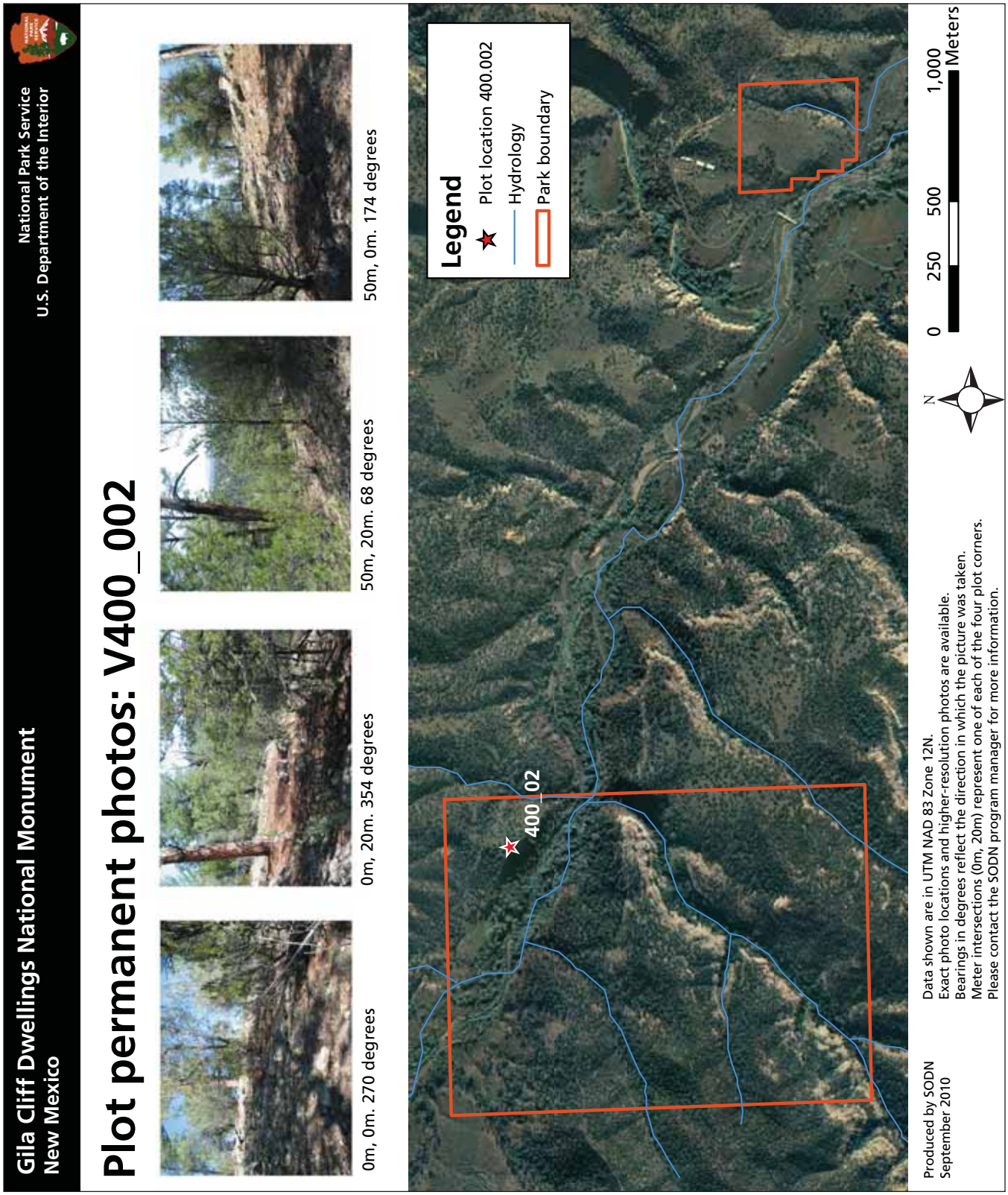
Table A7c. Within-plot and landscape frequency (%) for species sampled on frequency subplots in all strata (10 plots), Gila Cliff Dwellings NM, 2009, cont.

Species	Nativity	Within-plot frequency (%)		Landscape frequency
		Mean	SE	
Subshrubs, cont.				
Eriogonum alatum	Native	10%	10.80%	3 (30%)
Eriogonum jamesii	Native	6%	9.20%	1 (10%)
Gutierrezia microcephala	Native	4%	8.20%	1 (10%)
Gutierrezia sarothrae	Native	2%	7.70%	1 (10%)
Krascheninnikovia lanata	Native	2%	7.70%	1 (10%)
Phoradendron juniperinum	Native	2%	7.70%	1 (10%)
Polygala obscura	Native	4%	8.40%	1 (10%)
Solanum elaeagnifolium	Native	2%	7.70%	1 (10%)
Sphaeralcea fendleri	Native	22%	10.20%	7 (70%)
Toxicodendron pubescens	Native	2%	7.70%	1 (10%)
Succulents				
Echinocereus coccineus	Native	2%	7.70%	1 (10%)
Echinocereus fendleri	Native	4%	8.20%	1 (10%)
Echinocereus triglochidiatus	Native	4%	8.20%	1 (10%)
Escobaria vivipara	Native	2%	7.70%	1 (10%)
Opuntia spinosior	Native	6%	10.00%	3 (30%)
Vines				
Phaseolus	Native	10%	11.10%	2 (20%)
Phaseolus angustissimus	Native	10%	9.80%	1 (10%)
Rhynchosia senna	Native	4%	8.40%	1 (10%)
Vitis arizonica	Native	2%	7.70%	1 (10%)

Bolded species are new to park lists.
Highlighted values do not meet our 10% change criteria.

Appendix B. Plot Maps




Gila Cliff Dwellings National Monument
New Mexico
National Park Service
U.S. Department of the Interior
Plot permanent photos: V400_002
0m, 0m. 270 degrees
0m, 20m. 354 degrees
50m, 20m. 68 degrees
50m, 0m. 174 degrees
400_02
Legend
Plot location 400.002
Hydrology
Park boundary
N
0
250
500
1,000
Meters
Produced by SODN
September 2010
Data shown are in UTM NAD 83 Zone 12N.
Exact photo locations and higher-resolution photos are available.
Bearings in degrees reflect the direction in which the picture was taken.
Meter intersections (0m, 20m) represent one of each of the four plot corners.
Please contact the SODN program manager for more information.

Gila Cliff Dwellings National Monument
New Mexico

National Park Service
U.S. Department of the Interior

Plot permanent photos: V400_002 TJ Ruin unit

0m, 0m. 138 degrees

0m, 20m. 234 degrees

50m, 20m. 320 degrees

50m, 0m. 56 degrees

Produced by SODN
September 2010

Data shown are in UTM NAD 83 Zone 12N.
Exact photo locations and higher-resolution photos are available.
Bearings in degrees reflect the direction in which the picture was taken.
Meter intersections (0m, 20m) represent one of each of the four plot corners.
Please contact the SODN program manager for more information.

N

0 250 500 1,000 Meters

Gila Cliff Dwellings National Monument
New Mexico

National Park Service
U.S. Department of the Interior

Plot permanent photos: V400_004

0m, 0m. 326 degrees

0m, 20m. 24 degrees

50m, 20m. 136 degrees

50m, 0m. 216 degrees

Produced by SODN
September 2010

Data shown are in UTM NAD 83 Zone 12N.
Exact photo locations and higher-resolution photos are available.
Bearings in degrees reflect the direction in which the picture was taken.
Meter intersections (0m, 20m) represent one of each of the four plot corners.
Please contact the SODN program manager for more information.

N

0 250 500 1,000 Meters

Gila Cliff Dwellings National Monument
New Mexico

National Park Service
U.S. Department of the Interior

Plot permanent photos: V400_005

0m, 0m. 260 degrees

0m, 20m. 329 degrees

50m, 20m. 82 degrees

50m, 0m. 190 degrees

Produced by SODN
September 2010

Data shown are in UTM NAD 83 Zone 12N.
Exact photo locations and higher-resolution photos are available.
Bearings in degrees reflect the direction in which the picture was taken.
Meter intersections (0m, 20m) represent one of each of the four plot corners.
Please contact the SODN program manager for more information.

N

0 250 500 1,000 Meters

Gila Cliff Dwellings National Monument
New Mexico

National Park Service
U.S. Department of the Interior

Plot permanent photos: V500_001

0m, 0m. 194 degrees

0m, 20m. 240 degrees

50m, 20m. 164 degrees

50m, 0m. 85 degrees

Produced by SODN
September 2010

Data shown are in UTM NAD 83 Zone 12N.
Exact photo locations and higher-resolution photos are available.
Bearings in degrees reflect the direction in which the picture was taken.
Meter intersections (0m, 20m) represent one of each of the four plot corners.
Please contact the SODN program manager for more information.

N

0 250 500 1,000 Meters

Gila Cliff Dwellings National Monument
New Mexico

National Park Service
U.S. Department of the Interior

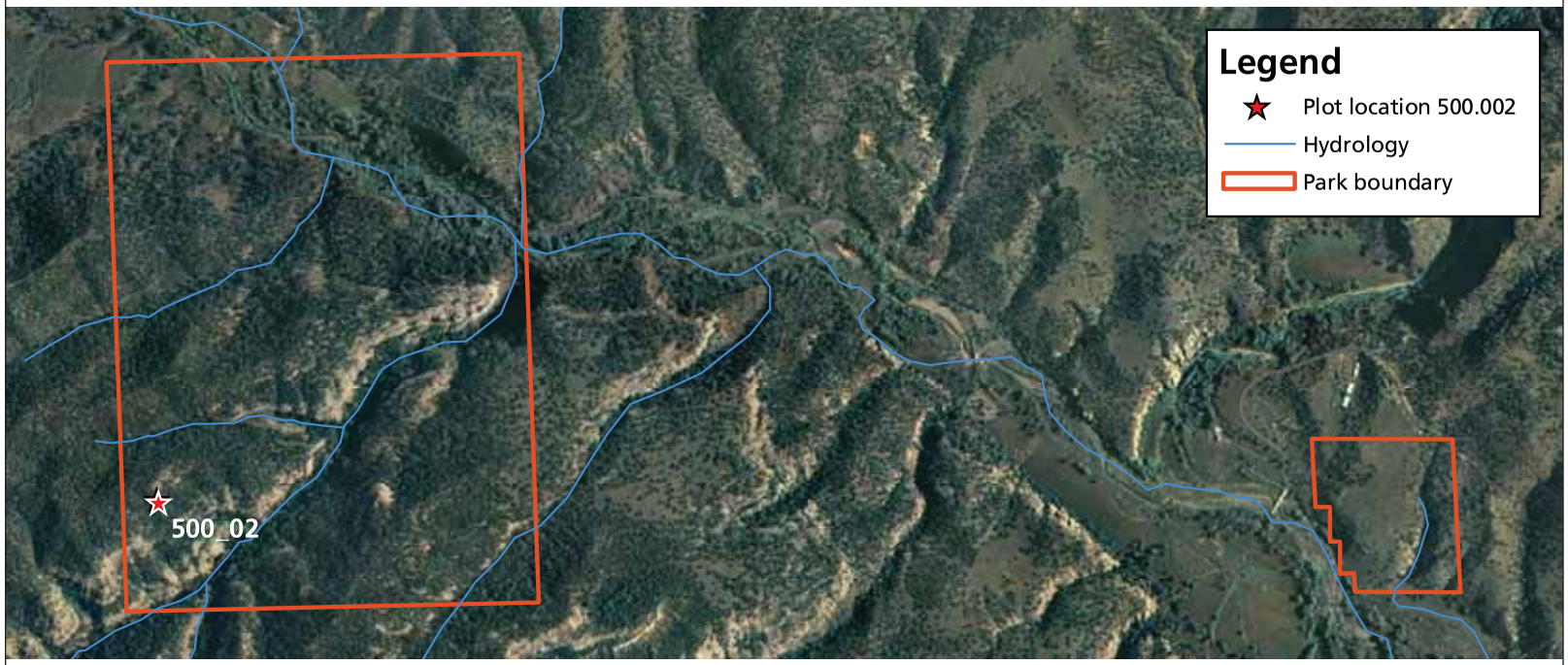
Plot permanent photos: V500_002

0m, 0m. 28 degrees

0m, 20m. 94 degrees

50m, 20m. 180 degrees

50m, 0m. 280 degrees



Produced by SODN
September 2010

Data shown are in UTM NAD 83 Zone 12N.
Exact photo locations and higher-resolution photos are available.
Bearings in degrees reflect the direction in which the picture was taken.
Meter intersections (0m, 20m) represent one of each of the four plot corners.
Please contact the SODN program manager for more information.

N

0 250 500 1,000 Meters

Gila Cliff Dwellings National Monument
New Mexico

National Park Service
U.S. Department of the Interior

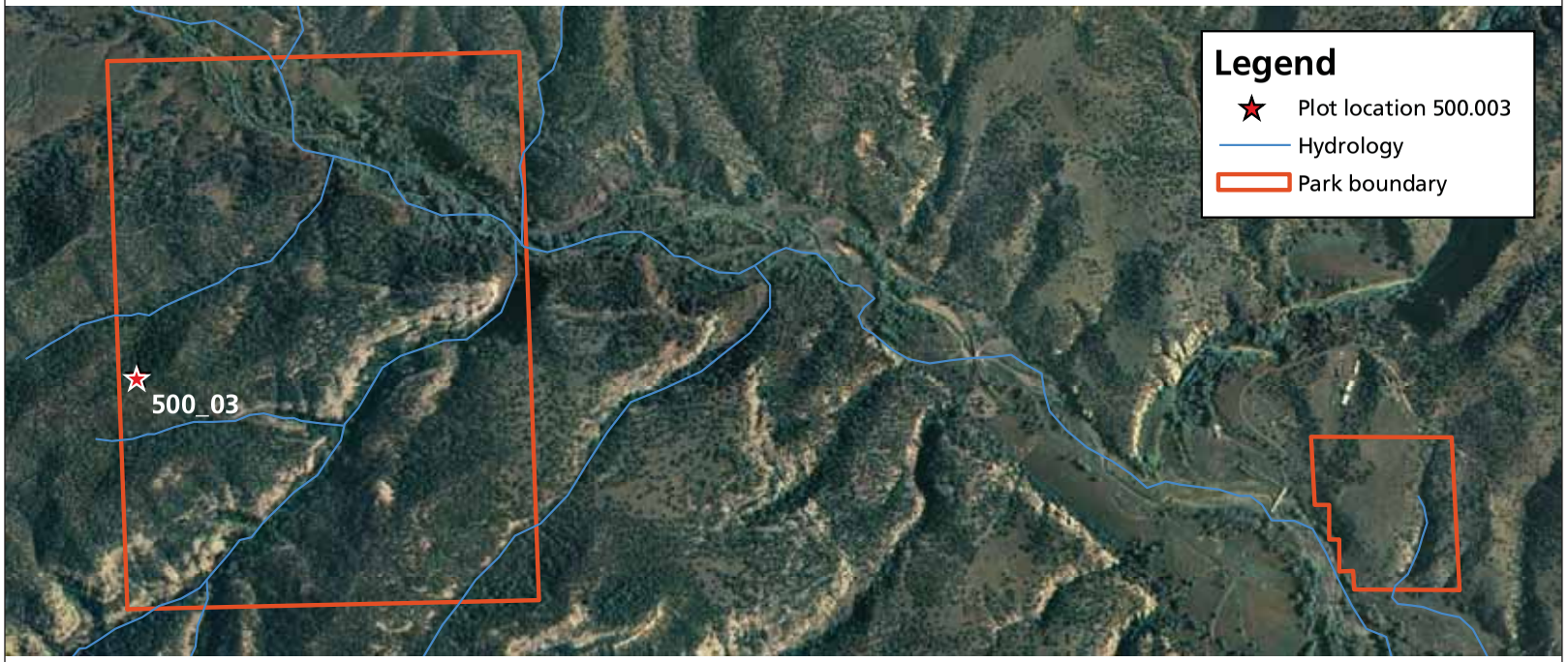
Plot permanent photos: V500_003

0m, 0m. 218 degrees

0m, 20m. 291 degrees

50m, 20m. 24 degrees

50m, 0m. 141 degrees



Produced by SODN
September 2010

Data shown are in UTM NAD 83 Zone 12N.
Exact photo locations and higher-resolution photos are available.
Bearings in degrees reflect the direction in which the picture was taken.
Meter intersections (0m, 20m) represent one of each of the four plot corners.
Please contact the SODN program manager for more information.

N

0 250 500 1,000
Meters

Gila Cliff Dwellings National Monument
New Mexico

National Park Service
U.S. Department of the Interior

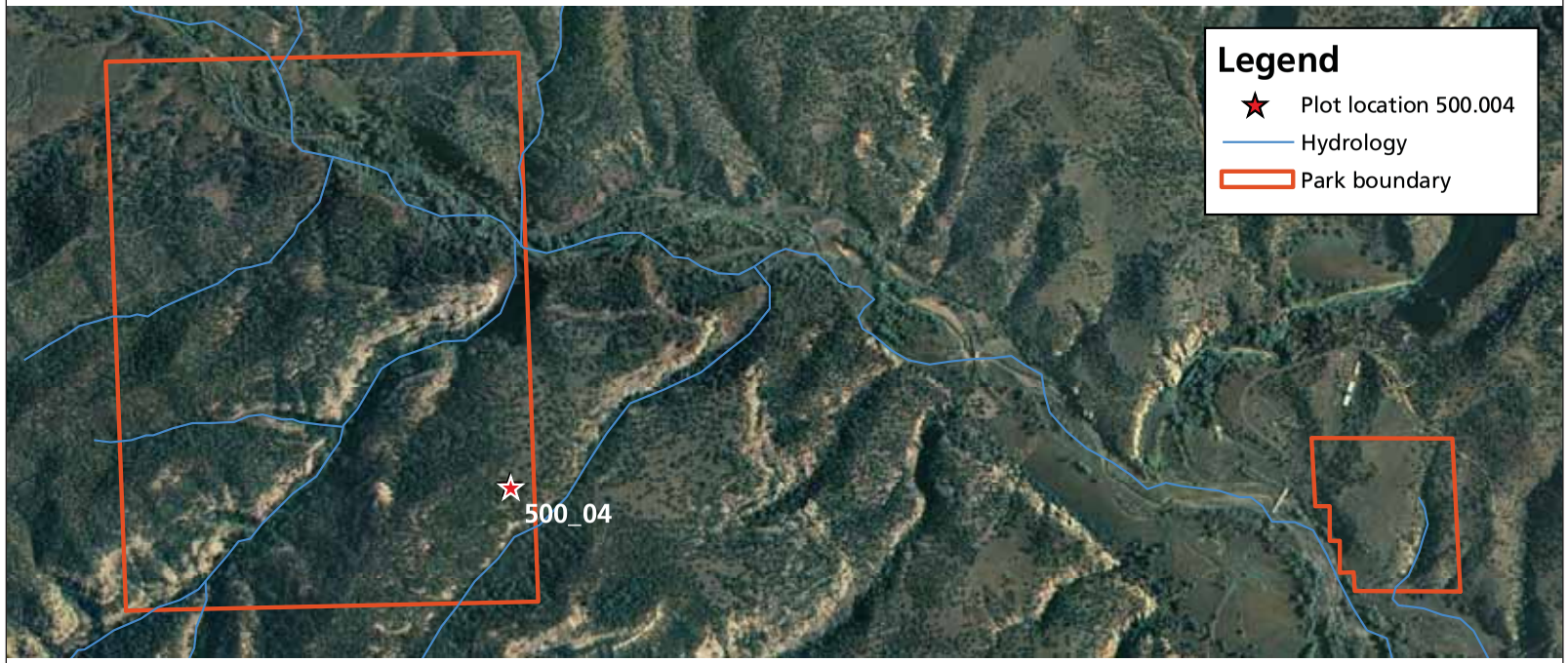
Plot permanent photos: V500_004

0m, 0m. 4 degrees

0m, 20m. 70 degrees

50m, 20m. 164 degrees

50m, 0m. 244 degrees



Produced by SODN
September 2010

Data shown are in UTM NAD 83 Zone 12N.
Exact photo locations and higher-resolution photos are available.
Bearings in degrees reflect the direction in which the picture was taken.
Meter intersections (0m, 20m) represent one of each of the four plot corners.
Please contact the SODN program manager for more information.

N

0 250 500 1,000
Meters

Gila Cliff Dwellings National Monument
New Mexico

National Park Service
U.S. Department of the Interior

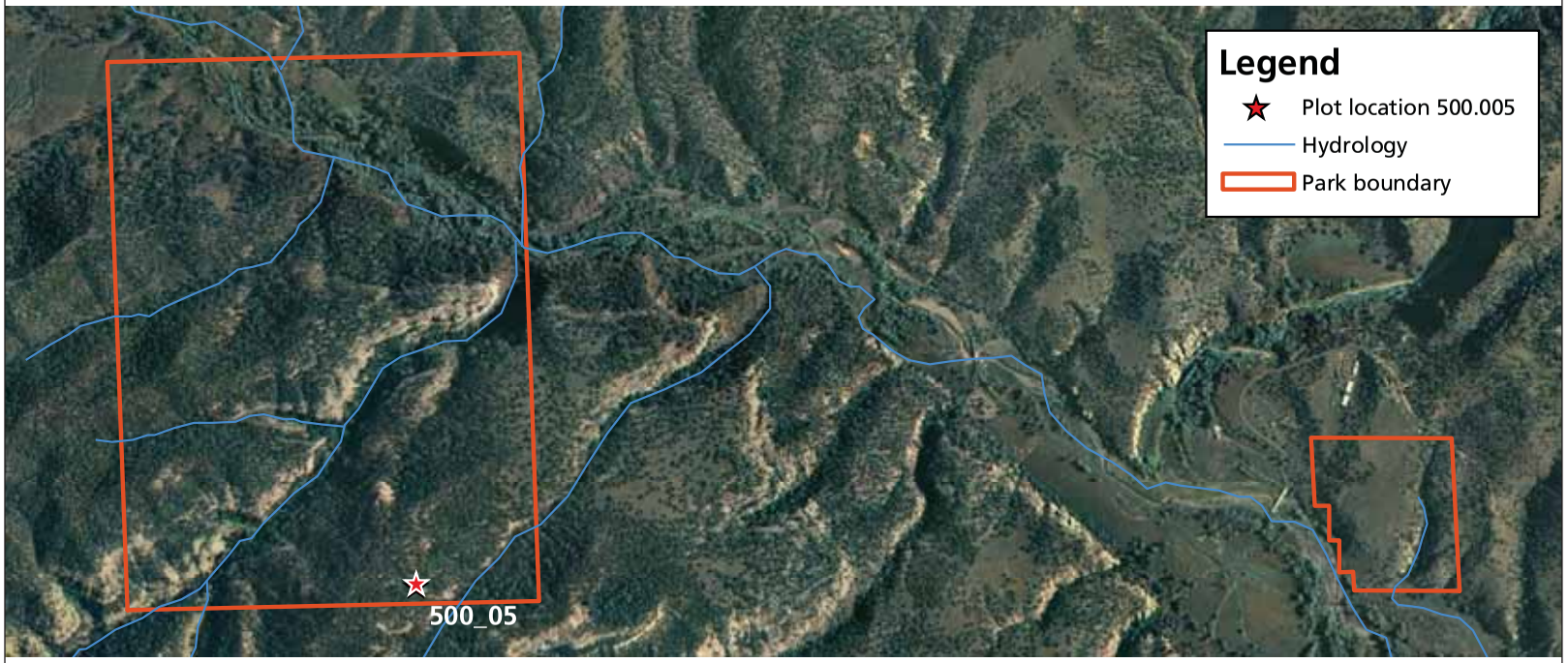
Plot permanent photos: V500_005

0m, 0m. 40 degrees

0m, 20m. 150 degrees

50m, 20m. 245 degrees

50m, 0m. 318 degrees



Produced by SODN
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0 250 500 1,000 Meters

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.

NPS 349/105742, September 2010

National Park Service
U.S. Department of the Interior

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