National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Status of Terrestrial Vegetation and Soils at Chiricahua National Monument, 2007–2010

Natural Resource Report NPS/SODN/NRR—2015/1081

ON THE COVER

Looking north from Massai Point, Chiricahua National Monument. NPS/S. Buckley.

Status of Terrestrial Vegetation and Soils at Chiricahua National Monument, 2007–2010

Natural Resource Report NPS/SODN/NRR—2015/1081

Prepared by
J. A. Hubbard[1]
Cheryl L. McIntyre[2]
Sarah E. Studd[1]

[1]Sonoran Desert Network
National Park Service
12661 E. Broadway Blvd.
Tucson, AZ 85748

[2]Chihuahuan Desert Network
National Park Service
New Mexico State University
MSC 3ARP
Las Cruces, NM 88003

Editing and Design
Alice Wondrak Biel
Sonoran Desert Network
National Park Service
12661 E. Broadway Blvd.
Tucson, AZ 85748

November 2015

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

This report is available from the Sonoran Desert Network website, http://www.nature.nps.gov/im/units/sodn, as well as at the Natural Resource Publications Management web site, http://www.nature.nps.gov/publications/nrpm. To receive this report in a format optimized for screen readers, please email irma@nps.gov.

Please cite this publication as:

Hubbard, J. A., C. L. McIntyre, and S. E. Studd. 2015. Status of terrestrial vegetation and soils monitoring at Chiricahua National Monument, 2007–2010. Natural Resource Report NPS/SODN/NRR–2015/1081. National Park Service, Fort Collins, Colorado.

NPS 145/130531, November 2015

Contents

Figures

Tables

Plants Named in this Report

Agave palmeri	Palmer's century plant
Agave parryi	Parry's agave
Arctostaphylos pungens	pointleaf manzanita
Bothriochloa barbinodis	cane bluestem
Bouteloua curtipendula	sideoats grama
Bouvardia ternifolia	firecrackerbush
Brickellia lemmonii	Lemmon's brickellbush
Bromus arvensis	field brome
Centaurea melitensis	Malta starthistle
Cercocarpus montanus	alderleaf mountain mahogany
Cheilanthes lindheimeri	fairyswords
Cupressus arizonica	Arizona cypress
Cyperus fendlerianus	Fendler's flatsedge
Dasylirion wheeleri	desert spoon or sotol
Echinocereous sp.	hedgehog cactus
Echinochloa sp.	cockspur grass
Echinochloa colona	jungle rice
Echinochloa crus-galli	barnyardgrass
Echinocereus pectinatus	rainbow cactus
Echinocereus triglochidiatus	kingcup cactus
Eragrostis intermedia	plains lovegrass
Eragrostis lehmanniana	Lehmann lovegrass
Garrya wrightii	Wright's silktassel
Gymnosperma glutinosum	gumhead
Hedeoma dentata	dentate false pennyroyal
Heteropogon contortus	tanglehead
Juniperus deppeana	alligator juniper
Muhlenbergia emersleyi	bullgrass
Muhlenbergia polycaulis	cliff muhly
Nolina microcarpa	bear grass, or sacahuista
Opuntia engelmannii	cactus apple
Opuntia phaeacantha	tulip pricklypear
Pellaea truncata	spiny cliffbrake
Pennisetum ciliare	buffelgrass
Pinus discolor	border pinyon pine
Piptochaetium fimbriatum	pinyon ricegrass
Quercus arizonica	Arizona white oak
Quercus hypoleucoides	silverleaf oak
Quercus rugosa	netleaf oak
Quercus toumeyi	Toumey oak
Quercus turbinella	Sonoran scrub oak
Rhus virens	evergreen sumac
Schizachyrium cirratum	Texas bluestem

Executive Summary

This report summarizes results of the Sonoran Desert Network's first round of terrestrial vegetation and soils monitoring in upland areas of Chiricahua National Monument (NM), in southeastern Arizona. Forty-six permanent field-monitoring sites were established and sampled from 2007 to 2010. A planned fifth year of sampling was precluded by the Horseshoe II Fire in June 2011. The Horseshoe II Fire was the first large landscape-scale fire within the monument in 125 years.

Despite the reduced sample size, our data exceeded the sampling design criteria. Our objectives were to determine the status of and detect trends in vegetation cover, frequency, soil cover, surface soil stability, and biological soil crust cover.

Our results illustrate a complex landscape in which both elevation and soils govern vegetation by mediating soil moisture. Prior to the 2011 Horseshoe II Fire, rocky, mid-mountain sites (≤6,000'), characterized by semi-desert grasslands and savannas, gave way to pine-oak woodlands and dense manzanita shrub thickets as elevation increased. Finer soils at higher elevations supported relatively tall and dense forests of pinyon pine and juniper. Dead trees and shrubs were common across all sites—a foreshadowing of the 2011 Horseshoe II Fire.

Rock outcrop sites (>6,000') contain the characteristic rock pinnacles, or "hoodoos," for which the monument is famous. Prior to the 2011 Horseshoe II Fire (i.e., during the years covered in this report), they also contained the lowest vegetation cover within the monument. These are dual-type systems, in which clusters of oaks and manzanita occurr on disjunct soil patches and cracks interspersed between relatively large bedrock areas. These vegetation "islands" appear to receive considerable runoff from adjacent bedrock areas, favoring dense growth within the relatively small soil patches.

Preventing the spread and dominance of exotic plants is an important management goal at Chiricahua NM. Our data indicate that the exotic bunchgrass, Lehmann lovegrass (*Eragrostis lehmanniana*) has extensively colonized rocky, mid-mountain (≤6,000') areas of the monument. Lehman lovegrass was one of the three most-common grasses in these areas, and has the potential to dominate disturbed sites. This was not the case for other exotic species, or for Lehmann lovegrass on high-mountain (>6,000') sites. An additional exotic species—the annual grass, field brome (*Bromus arvensis*)—was sparse and localized. Colonization by exotics has been an important concern following the Horseshoe II Fire.

Uplands areas of the park, as a whole, appeared to be free of substantial soil erosion, although a few sites had evidence of sheet flow and rill development. Soil surfaces were well armored, with less than 2% of the soil surface consisting of unprotected, bare mineral soil. However, the majority of the resistant soil cover was composed of vegetation, leaf litter, and duff—materials that could be rapidly lost following wildfire or prolonged drought. Surface soil aggregates were relatively unstable on rocky, mid-mountain sites (≤6,000'), suggesting the potential for substantial soil loss if protective cover is lost. As soil erosion has important consequences for natural and cultural resources at Chiricahua NM, this is a key consideration for management.

We conclude that terrestrial vegetation conditions in uplands of Chiricahua NM prior to the 2011 Horseshoe II Fire were outside the historic range of natural variability. Our findings suggest that the lack of significant fire prior to 2011 resulted in an unusually high cover of fire-sensitive woody plants throughout the monument. Whether the Horseshoe II Fire restores pre-settlement conditions or sends vegetation on a new trajectory (perhaps through interactions with climate change) will be a focus of monitoring and management in the years to come.

Acknowledgements

We thank the late Superintendent Lane Baker, Chief of Resources Jason Mateljak, Biologist Adam Springer, and the staff and volunteers of Chiricahua National Monument for their on-site support of the field effort and the overall Sonoran Desert Network (SODN) Inventory and Monitoring Program. Lane was a tireless supporter of resource protection throughout her 30-year NPS career, and will be dearly missed. Beth Fallon, Laura Crumbacher, Aaron Curtis, Aedan Berge, Kate Connor, Betsy Vance, Laura Bassaraba, and Daniel Stauning conducted the field-data collection, which involved traversing some of the roughest country in the American Southwest. Betsy Vance and Megan Kimball processed the soils samples, and Steve Buckley provided expert botanical expertise for crew training and identification of unknown samples. Expert data processing and management were completed by SODN Data Manager Kristen Bonebrake and her staff; we appreciate their painstaking attention to detail and quality control. Finally, we would be remiss if we did not thank former Chief of Resources Danielle Foster for her insights into the overall monitoring protocol design, and her embrace of the management assessment-point concept.

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 (1951):

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.

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 Natural Resources 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 Chiricahua National Monument (NM; Figure 1-1). 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, stability of surface soil aggregates, and cover of biological soil crusts.

NPS/S. STUDD

Figure 1-1. A hoodoo (rock pinnacle) extends above the woodland canopy, Chiricahua 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, ecological 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 builds 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. 2012) at Chiricahua NM are to determine the status of and detect trends in (over five-year intervals):

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).
5. Biological soil crust cover by morphological group (bryophyte, light cyanobacteria, dark cyanobacteria).

1.3 How to use this report

Readers with specific interests can focus on particular sections of this report, as follows:

Just the highlights, please:
Executive Summary
Sections 4.1–4.5, 4.7
Figures 4-6, 4-7, 4-8.

Add detail on management implications:
Sections 3.2.6, 3.3.6, 3.4.6, 3.5.6
Tables 3-3, 3-6, 3-9, 3-12

Add detail on sampling design:
Chapter 2
Sections 3.1 and 4.6
Figure 2-1

This document reports and interprets the results of the first round of terrestrial vegetation and soils monitoring at Chiricahua NM, from 2007 to 2010. The original design (Hubbard et al. 2012) for this relatively large, complex park included a fifth year of sampling, which would have been 2011. However, in June 2011, the Horseshoe II Fire occurred in the park—the first large landscape fire within the monument in 125 years.

The Horseshoe II Fire had some important implications for the sampling design that are addressed in Chapters 3 and 4 of this report. In short, we decided to only include the plots sampled before the fire (2007–2010) in this status report. A later report, evaluating the effects of the fire, will compare the 2011 data with the other four years of sampling, as originally planned. A companion report summarizing fire effects and addressing post-fire management questions is currently in development. As such, this report focuses on pre-fire status, with trends to follow after subsequent sampling.

The thematic scope of this report is limited to terrestrial ecosystems. Aquatic resources, including riparian and xeroriparian vegetation, are addressed in the SODN Streams and Springs protocols.

1.4 Overview of terrestrial ecosystems

1.4.1 Park establishment and purpose

Chiricahua National Monument (Figure 1-2) was established on April 18, 1924. According to its enabling legislation, the unit was created because "certain natural formations, known as The Pinnacles, within the Coronado National Forest, in the state of Arizona, are of scientific interest, and it appears that the public interests will be promoted by reserving as much land as may be necessary for the proper protection thereof, as a National Monument" (NPS 2005). Initially managed by the U.S. Forest Service, the monument has been managed by the National Park since 1933.

1.4.2 Biogeographic and physiographic context

Chiricahua NM is located near the confluence of three major ecoregions in the American Southwest: the Apache Highlands, Chihuahuan Desert, and Arizona–New Mexico Mountains. Though it is part of the Sonoran Desert Network, Chiricahua NM actually lies east of the Sonoran Desert, in the Apache Highlands (Gori and Enquist 2003). This 30 million-acre area comprises the western section of the Chihuahuan Desert and northern limits of the Madrean ecoregions (Bailey 1998; Figure 1-3). The monument shares

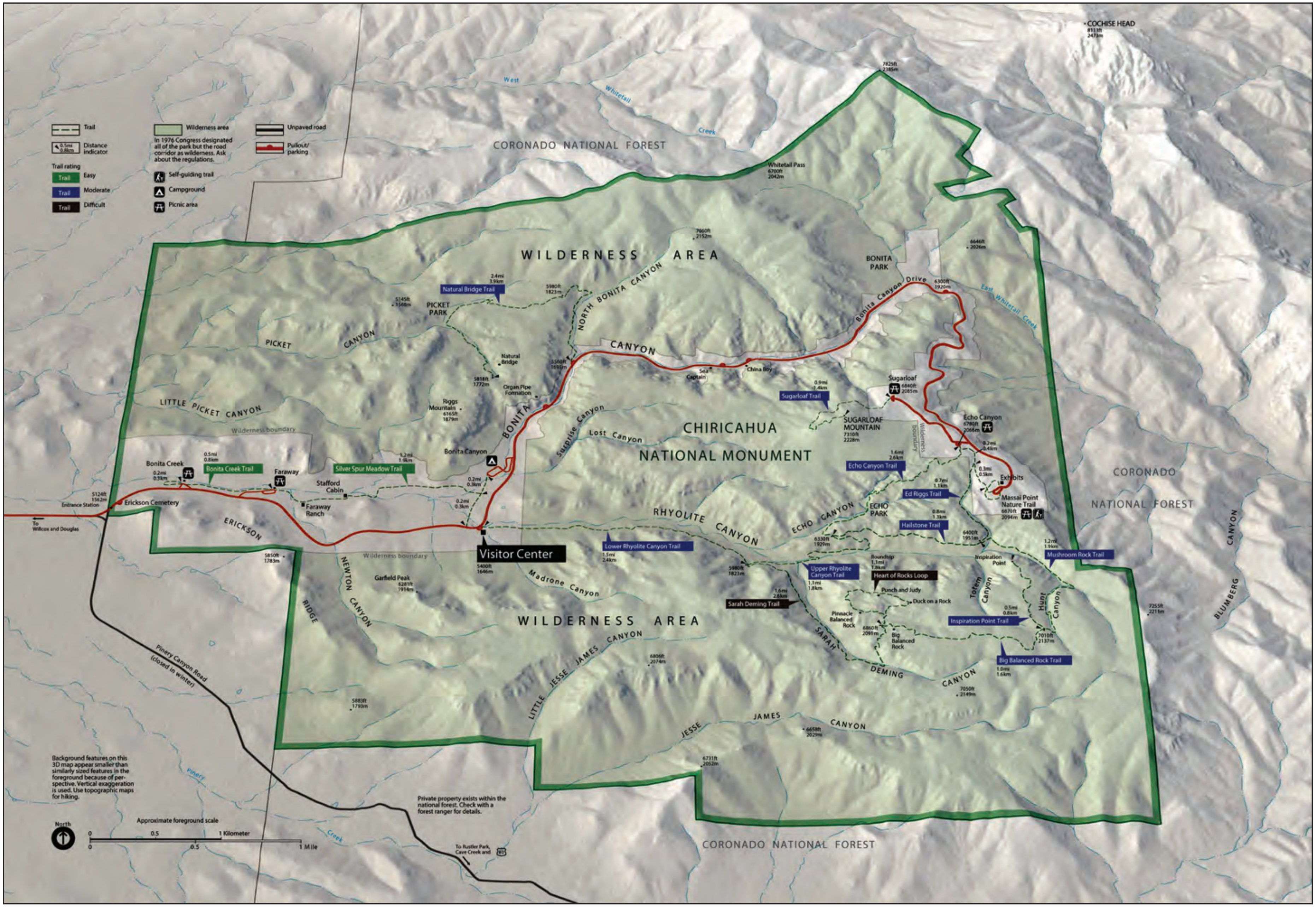


Figure 1-2. General map of Chiricahua National Monument.

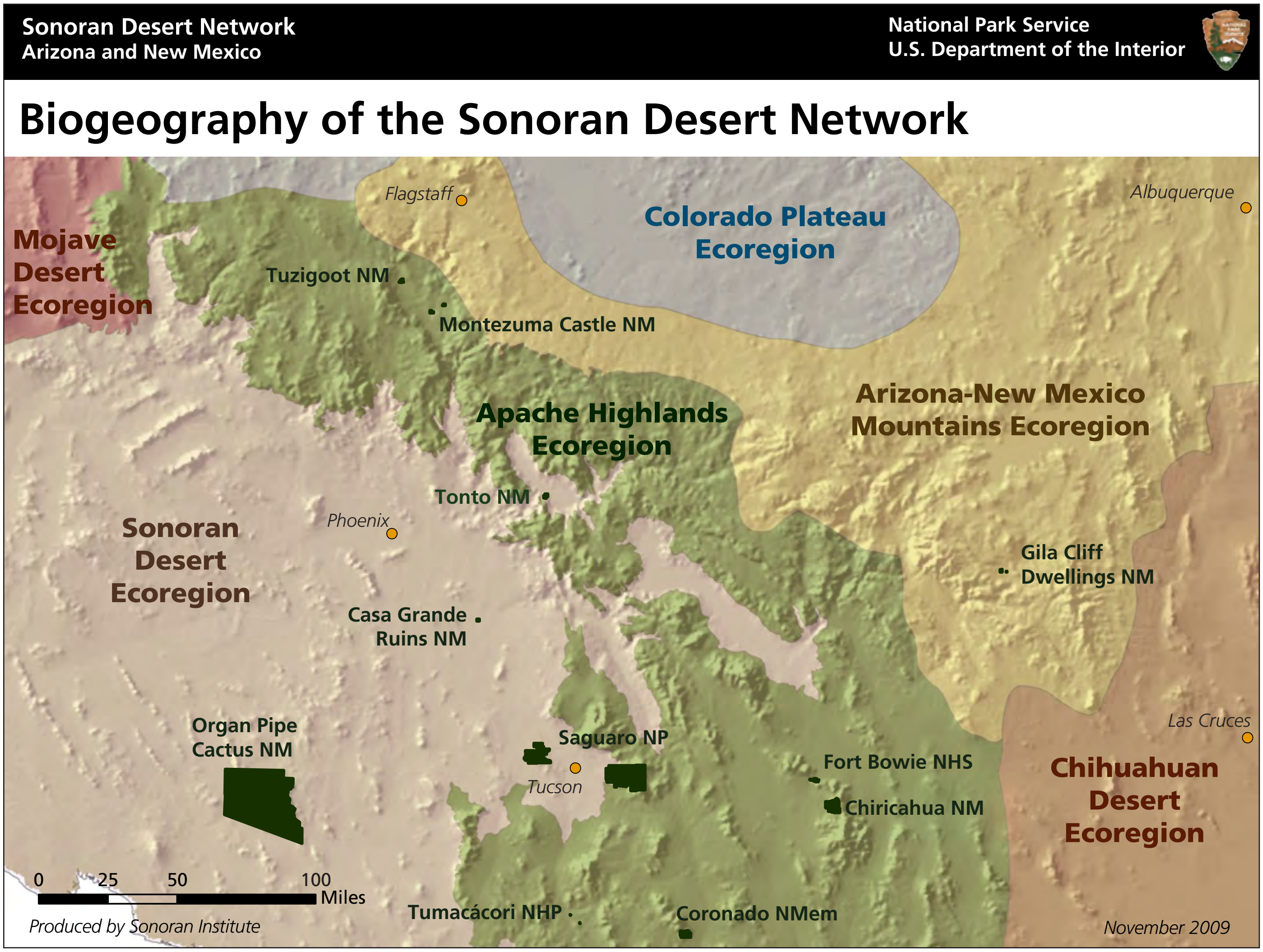


Figure 1-3. Regional biogeography, Chiricahua National Monument.

many ecological traits with three other SODN units also located in the Apache Highlands: Coronado National Memorial (NMem), Fort Bowie National Historic Site (NHS), and the Rincon Mountains of Saguaro National Park (NP). It also shares traits with Gila Cliff Dwellings NM and Guadalupe Mountains NP, located in the Arizona–New Mexico Mountains and Chihuahuan Desert ecoregions to the northeast and east, respectively.

The monument's continental position at the transition from the Sonoran to Chihuahuan deserts on the east and west, and the Rocky Mountains to Sierra Madre on the north and south, is reflected in the composition and biodiversity of its flora and fauna (Powell et al. 2008).

Situated between ~5,180 and 7,825 feet (1,579 and 2,408 m) in elevation, Chiricahua NM encompasses steep, deep canyons that dissect surrounding plateaus and mountain mesas along the northern extent of the Chiricahua Mountains in southeastern Arizona. There are three major canyon systems: Bonita and Rhyolite canyons, which converge near Faraway Ranch near the center of the monument, and the more remote Jesse James Canyon, near the unit's southern boundary (see Figure 1-2).

The rugged country found within the monument is typical of the Apache Highlands ecoregion (TNC 1999) and, more generally, the Basin and Range topography of the Intermountain West (Scarborough 2000).

1.4.3 Local geology and soils

The monument was set aside for the unique rock pinnacles, or "hoodoos," that are most common in its central and eastern portions (see Figure 1-1). Hoodoos are erosional features formed in the Rhyolite Canyon Tuff, which accumulated in large quantities following three massive volcanic eruptions about 26.9 million years ago (Graham 2009). The subsequent collapse of the magma chamber produced the giant Turkey Creek caldera. Evidence of this dynamic geologic past is found throughout Chiricahua NM. The park also includes late Paleozoic, Permian limestone that is an order of magnitude older than the more evident and iconic volcanic features (Graham 2009).

Uplands soils within Chiricahua NM are generally shallow and rocky, with important exceptions in upper Whitetail Canyon (near Cochise's Head) and around the base of Sugarloaf Mountain, where surface soils are generally less rocky (Denney and Peacock 2000). By contrast, soils are relatively deep along the canyon bottoms, particularly where Bonita and Pickett Canyons exit the park along the western boundary (Denney and Peacock 2000).

1.4.4 Climate and hydrology

Chiricahua NM experiences climate typical of the Apache Highlands ecoregion: highly variable, bimodal precipitation with a considerable range in daily and seasonal air temperature, and relatively high potential evapotranspiration rates (TNC 1999). Approximately two-thirds of the annual precipitation falls during summer thunderstorms (Figure 1-4a), where maximum air temperatures often approach 30°C (Figure 1-4b) and lead to violent (and often localized) rainstorms. The bulk of the remaining annual precipitation falls in relatively gentle cool-season events of broad extent, often as snow (Davey et al. 2007). Winters are often cold relative to those in many other SODN parks.

Maximum and minimum average air temperatures were generally comparable with 30-year normals, although mid-summer maximum average air temperatures were slightly higher than the normals from 2002 to 2010 (Figure 1-4b). Monthly precipitation during and preceding vegetation and soil sampling was substantially lower than the 30-year normal, particularly during the summer monsoon. Precipitation was also much lower during autumn/early winter periods when tropical storms are historically common (Figure 1-4a; Davey et al. 2007).

Unfortunately, records from the monument weather station are generally absent from 2006 to 2010, but regional observations (Weiss et al. 2009) suggest the drought of the early 2000s continued and perhaps intensified through the sampling period.

1.4.5 Brief overview of natural resource inventories

Twelve basic natural resource inventories were authorized and funded through the National Park Service for all 270 parks deemed to have "significant" natural resources, including Chiricahua NM (NPS 2009). At time of writing, ten of these inventories had been completed for the park, one was in progress, and one was to be completed at some future date (Table 1-1). Coordinated at the national level, most of these inventories rely on existing information and deliver products ranging from electronic datasets to short reports. However, three inventories (species lists, species occurrence and distribution, and vegetation characterization) involved extensive fieldwork culminating in detailed reports. See NPS (2009) for additional information on the Natural Resource Inventory Program.

1.4.6 Other long-term monitoring and related ecological research

In addition to terrestrial vegetation and soils monitoring, the Sonoran Desert Network conducts long-term monitoring on air quality, birds, climate, exotic plants (early detection), groundwater, springs, and xeroriparian resources associated with the major canyon systems within the monument. Details on these efforts are provided in NPS (2005) and at the SODN website (http://science.nature.nps.gov/im/units/sodn/).

Bat community dynamics in and around surface waters have been the focus of ongoing surveys by the Arizona-Sonora Desert Museum (Krebbs 2013). Conducted annually at five locations since 2000, this is one of the longest-running projects in the region that focuses on areas other than roosts.

Vegetation and fire ecology have been long-standing research topics at Chiricahua NM.

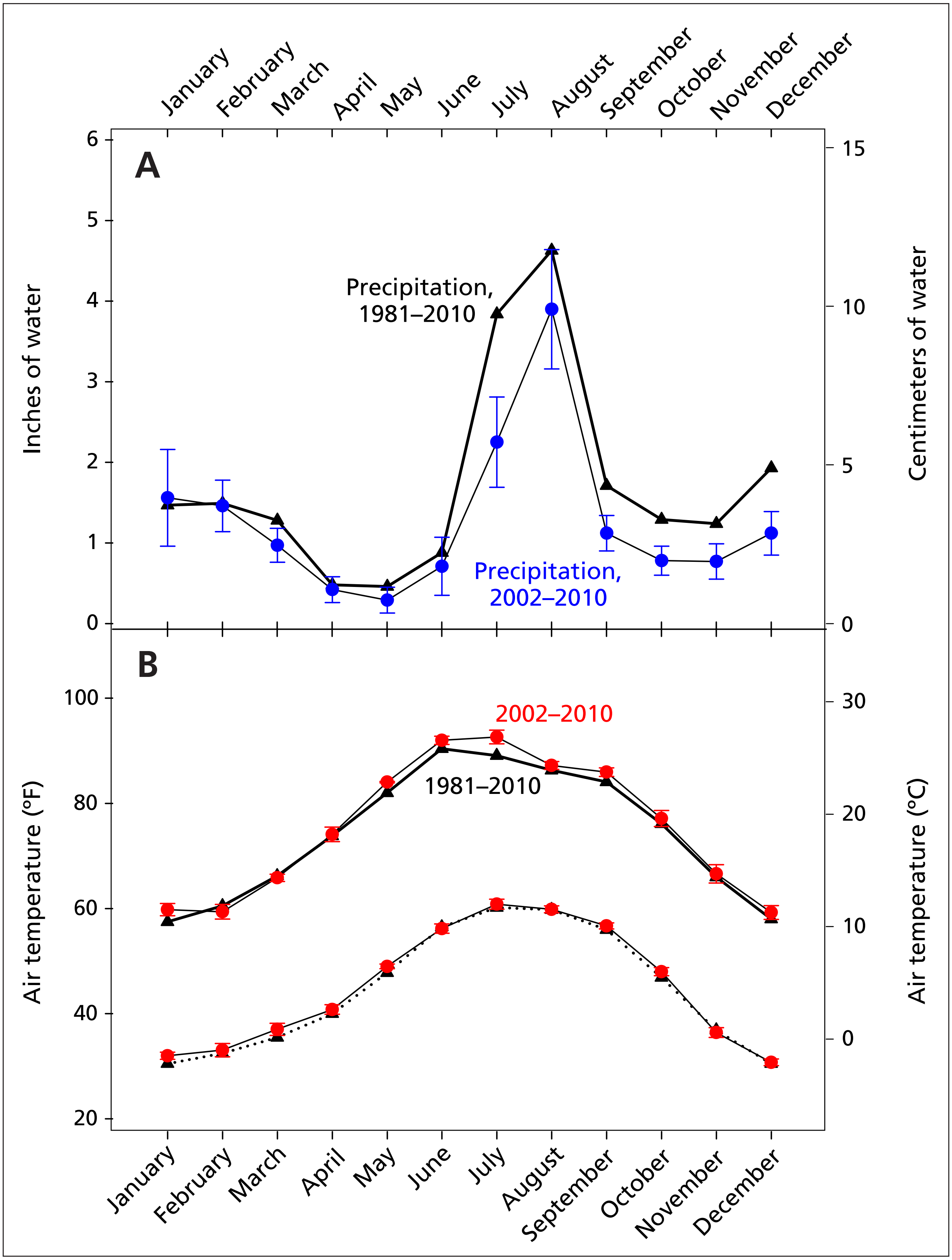


Figure 1-4. Climate data in the context of 30-year normals (1981–2010) for (a) minimum and maximum average monthly air temperature and (b) average monthly precipitation, Chiricahua National Monument, 2002–2010. Data are from the NOAA Cooperative Observer weather station located at the Visitor Center. Numerous missing values occurred from 2006 to 2008 (www.climateanalyzer.org). Error bars represent standard error by month.

Table 1-1. Status of natural resource inventories at Chiricahua National Monument, March 2015.

Inventory	Description	Status (2015)
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/	Complete
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 at the Cave Canyon Spring. *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.	Complete
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 Species Occurrence and Distribution	Documentation of the occurrence and distributions of >90% of the vertebrates & vascular plant species, based on prior research and fieldwork. *Products:* Powell and others (2007)	Complete
Vegetation Characterization	Description, classification, and mapping of vegetation communities, based on fieldwork.	In progress
Water Body Location and Classification	Basic geographic data on hydrologic units.	Complete

Roseberry and Dole (1939) used field data to generate a detailed vegetation map, which served as the basis for investigating the effects of fire suppression by later authors. Taylor and students (summarized in Taylor 2004) updated and extrapolated the 1937 vegetation map using aerial photos and field data in the 1990s and early 2000s.

Tree rings, aerial photos, and plot data have served as the basis for a number of fire and flood reconstructions for the park from the 1980s and 1990s (Swetnam et al. 1989; Barton 1996; Baisan and Morino 2000). The recent Horseshoe II Fire (2011) may again stimulate research of fire ecology and vegetation structure and function.

Two park-based long-term research projects were being initiated at the time of writing: mammal monitoring using remote wildlife cameras, and watershed-scale climate investigations (pers. comm., J. Mateljak).

In 2011, a comprehensive Natural Resource Condition Assessment (NRCA) was completed by Dimmit and others (2011). Readers are directed to this excellent source for additional details on the history of research in and around the monument, local and regional ecology and anthropogenic stressors, and management recommendations.

1.5 Leading natural resource management issues

The recent NRCA (Dimmitt et al. 2011) summarized leading natural resource issues related to terrestrial vegetation and soils at Chiricahua NM. They include (1) colonization by invasive exotic plants, (2) altered fire regimes, and (3) the consequences of climate change.

1.5.1 Invasive exotic plants

Biological invasions into new regions, whether natural, accidental, or deliberate, have increased at unprecedented rates in the past few hundred years (D'Antonio and 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 and 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 living soil cover are indicative of communities that have been degraded by grazing. These factors have been linked to displacement, by non-native grasses, of native species that are less well-adapted to such pressures (Shinneman and Baker 2009). In general, Southwestern semi-desert grasslands, savannas, and riparian community types are at greatest risk of invasion, due to modified disturbance regimes involving fire and herbivory.

Previous vegetation research at Chiricahua NM documented a total of 61 non-native species (Table 1-2), which is approximately 6% of the monument's known flora (Powell et al. 2008). Note that many of the non-native species are ornamental, garden, or forage plants associated with the Faraway Ranch Historic District (Powell et al. 2008). Halvorson and Guertin (2003) mapped the distribution of 25 non-native species via roaming surveys, finding the greatest extent and abundance of exotics at lower elevations on the west side of the monument.

Invasive exotic plants are components of three additional SODN monitoring procotols at Chiricahua NM: Invasive Species–Early Detection, Springs, and Washes (see http://go.nps.gov/sodn).

Dimmit and others (2011) noted that "although there are numerous exotic species established in the park, the great majority do not appear to be invasive (e.g., they are not causing significant ecological harm or posing a health hazard)." Good examples are the many non-native ornamental or crop species in the vicinity of Faraway Ranch.

In addition to a number of troublesome xeroriparian invasive species, Dimmit and others (2011) recommended that management and monitoring focus on the upland annual herb, Malta starthistle (*Centaurea melitensis*). The authors also cited invasion by the South African perennial bunchgrass, buffelgrass (*Pennisetum ciliare*) as a major concern. This exotic has developed new, more cold-hardy strains and is expected to flourish under the warmer temperatures likely to be associated with climate change. Park management has also made Lehmann lovegrass (*Eragrostis lehmanniana*) a management priority (pers. comm., J. Mateljak).

1.5.2 Altered fire regimes

Several tree-ring studies (Swetnam et al. 1989; Barton 1999; Baisan and Morino 2000; Barton et al. 2001) of historic fire occurrence in and around Chiricahua NM exhibit a pattern similar to that of most of the American Southwest: relatively frequent ground fire prior to the late 19th century, when extensive fire-suppression activities and the onset of livestock grazing greatly limited the occurrence and extent of wildfire (Barton 1993; Covington and Moore 1994). The result was the absence of widespread fire at Chiricahua NM from 1886 (Swetnam et al. 1989) until the Horseshoe II Fire of 2011.

Effective fire suppression had important consequences for the Chiricahua landscape. Taylor (2004) combined repeat aerial photography (1935 vs. 1993) and field plots to document dramatic increases in woody plant cover, particularly that of fire-sensitive trees, such as border pinyon pine (*Pinus discolor*).

Fire ecology and the importance of altered fire regimes at Chiricahua NM will be addressed in greater depth in a future report that considers post-fire (2012) data.

1.5.3 The consequences of climate change

Although there is a near consensus among scientists regarding the occurrence, causes, mechanisms, and broad-scale ecological consequences of global climate change, rates and patterns at finer spatial and temporal scales can be challenging to predict (IPCC 2007). However, as science and society increasingly focus on climate change and the contingent consequences for ecosystems and human civilization, our understanding of these impacts is improving.

Table 1-2. Non-native, potentially invasive plants (by lifeform) documented at Chiricahua National Monument through 2010.

Scientific name	Common name
FORB/HERBS	
Amaranthus blitoides	mat amaranth
Anagallis arvensis	scarlet pimpernel
Asparagus officinalis	garden asparagus
Brassica rapa var. *rapa*	field mustard
Capsella bursa-pastoris	shepherd's purse
Centaurea melitensis	Malta star-thistle
Centaurea rothrockii	Rothrock's knapweed
Chenopodium album	lambsquarters
Convolvulus arvensis	field bindweed
Datura inoxia	pricklyburr
Descurainia sophia	herb sophia
Erodium cicutarium	redstem stork's bill
Erodium cicutarium ssp. *jacquinianum*	redstem stork's bill
Euphorbia dentata	toothed spurge
Ipomoea coccinea	redstar
Ipomoea hederacea	ivyleaf morning-glory
Ipomoea purpurea	tall morning-glory
Latuca serriola	prickly lettuce
Lonicera japonica	Japanese honeysuckle
Macroptilium gibbosifolium	variable bushbean
Medicago sativa	alfalfa
Melitotus albus	white sweetclover
Melitotus officinalis	yellow sweetclover
Nepeta cataria	catnip
Rumex crispus	curly dock
Salsola kali	Russian thistle
Salsola tragus	prickly Russian thistle
Sida abutifolia	spreading fanpetals
Sisymbrium irio	London rocket
Sonchus asper	spiny sowthistle
Sonchus oleraceus	common sowthistle
Taraxacum officinale	common dandelion
Tribulus terrestris	puncturevine
Trifolium repens	clover
Verbascum blattaria	moth mullein
Verbascum thapsus	common mullein
Verbascum virgatum	wand mullein

Scientific name	Common name
GRAMINOIDS	
Bromus catharticus	rescuegrass
Bromus hordeaceus	soft brome
Bromus rubens	red brome
Cynodon dactylon	Bermudagrass
Cyperus esculentus	chufa flatsedge
Echinochloa colona	jungle rice
Echinochloa crus-galli	barnyardgrass
Eragrostis cilianensis	stinkgrass
Eragrostis curvula	weeping lovegrass
Eragrostis lehmanniana	Lehmann lovegrass
Hackelochloa granularis	pitscale grass
Hordeum murinum	mouse barley
Hordeum murinum ssp. *glaucum*	smooth barley
Hordeum murinum ssp. *leporinum*	leporium barley
Lolium pratense	meadow ryegrass
Panicum miliaceum	broomcorn millet
Polypogon monspeliensis	annual rabbitsfoot grass
Polypogon viridis	beardless rabbitsfoot grass
Setaria viridis	green bristlegrass
Sorghum halepense	Johnsongrass
SUBSHRUBS	
Marrubium vulgare	horehound
Salvia microphylla	baby's sage
SHRUB	
Pyracantha coccinea	scarlet firethorn
TREES	
Diospyros kaki	Japanese persimmon
Prosopis juliflora	mesquite
Pyrus communis	common pear

See Powell and others (2008) for a detailed discussion of data sources.

The Assessment of Climate Change in the Southwest United States (Overpeck et al. 2013) predicted, with high or medium-high confidence, that the Southwestern U.S. will sustain increased drought and heat extremes, and decreased available water resources, due to climate change. Positive feedback cycles with drought, fire, and insect outbreaks are forecast, as are increased occurrence of extreme weather events. See Overpeck and others (2013) and the Intergovernmental Panel of Climate Change (IPCC 2007, with focus on Chapter 14) for additional information on the predicted consequences of global climate change.

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 (2012) 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) (Table 2-1).

Perennial vegetation was recorded to species. 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. 2012, SOP#4) was recorded by substrate class (e.g., rock, gravel, litter), with biological soil crusts recorded to morphological group (light cyanobacteria, dark cyanobacteria, lichen, moss).

Table 2-1. Vegetation height categories used in upland monitoring, Chiricahua National Monument.

Category	Height
Field	<0.5 m
Subcanopy	0.5–2.0 m
Canopy	(>2.0 m

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 (see Figure 2-1). The occurrence of any species/lifeform that was not measured on the adjacent line-point transect was recorded to determine a within-plot frequency of 0–5.

2.1.3 Soil aggregate stability

Surface soil aggregate stability was measured using a modified wet aggregate stability method (Herrick et al. 2005a). From 2007 to 2010, samples were collected at pre-determined points within each plot, on both sides of the six line-point intercept transects. A total of 48 uniformly sized samples (2–3 mm thick and 6–8 mm on each side) 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 dipped slowly 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 (Herrick et al. 2005a ; Table 2-2).

Table 2-2. Categories for aggregate stability of surface soils.

Class	Category*	Criteria
1	Very unstable	50% of structural integrity lost (melts) within 5 seconds of immersion in water AND <10% of soil remains on sieve after 5 dipping cycles, OR soil too unstable to sample (falls through sieve)
2	Unstable	50% of structural integrity lost (melts) within 5–30 seconds of immersion in water AND <10% of soil remains on sieve after 5 dipping cycles
3	Somewhat unstable	50% of structural integrity lost (melts) within 30–300 seconds of immersion in water OR <10% of soil remains on sieve after 5 dipping cycles
4	Moderately stable	10–25% of soil remains on sieve after 5 dipping cycles
5	Stable	25–75% of soil remains on sieve after 5 dipping cycles
6	Very stable	75–100% of soil remains on sieve after 5 dipping cycles

*Adapted from Herrick and others (2005a)

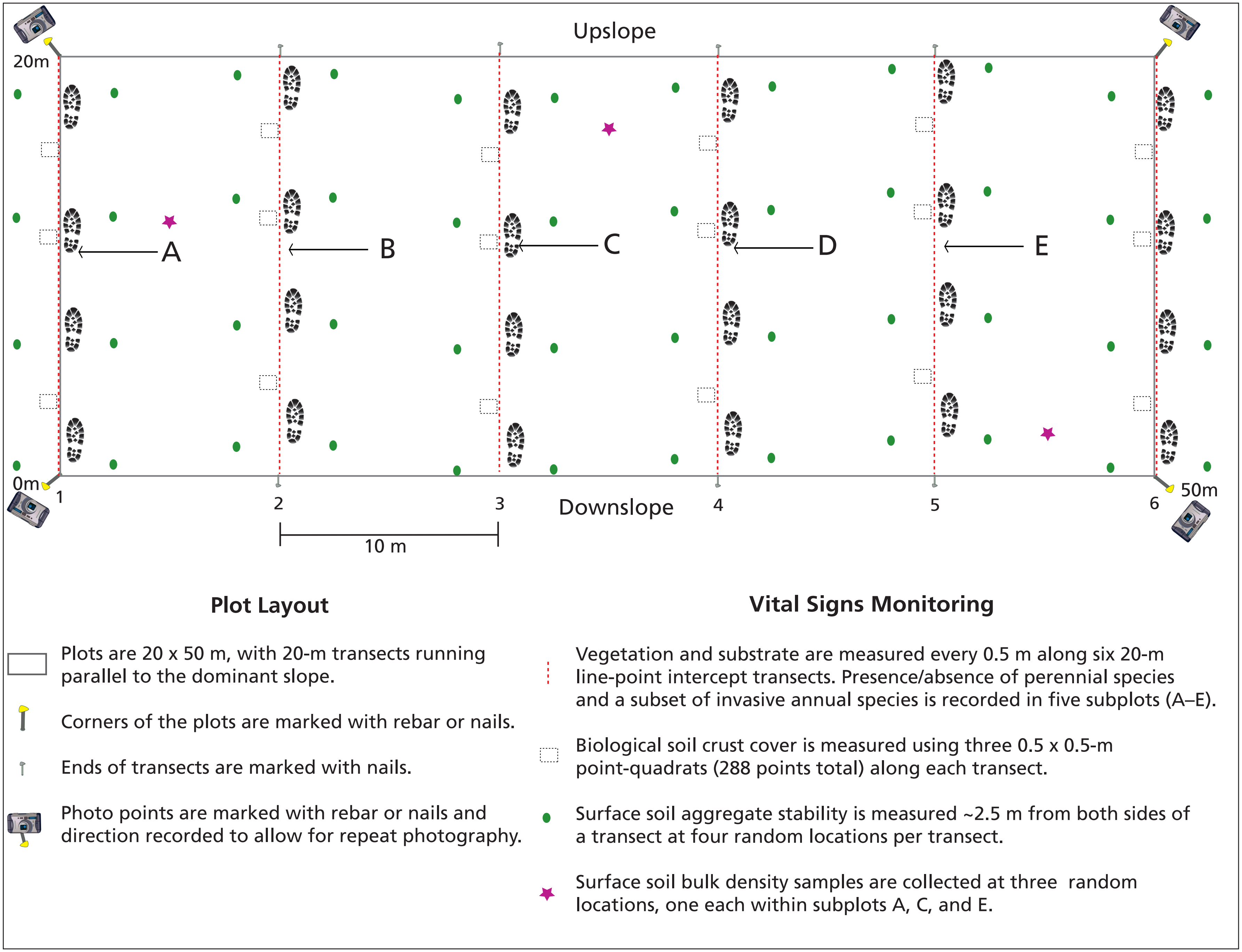


Figure 2-1. Terrestrial vegetation and soils monitoring plot design. See Hubbard and others (2012) for additional details on design and data collection.

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, erosion features, slope, and slope position were recorded at 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 terrestrial vegetation and soils plots are permanent plots that are revisited on 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. Such an event—the Horseshoe II Fire—occurred in the fifth year of sampling (2011). The implications for our sampling design are addressed in Section 4.6 of this document.

Plots were allocated by elevation and soil rock-fragment classes (see Section 3.2.3, Hubbard et al. 2012), with plots being proportionately allocated to four strata (Table 2-3). We allocated a total of 48 monitoring plots in a spatially balanced arrangement (Section 2.2.2), based on a priori expectations of required sample size to meet our criteria for statistical power and detectability (Sections 2.2.5–2.2.6).

Plots were not allocated to strata that occupied less than 5% of the sampling frame. Therefore, inference from the plots at Chiricahua NM is to most terrestrial areas of the park by elevation strata, excepting the areas discussed in Section 2.2.3.

2.2.2 Spatial balance

The permanent, 20 × 50-m sampling plots used in this protocol are allocated through a Reversed Randomized Quadrant-Recursive Raster (RRQRR) spatially balanced design (Theobald et al. 2007), using the "spatially

Table 2-3. Initial allocation of permanent terrestrial vegetation and soils monitoring plots by stratum, Chiricahua National Monument.

Stratum	Elevation	% rock fragments	Percentage of total: Total area (acres)	Percentage of total: Park area	Percentage of total: Frame area	Plots per stratum: Number	Plots per stratum: Number per year	Plots per stratum: 2007–2010 only
0 (Excluded)			3,007	25	0	0	0	0
401	4,500–6,000'	<35%	190	2	2	0	0	0
402 (Rocky, mid-mountain)	4,500–6,000'	35–90%	2,476	21	28	15	3	15
403	4,500–6,000'	BRO	272	2	3	0	0	0
501 (Non-rocky, high-mountain)	>6,000'	<35%	679	6	8	5*	1	3
502 (Rocky, high-mountain)	>6,000'	35–90%	3,518	29	39	18	3 or 4	12
503 (High-mountain rock outcrops)	>6,000'	BRO	1,862	16	21	10	2	8

Strata with <5% of park area (shown in grey) were excluded.

*Stratum 501 was initially allocated 4 plots. One plot was added to the stratum to comply with new protocol rule of 5 plots per stratum (see Hubbard et al. 2012).

BRO = bedrock, rock outcrop

balanced sample" function in the STAR-MAP 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 also 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. 2012) 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 Chiricahua NM includes all terrestrial areas within park boundaries, except for the following (Figure 2-2):

- Slopes of ≥ 45° (for crew safety)
- Roads, buildings, and parking areas (including 100-m buffer)
- Trails washes, and streams (including 50-m buffer)
- Selected fragile cultural features
- Strata that contained <5% of the area of the park

The total area excluded under the first four criteria was 3,007 acres (~1,217 ha), or 25% of the park area. An additional 4% of the park (462 acres/187 hectares) was excluded because it occurred in strata that occupied less than 5% of the sampling frame (see Table 2-3).

2.3 Analysis

2.3.1 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 provide context and aid interpretation of ecological information in 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 where scientists and managers pause, review the available information in detail, and consider options. Bennetts and others (2007) provide 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 Chiricahua NM, we propose some assessment points based on the ecological literature and our knowledge of these ecosystems and park management goals (Table 2-4). We intend these to (1) initiate a discussion of potential indicators and assessment points and (2) to provide a useful framework for evaluating terrestrial vegetation and soils data in a broader ecological and managerial context.

2.3.2 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. The assumption is that vegetation and dynamic soil functional attributes respond differently to environmental factors that can be clearly defined and are immutable over

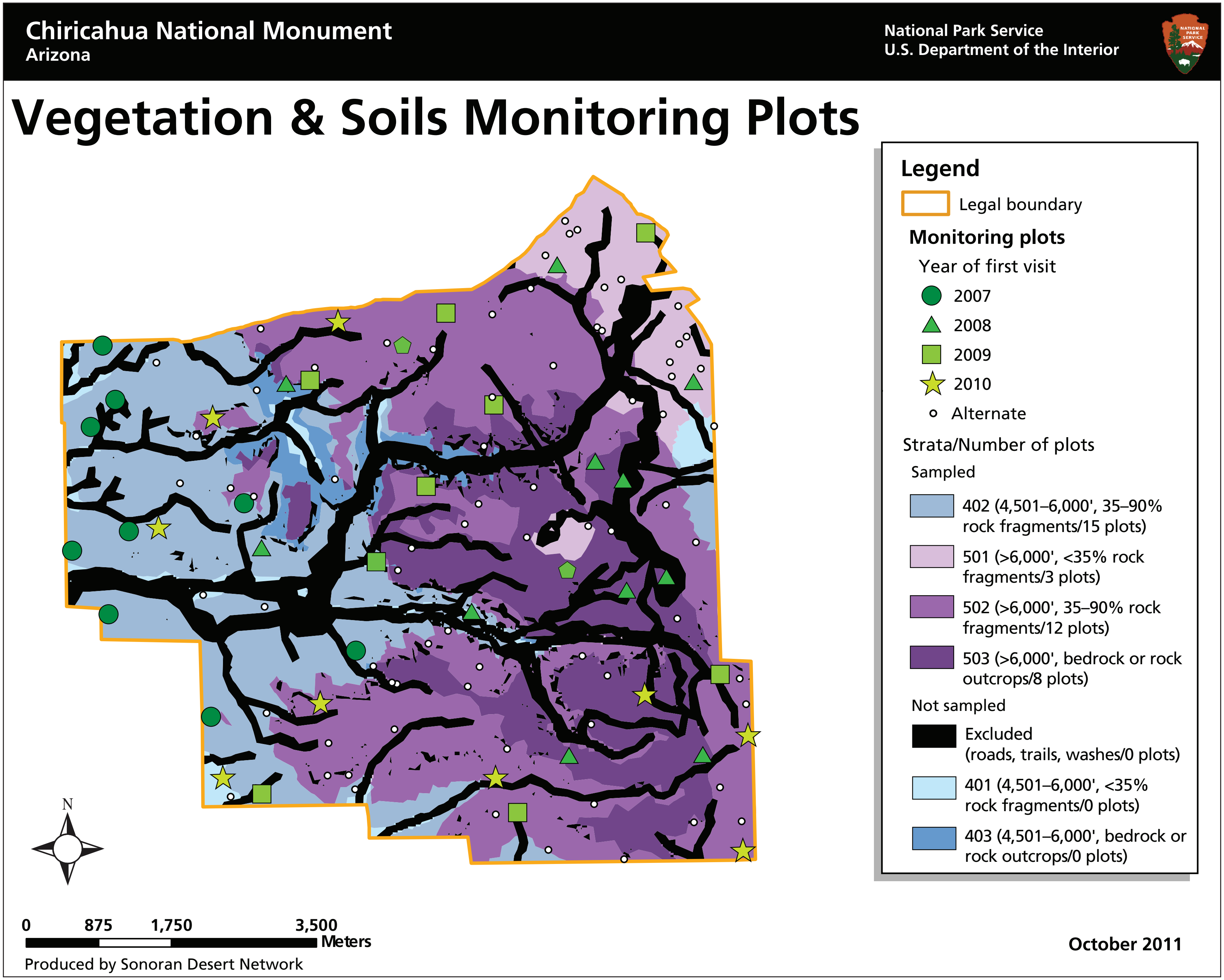


Figure 2-2. Sampling frame for terrestrial vegetation and soils monitoring, Chiricahua National Monument.

Table 2-4. Proposed management assessment points for terrestrial vegetation and soils parameters, Chiricahua National Monument.

Issue	Management assessment point	Stratum			
		402	501	502	503
Erosion hazard	Bare ground (with no overhead vegetation) >20%	X	X	X	X
	Surface soil aggregate stability (with no overhead canopy) <Class 3	X	X	X	X
Plant community resilience	Annual plant cover: total plant cover >1:4 (field)	X	X	X	X
	Percent cover of perennial grasses <25% (field)	X			
	Tree + shrub cover >50% (subcanopy)	X			
	Percent cover of dead plants >5% (subcanopy)		X	X	X
	Percent cover of dead plants >5% (canopy)		X	X	X
Exotic plant dispersal	Extent of exotic plants >50%	X	X	X	X
Exotic plant invasion	Total exotic plant cover >10% (field)	X	X	X	X
	Exotic plant cover: total plant cover >1:4 (field)	X	X	X	X
Fire hazard	Litter + duff >50%	X	X	X	X
	Percent cover of dead plants >5% (field)	X	X	X	X
	Percent cover of dead plants >5% (subcanopy)	X			

402=rocky, mid-mountain, 501=non-rocky, high-mountain, 502=rocky, high-mountain, 503=high-mountain rock outcrop

management and monitoring timescales (Bonham 1989).

To evaluate the efficiency and pertinence of our pre-selected elevation strata, we contrasted the similarity of the vegetation communities on each stratum using permutational multivariate analysis of variance on vegetation similarity matrices (PERMANOVA+), non-metric multidimensional scaling (MDS), and SIMPER, a permutation procedure that reveals which species contribute the 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). Based on the results of the strata evaluation, we may combine some strata or modify sample sizes for a given stratum.

2.3.3 Statistical power to distinguish status from management assessment points

Estimating our statistical power to distinguish current conditions (status) from management assessment points (see Section 2.2.4) is important for both protocol design (especially determining adequate sample sizes) and data interpretation. Adequate sample size (number of plots) is estimated by Herrick and others (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 (we set at 90%),

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

MDC = minimum detectable change from the assessment point (we 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.

2.3.4 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:

Sdiff = Standard deviation of the differences between paired samples,

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

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

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

In this case, we only have one year of data, so we estimate "*Sdiff*" using the following equation:

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

Where:

S1 = Sample standard deviation among sampling units at first time period and

$coor_{diff}$ = 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.

2.3.5 Vegetation formations

Vegetation formation types were determined using a key (Figure 2-3), and based on the relative abundances of different plant lifeforms within each monitoring plot. Vegetation formations (Keddy 2007) describe the overall structure of a plant community from the perspective of lifeforms rather than species (e.g, "perennial bunchgrasses" vs. *Bouteloua curtipendula*). Using the data collected in accordance with Section 2.1.1. above, we assign a formation to each plot, to provide additional detail and context for understanding the conditions of monitoring sites and as a linkage to vegetation mapping and other landscape-scale research and monitoring applications.

Key to Vegetation Formations in Sonoran Desert Network Parks

1. What is the dominant surface cover?

- Trees..go to......................... **2**
- Shrubs..go to......................... **3**
- Herbaceous...go to......................... **4**
- Sparse vegetation (1–10%) or Rock/Bare Soil...................go to......................... **5**
- Agriculture ....go to......................... **6**

2. Trees:

1^1 Tree Cover >60%?

2^1 Site is predominantly associated with an ephemeral watercourse. **Intermittently Flooded Forest (IFF)**

2^2 Site is predominantly associated with a perennial watercourse. **Riparian Forest (RF)**

2^3 Site is in an upland zone. **Forest (F)**

1^2 Tree Cover <60%?

3^1 Site is predominantly associated with an ephemeral watercourse. **Intermittently Flooded Woodland (IFW)**

3^2 Site is predominantly associated with a perennial watercourse. **Riparian Woodland (RW)**

3^3 Site is in an upland zone. **Woodland (W)**

3. Shrubs:

1^1 Tree Cover > 10%. **Wooded Shrubland (WS)**

1^2 Tree Cover < 10%. **Shrubland (S)**

4. Herbaceous:

1^1 Tree cover < 10% AND Shrub cover < 10% **Herbaceous (H)**

1^2 Tree and/or Shrub cover >10%

2^1 Tree cover > Shrub cover **Tree Savanna (TS)**

2^2 Tree cover < Shrub cover **Shrub Savanna (SS)**

5. Sparse Vegetation/Rock/Bare Soil:

1^1 Site is predominantly bedrock or surface rock with vegetative cover less than 10%.

2^1 Vegetation is primarily tree cover. **Wooded Rock Outcrop (WRO)**

2^2 Vegetation is primarily shrub cover. **Shrubby Rock Outcrop (SHRO)**

2^3 Vegetation is primarily herbaceous cover. **Herbaceous Rock Outcrop (HRO)**

2^4 There is no clear dominant. **Sparse Rock Outcrop (SRO)**

1^2 Site is predominantly covered with boulders, cobble, bare soil, or gravel with vegetative cover less than 10%.

3^1 There is no vegetation cover. **Barren (B)**

3^2 Vegetation is primarily tree cover. **Wooded Barren (WB)**

3^3 Vegetation is primarily shrub cover. **Shrubby Barren (SHB)**

3^4 Vegetation is primarily shrub cover. **Herbaceous Barren (HB)**

3^5 There is no clear dominant. **Sparse Barren (SB)**

6. Agriculture:

1 Site is predominantly agricultural land. **Agricultural (A)**

Figure 2-3. Key to vegetation formations in Sonoran Desert Network parks (follows Studd et al. 2013).

3 Results

3.1 Design considerations

3.1.1 Evaluation of strata

PERMANOVA+ results indicated strong differentiation of plant communities by the two elevation zones (above vs. below 6,000', Pseudo-F = 7.85, P(perm.) = 0.001) and by the three surface soil rock-fragment classes (<35%, 35–90%, rock outcrop; Pseudo-F = 3.35, P(perm) = 0.001). Non-metric multi-dimensional scaling (MDS) and cluster analysis supported this ordering by stratum, with the plots arranged in a continuum of vegetation similarities from lower, non-rocky sites toward higher, rockier sites (Figure 3-1), rather than distinct, tight groupings of abruptly dissimilar plots.

Based on this analysis, we maintained the original stratification design on all subsequent data presentation and analysis (see Figure 2-3), using strata 402 (rocky, mid-mountain), 501 (non-rocky, high-mountain), 502 (rocky, high-mountain), and 503 (high-mountain rock outcrop).

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

Despite using only about four-fifths of our planned sample size (38 versus 48 plots) due to the Horseshoe II Fire in 2011 (see Section 1.3), our design generally exceeded our expectations for statistical power to detect trends in plant lifeforms and common perennial species (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 most detected perennial species and lifeforms (see Tables 3-1, 3-4, 3-7, 3-11).

The only exceptions were in the non-rocky, high-mountain (501) stratum (see Table 3-4), where the grasses, bullgrass (*Muhlenbergia emersleyi*) and cliff muhly (*M. polycaulis*), had estimated change detections of 15% and 11%, respectively, in the field layer (see Table 2-1). Border pinyon pine (*Pinus discolor*) was also problematic in the canopy layer (25% change detection) and, to a lesser extent, the subcanopy (13% change detection). These species-level issues carried through to their corresponding lifeforms and to total vegetation cover (Table 3-4).

3.2 Rocky, mid-mountain (402) stratum

Comprising nearly 21% of Chiricahua NM, sites in the rocky mid-mountain (402) stratum (see Table 2-3 for strata descriptions) occur primarily in the western and southern foothills of the monument (Figure 3-2; fig-

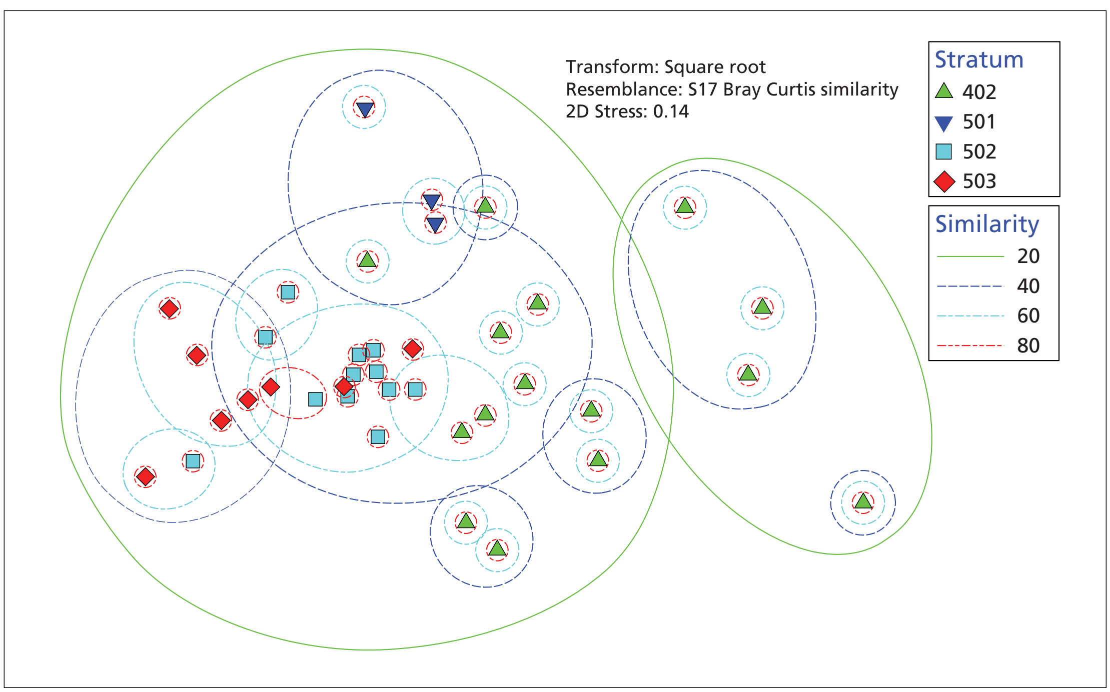


Figure 3-1. Non-metric multidimensional scaling indicates similarity of vegetation communities by elevation and soil strata. The distance between any two points increases as their composition and structure differ.

ures and tables begin on page 22). This stratum is found extensively in mountain ranges and "sky islands" of the American Southwest—including Big Bend, Carlsbad Caverns, Guadalupe Mountains, and Saguaro national parks, Coronado National Memorial, Fort Bowie NHS, and Gila Cliff Dwellings NM. See Appendix A for photographs.

3.2.1 Vegetation formations and lifeforms

All but four rocky, mid-mountain monitoring plots comprised tree or shrub savannas. One plot each was grassland, wooded shrubland, woodland, and forest (see Figure 3-2). The dominance of savannas (dual-type systems with scattered trees or shrubs in a matrix of grasses and forbs) is reflected in the tremendous lifeform diversity recorded within these plots (Figure 3-3).

All major lifeforms were encountered on rocky, mid-mountain monitoring plots, with slightly more total vegetation cover in field than subcanopy layers (see Table 2-1 for layer descriptions). Canopy cover was approximately one-third to one-fifth that of the other height categories, and (unsurprisingly) consisted of shrubs and trees (Figure 3-3).

The greatest lifeform diversity was found in the field layer, with comparable cover for all plant lifeforms except the more dominant perennial grasses and snags (i.e., standing dead perennial vegetation), and the low cover of vines (Figure 3-3).

3.2.2 Cover and extent of perennial plant species

Rocky, mid-mountain monitoring sites were co-dominated by the native perennial bunchgrasses, bullgrass and sideoats grama (*Bouteloua curtipendula*), and the non-native Lehmann lovegrass (Table 3-1). Common associates in the field layer included the bunchgrass, tanglehead (*Heteropogon contortus*); the shrub, pointleaf manzanita (*Arctostaphylos pungens*); the subshrubs, beargrass, or sacahuista (*Nolina microcarpa*) and desert spoon, or sotol (*Dasylirion wheeleri*); and the succulent, Palmer's century plant (*Agave palmeri*; Table 3-1).

The evergreen oaks, Sonoran scrub oak (*Quercus turbinella*) and, to a lesser extent, Arizona white oak (*Quercus arizonica*), dominated subcanopies. The shrubs, pointleaf manzanita and Wright's silktassel (*Garrya wrightii*), the tree, evergreen sumac (*Rhus virens*), were also common, as was beargrass (Table 3-1).

Bullgrass was detected on all 15 rocky, mid-mountain monitoring sites. Other extensive species included beargrass and sotol (14 sites), Palmer's century plant (13 sites) and Toumey oak (*Quercus toumeyi,* 11 sites), plains lovegrass (*Eragrostis intermedia*, 13 sites) and the non-native, Lehmann lovegrass (12 sites; Table 3-1). Plot-specific results are provided in Appendix B.

3.2.3 Frequency and extent of uncommon plant species

An additional 60 perennial and/or non-native species were detected only on frequency subplots of rocky, mid-mountain sites (Table 3-2). We consider those species uncommon in our analysis. Only two species had average within-plot frequencies above 10%: fairyswords (*Cheilanthes lindheimeri*) and cactus apple (*Opuntia engelmannii*). Rainbow cactus (*Echinocereus pectinatus*) was also the most extensive uncommon plant in this stratum, detected at 6 of the 15 monitoring sites. Plot-specific results are provided in Appendix B.

3.2.4 Cover and frequency of exotic species

The non-native perennial bunchgrass, Lehmann lovegrass, was the third-most abundant species on rocky, mid-mountain sites, although absolute cover was relatively moderate (5.4 ± 2.7% mean ± SE in the field layer; Table 3-1). Lehmann lovegrass was found on 12 of the 15 rocky, mid-mountain monitoring sites. No other non-native species were detected along the line transects. Plot-specific results are provided in Appendix B.

3.2.5 Soil cover, biological soil crusts, and stability

Plant litter and woody debris, rocks, and gravel dominated the soil surface, whereas only 2% of the soil surface was bare soil without vegetative cover (Figure 3-4). Biological soil crusts were nearly absent from line-point transects. Lichen was the only biocrust morphological group detected; it covered less than 0.1% of the soil surface on transects. We met or exceeded our expectations for statistical power for all substrate types (i.e., to detect a 10% absolute change in foliar cover with 90% power and 10% chance of false change error).

Average stability of surface soil aggregates under vegetation canopies was 3.8 ± 0.3 (somewhat stable). Average stability of surface soil aggregates without overhead canopy cover were only 3.0 ± 0.3 (somewhat unstable).

3.2.6 Management assessment points

Our results for rocky, mid-mountain sites in the context of management assessment points (see Section 2.2.4) indicated several potential issues for management consideration (Table 3-3).

Surface aggregate stability values were right at our "somewhat unstable" threshold for sampling points without overhead vegetation cover (Table 3-3), indicating a degree of potential soil erosion hazard. Lehmann lovegrass was the only exotic plant detected but was found on 80% (12 of 15) of the rocky, mid-mountain monitoring sites, suggesting that Lehmann lovegrass is not dispersal-limited from colonizing these areas of the monument. However, both the total exotic plant cover and ratio of exotic to total vegetative cover indicate that exotic plant invasion of the rocky, mid-mountain sites is likely not imminent (Table 3-3).

With the benefit of hindsight following the Horseshoe II Fire of 2011, the fire hazard assessment points for the rocky, mid-mountain sites are telling: foliar cover of dead plants in the field layer was nearly twice our management assessment point, and dead material in the subcanopies approached the point, as well (Table 3-3), although moderate litter and duff values were well below the fire hazard threshold.

All three of the plant community resilience indicators were well below their corresponding assessment points (Table 3-3), suggesting a good deal of persistence of the grassland/savanna communities in the face of disturbance, stress, and succession.

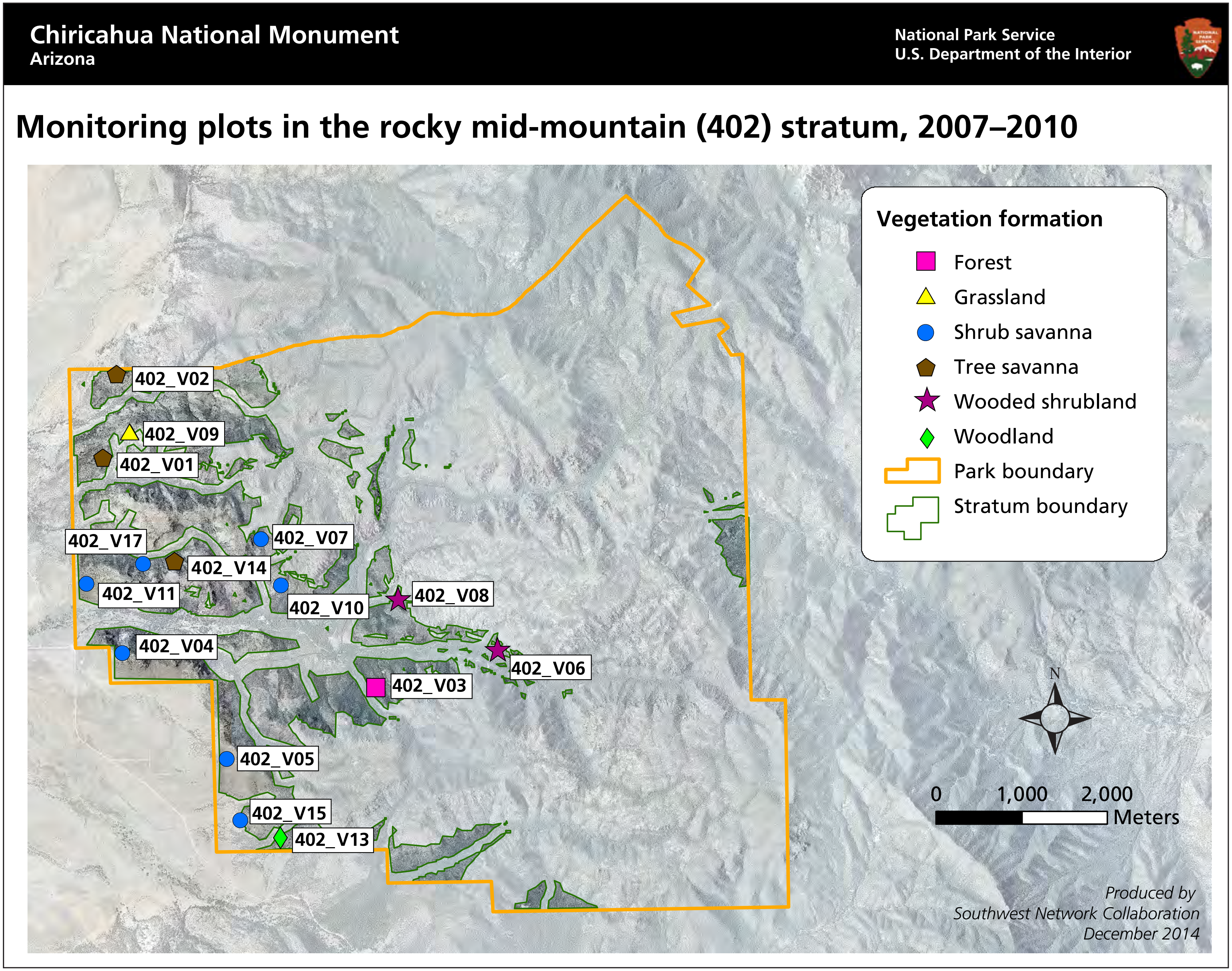


Figure 3-2. Locations of monitoring plots, by formation type, in the rocky, mid-mountain (402) stratum, Chiricahua National Monument, 2007–2010. See Table 2-3 for strata descriptions.

Percent Cover of Lifeforms in Rocky, Mid-mountain (402) Plots, Chiricahua National Monument, 2007–2010

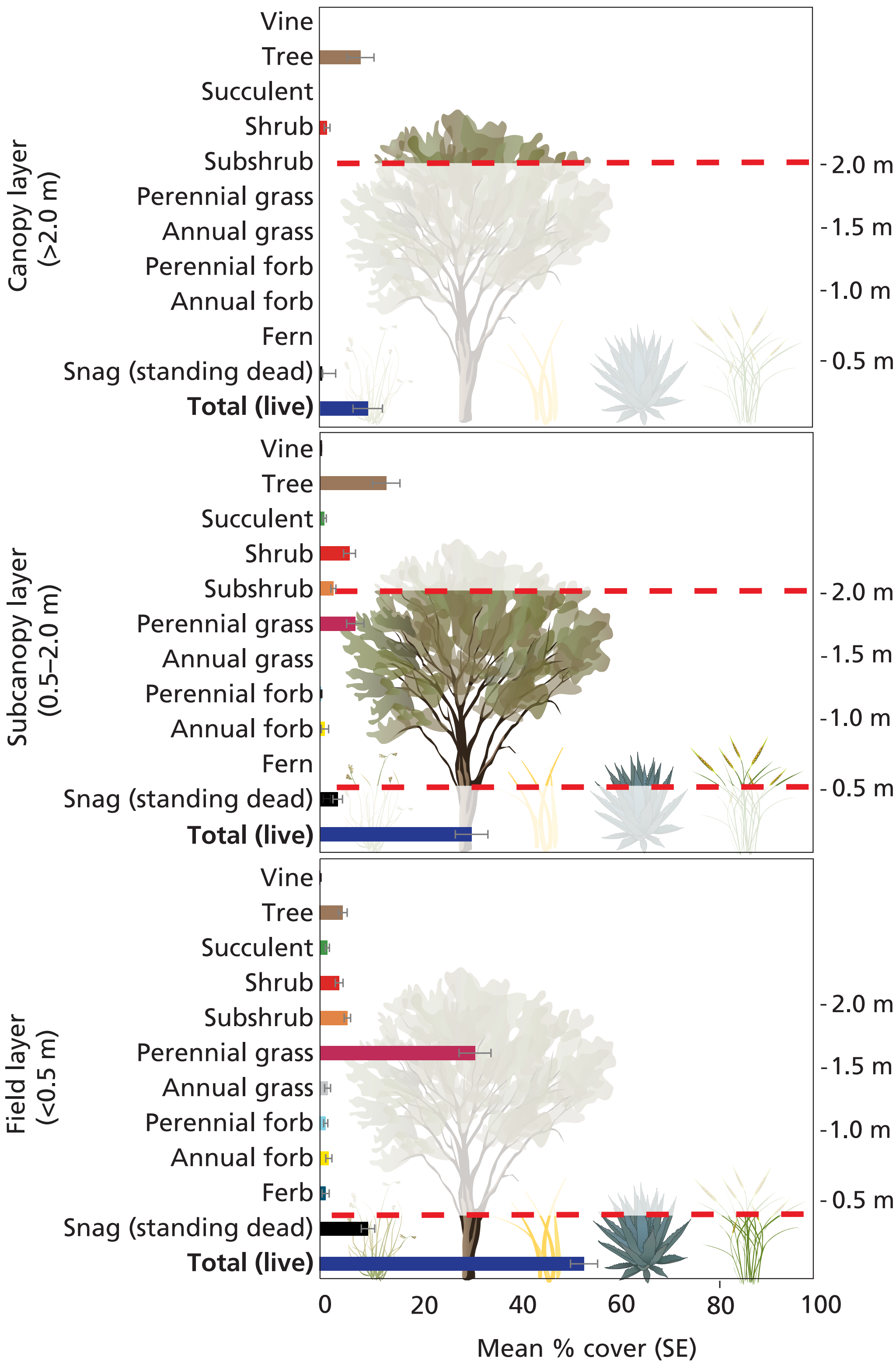


Figure 3-3. Lifeform cover in monitoring plots in the rocky, mid-mountain (402) stratum, Chiricahua National Monument, 2007–2010.

Table 3-1. Percent cover for perennial and non-native annual species (by lifeform) measured in the field, subcanopy, and canopy layers of sites in the rocky, mid-mountain (402) stratum, Chiricahua National Monument, 2007–2010.

Scientific name	Common name	Field (<0.5 m)			Subcanopy (0.5–2.0 m)			Canopy (>2.0 m)			Extent (of 15)
		AVG	SE	MDC	AVG	SE	MDC	AVG	SE	MDC	
FERN											
Bommeria hispida	copper fern	0.03%	0.03%	5%	---	---	---	---	---	---	2
Cheilanthes feei	slender lipfern	0.06%	0.06%	5%	---	---	---	---	---	---	2
Cheilanthes fendleri	Fendler's lipfern	0.78%	0.67%	5%	---	---	---	---	---	---	3
Cheilanthes hookeri	star cloak fern	0.03%	0.03%	5%	---	---	---	---	---	---	4
Cheilanthes sp.	lipfern	0.33%	0.20%	5%	---	---	---	---	---	---	4
FORB/HERB											
Acourtia mexicana	Thurber's desertpeony	0.03%	0.03%	5%	0.06%	0.06%	5%	---	---	---	2
Artemisia ludoviciana	white sagebrush	0.14%	0.08%	5%	---	---	---	---	---	---	8
Bidens sp.	beggarticks	0.19%	0.19%	5%	---	---	---	---	---	---	2
Dalea sp.	prairie clover	0.11%	0.11%	5%	---	---	---	---	---	---	1
Erigeron oreophilus	chaparral fleabane	0.03%	0.03%	5%	---	---	---	---	---	---	1
Erigeron sp.	fleabane	0.33%	0.24%	5%	---	---	---	---	---	---	2
Eriogonum sp.	buckwheat	0.03%	0.03%	5%	---	---	---	---	---	---	1
Lasianthaea podocephala	San Pedro daisy	0.03%	0.03%	5%	---	---	---	---	---	---	1
Mirabilis albida	white four o'clock	0.03%	0.03%	5%	---	---	---	---	---	---	2
Psoralidium tenuiflorum	slimflower scurfpea	0.11%	0.11%	5%	---	---	---	---	---	---	1
Senecio sp.	ragwort	0.08%	0.08%	5%	---	---	---	---	---	---	1
Viguiera sp.	goldeneye	0.06%	0.06%	5%	0.06%	0.06%	5%	---	---	---	2
GRASS											
Aristida divaricata	poverty threeawn	0.06%	0.06%	5%	---	---	---	---	---	---	2
Aristida purpurea	purple threeawn	0.19%	0.13%	5%	0.08%	0.06%	5%	---	---	---	4
Aristida schiedeana	single threeawn	0.53%	0.36%	5%	0.06%	0.04%	5%	---	---	---	7
Aristida sp.	threeawn	0.06%	0.04%	5%	---	---	---	---	---	---	2
Aristida ternipes	spidergrass	0.25%	0.09%	5%	0.03%	0.03%	5%	---	---	---	8
Bothriochloa barbinodis	cane bluestem	0.42%	0.23%	5%	0.14%	0.09%	5%	---	---	---	8
Bouteloua curtipendula	sideoats grama	6.56%	1.88%	5%	2.47%	1.06%	5%	---	---	---	15
Bouteloua gracilis	blue grama	0.64%	0.29%	5%	0.11%	0.11%	5%	---	---	---	9
Bouteloua hirsuta	hairy grama	0.67%	0.29%	5%	0.03%	0.03%	5%	---	---	---	9
Bouteloua repens	slender grama	0.14%	0.11%	5%	---	---	---	---	---	---	10
Bouteloua sp.	grama	0.03%	0.03%	5%	---	---	---	---	---	---	1
Digitaria californica	Arizona cottontop	0.22%	0.22%	5%	0.03%	0.03%	5%	---	---	---	2
Disakisperma dubium	green sprangletop	0.03%	0.03%	5%	---	---	---	---	---	---	2

Table 3-1. Percent cover for species (by lifeform) measured in the field, subcanopy, and canopy layers of sites in the rocky, mid-mountain (402) stratum, Chiricahua National Monument, 2007–2010, cont.

Scientific name	Common name	Field (<0.5 m)			Subcanopy (0.5–2.0 m)			Canopy (>2.0 m)			Extent (of 15)
		AVG	SE	MDC	AVG	SE	MDC	AVG	SE	MDC	
Elionurus barbiculmis	woolyspike balsamscale	0.08%	0.06%	5%	---	---	---	---	---	---	3
Eragrostis intermedia	plains lovegrass	0.58%	0.19%	5%	0.11%	0.06%	5%	---	---	---	13
Eragrostis lehmanniana	**Lehmann lovegrass**	**4.75%**	**2.36%**	**5%**	**1.42%**	**0.73%**	**5%**	**---**	**---**	**---**	**12**
Heteropogon contortus	tanglehead	1.81%	0.88%	5%	0.61%	0.38%	5%	---	---	---	7
Hilaria mutica	tobosagrass	0.50%	0.50%	5%	---	---	---	---	---	---	1
Hopia obtusa	vine mesquite	0.03%	0.03%	5%	---	---	---	---	---	---	2
Muhlenbergia alopecuroides	bristly wolfstail	0.53%	0.16%	5%	0.03%	0.03%	5%	---	---	---	12
Muhlenbergia emersleyi	bullgrass	9.69%	2.42%	5%	1.28%	0.43%	5%	---	---	---	15
Muhlenbergia polycaulis	cliff muhly	0.14%	0.14%	5%	---	---	---	---	---	---	3
Muhlenbergia sp.	muhly	0.11%	0.08%	5%	---	---	---	---	---	---	2
Piptochaetium fimbriatum	pinyon ricegrass	0.56%	0.34%	5%	0.03%	0.03%	5%	---	---	---	4
Schizachyrium cirratum	Texas bluestem	1.42%	0.46%	5%	0.42%	0.20%	5%	---	---	---	11
Schizachyrium sanguineum	crimson bluestem	0.17%	0.17%	5%	0.03%	0.03%	5%	---	---	---	1
Schizachyrium sp.	little bluestem	0.17%	0.10%	5%	0.03%	0.03%	5%	---	---	---	5
Setaria vulpiseta	plains bristlegrass	0.03%	0.03%	5%	---	---	---	---	---	---	1
Sporobolus cryptandrus	sand dropseed	0.06%	0.06%	5%	0.06%	0.06%	5%	---	---	---	1
Zuloagaea bulbosa	bulb panicgrass	0.06%	0.06%	5%	---	---	---	---	---	---	1
SUBSHRUB											
Acaciella angustissima	prairie acacia	0.17%	0.17%	5%	---	---	---	---	---	---	2
Baccharis thesioides	Arizona baccharis	0.19%	0.19%	5%	---	---	---	---	---	---	1
Boerhavia gracillima	slimstalk spiderling	0.03%	0.03%	5%	---	---	---	---	---	---	1
Brickellia lemmonii	Lemmon's brickellbush	0.08%	0.06%	5%	---	---	---	---	---	---	3
Brickellia sp.	brickellbush	0.17%	0.14%	5%	0.08%	0.08%	5%	---	---	---	6
Brickellia venosa	veiny brickellbush	0.06%	0.04%	5%	---	---	---	---	---	---	4
Calliandra eriophylla	fairyduster	0.03%	0.03%	5%	---	---	---	---	---	---	1
Carphochaete bigelovii	Bigelow's bristlehead	0.03%	0.03%	5%	---	---	---	---	---	---	1
Coleosanthus californicus	California brickellbush	0.22%	0.12%	5%	---	---	---	---	---	---	6
Dasylirion wheeleri	common sotol	2.00%	0.40%	5%	1.06%	0.33%	5%	---	---	---	14
Ericameria laricifolia	turpentine bush	0.36%	0.13%	5%	0.11%	0.05%	5%	---	---	---	7
Eriogonum jamesii	James' buckwheat	0.03%	0.03%	5%	---	---	---	---	---	---	1
Galium wrightii	Wright's bedstraw	---	---	---	0.03%	0.03%	5%	---	---	---	1
Gymnosperma glutinosum	gumhead	0.36%	0.26%	5%	0.22%	0.11%	5%	---	---	---	7

Table 3-1. Percent cover for species (by lifeform) measured in the field, subcanopy, and canopy layers of sites in the rocky, mid-mountain (402) stratum, Chiricahua National Monument, 2007–2010, cont.

		Field (<0.5 m)			Subcanopy (0.5–2.0 m)			Canopy (>2.0 m)			Extent
Scientific name	**Common name**	**AVG**	**SE**	**MDC**	**AVG**	**SE**	**MDC**	**AVG**	**SE**	**MDC**	**(of 15)**
Nolina microcarpa	sacahuista	1.36%	0.33%	5%	0.97%	0.35%	5%	---	---	---	14
Penstemon linarioides	toadflax penstemon	0.03%	0.03%	5%	---	---	---	---	---	---	1
Phoradendron californicum	mesquite mistletoe	---	---	---	0.03%	0.03%	5%	---	---	---	2
Sphaeralcea hastulata	spear globemallow	0.03%	0.03%	5%	---	---	---	---	---	---	1
Sphaeralcea laxa	caliche globemallow	0.03%	0.03%	5%	---	---	---	---	---	---	2
Sphaeralcea sp.	globemallow	0.06%	0.04%	5%	---	---	---	---	---	---	4
Trichostema arizonicum	Arizona bluecurls	0.39%	0.18%	5%	0.06%	0.04%	5%	---	---	---	6
SHRUB											
Aloysia wrightii	Wright’s beebrush	0.11%	0.08%	5%	0.11%	0.09%	5%	---	---	---	3
Arctostaphylos pungens	pointleaf manzanita	2.06%	0.64%	5%	3.20%	1.03%	5%	0.45%	0.29%	5%	10
Fouquieria splendens	ocotillo	0.06%	0.06%	5%	0.06%	0.06%	5%	0.06%	0.06%	5%	3
Garrya sp.	silktassel	0.03%	0.03%	5%	0.06%	0.06%	5%	---	---	---	1
Garrya wrightii	Wright’s silktassel	0.94%	0.32%	5%	2.39%	0.69%	5%	0.92%	0.57%	5%	10
Parthenium incanum	mariola	0.58%	0.58%	5%	---	---	---	---	---	---	1
SUCCULENT											
Agave palmeri	Palmer’s century plant	1.17%	0.39%	5%	0.53%	0.33%	5%	---	---	---	13
Agave parryi	Parry’s agave	0.03%	0.03%	5%	---	---	---	---	---	---	2
Opuntia phaeacantha	tulip pricklypear	0.08%	0.08%	5%	0.06%	0.06%	5%	---	---	---	3
Yucca madrensis	yucca	0.28%	0.22%	5%	0.19%	0.15%	5%	---	---	---	6
TREE											
Cercocarpus montanus	alderleaf mountain mahogany	0.25%	0.16%	5%	0.19%	0.15%	5%	0.03%	0.03%	5%	3
Hesperocyparis arizonica	Arizona cypress	---	---	---	---	---	---	0.06%	0.06%	5%	1
Juniperus deppeana	alligator juniper	0.17%	0.17%	5%	0.64%	0.38%	5%	1.16%	0.65%	5%	7
Juniperus monosperma	oneseed juniper	0.17%	0.17%	5%	0.86%	0.86%	5%	0.83%	0.77%	5%	2
Mimosa aculeaticarpa	catclaw mimosa	0.11%	0.09%	5%	0.03%	0.03%	5%	---	---	---	6
Pinus discolor	border pinyon	0.67%	0.33%	5%	2.06%	1.09%	5%	3.21%	1.34%	5%	11
Prosopis sp.	mesquite	0.03%	0.03%	5%	0.03%	0.03%	5%	---	---	---	1
Quercus arizonica	Arizona white oak	0.22%	0.09%	5%	1.00%	0.65%	5%	1.10%	0.83%	5%	5
Quercus emoryi	Emory oak	---	---	---	0.33%	0.26%	5%	0.33%	0.26%	5%	6
Quercus hypoleucoides	silverleaf oak	0.17%	0.11%	5%	0.33%	0.24%	5%	0.18%	0.12%	5%	2
Quercus rugosa	netleaf oak	0.03%	0.03%	5%	---	---	---	---	---	---	1
Quercus toumeyi	Toumey oak	2.17%	0.62%	5%	6.00%	2.15%	5%	1.10%	0.47%	5%	11

Table 3-1. Percent cover for species (by lifeform) measured in the field, subcanopy, and canopy layers of sites in the rocky, mid-mountain (402) stratum, Chiricahua National Monument, 2007–2010, cont.

		Field (<0.5 m)			Subcanopy (0.5–2.0 m)			Canopy (>2.0 m)			Extent
Scientific name	**Common name**	**AVG**	**SE**	**MDC**	**AVG**	**SE**	**MDC**	**AVG**	**SE**	**MDC**	**(of 15)**
Quercus turbinella	Sonoran scrub oak	---	---	---	0.03%	0.03%	5%	---	---	---	1
Rhus virens	evergreen sumac	0.72%	0.30%	5%	1.72%	0.62%	5%	0.17%	0.10%	5%	9
VINE											
Galactia wrightii	Wright's milkpea	0.03%	0.03%	5%	0.08%	0.08%	5%	---	---	---	2
Phaseolus sp.	bean	0.03%	0.03%	5%	---	---	---	---	---	---	2
TOTALS BY LIFEFORM											
Annual Forb		1.86%	0.62%	5%	0.86%	0.74%	5%	---	---	---	
Annual Grass		1.61%	0.60%	5%	---	---	---	---	---	---	
Perennial Forb		1.25%	0.41%	5%	0.14%	0.10%	5%	---	---	---	
Perennial Grass		31.31%	3.23%	7%	6.95%	1.75%	5%	---	---	---	
Fern		1.22%	0.73%	5%	---	---	---	---	---	---	
Subshrub		5.61%	0.63%	5%	2.56%	0.51%	5%	---	---	---	
Shrub		3.95%	0.78%	5%	5.81%	1.19%	5%	1.43%	0.59%	5%	
Succulent		1.56%	0.42%	5%	0.78%	0.34%	5%	---	---	---	
Tree		4.70%	0.87%	5%	13.22%	2.75%	6%	8.18%	2.68%	6%	
Vine		0.20%	0.08%	5%	0.08%	0.08%	5%	---	---	---	
Snag		9.75%	1.36%	5%	3.44%	0.97%	5%	0.39%	0.18%	5%	
Total (live)		**53.26%**	**2.74%**	**6%**	**30.40%**	**3.29%**	**7%**	**9.61%**	**2.97%**	**7%**	

AVG = average, SE = standard error, MDC = minimum detectable change (% cover), Extent is the number of plots in which the species was detected (either on transects or in subplots, out of 15 plots). Non-native plants are bolded. All species and lifeforms exceeded our statistical power criteria (MDC ≤10%).

Table 3-2. Within-plot frequency (%) and extent of uncommon plant species, by lifeform, sampled at sites in the rocky, mid-mountain (402) stratum, Chiricahua National Monument, 2007–2010.

Scientific name	Common name	Within-plot frequency	SE	Extent (of 15)
FERN				
Cheilanthes lindheimeri	fairyswords	15%	8.2%	3
Pellaea truncata	spiny cliffbrake	8%	5.5%	2
FORB/HERB				
Agastache pallidiflora	Bill Williams Mountain giant hyssop	1%	1.3%	1
Ambrosia psilostachya	Cuman ragweed	1%	1.3%	1
Artemisia dracunculus	tarragon	3%	2.7%	1
Berlandiera lyrata	lyreleaf greeneyes	1%	1.3%	1
Croton sp.	croton	3%	2.7%	1
Dalea albiflora	whiteflower prairie clover	4%	2.1%	3
Descurainia sp.	tansymustard	4%	4.0%	1
Erigeron divergens	spreading fleabane	1%	1.3%	1
Erigeron flagellaris	trailing fleabane	1%	1.3%	1
Galium microphyllum	bracted bedstraw	1%	1.3%	1
Glandularia bipinnatifida	Dakota mock vervain	3%	2.7%	1
Hedeoma hyssopifolia	aromatic false pennyroyal	3%	2.7%	1
Hedeoma nana	dwarf false pennyroyal	1%	1.3%	1
Ipomoea sp.	morning-glory	7%	4.6%	2
Ipomopsis sp.	ipomopsis	1%	1.3%	1
Lotus sp.	trefoil	1%	1.3%	1
Mentzelia sp.	blazingstar	5%	4.1%	2
Mirabilis comata	hairy-tuft four o’clock	1%	1.3%	1
Pectis sp.	chinchweed	3%	2.7%	1
Polygala sp.	polygala	1%	1.3%	1
Solanum elaeagnifolium	silverleaf nightshade	5%	3.6%	2
Tragia ramosa	branched noseburn	3%	2.7%	1
Tragia sp.	noseburn	1%	1.3%	1
Trifolium wormskioldii	cows clover	1%	1.3%	1
Xanthisma spinulosum	spiny haplopappus	1%	1.3%	1
GRASS				
Bouteloua eriopoda	black grama	1%	1.3%	1
Bromus sp.	brome	1%	1.3%	1
Carex sp.	sedge	1%	1.3%	1
Cyperus sp.	flatsedge	4%	4.0%	1
Eragrostis lugens	mourning lovegrass	7%	5.4%	2
Juncus sp.	rush	1%	1.3%	1
Panicum sp.	panicgrass	3%	1.8%	2
Trachypogon spicatus	spiked crinkleawn	1%	1.3%	1
SUBSHRUB				
Bebbia juncea	sweetbush	3%	2.7%	1
Calliandra humilis	dwarf stickpea	3%	2.7%	1
Chaetopappa ericoides	rose heath	3%	2.7%	1
Isocoma tenuisecta	burroweed	1%	1.3%	1
Zinnia grandiflora	Rocky Mountain zinnia	1%	1.3%	1

Table 3-2. Within-plot frequency (%) and extent of uncommon plant species, by lifeform, sampled at sites in the rocky, mid-mountain (402) stratum, Chiricahua National Monument, 2007–2010, cont.

Scientific name	Common name	Within-plot frequency	SE	Extent (of 15)
SHRUB				
Arctostaphylos pringlei	Pringle manzanita	1%	1.3%	1
Baccharis pteronioides	yerba de pasmo	5%	3.1%	3
Bahiopsis parishii	Parish's goldeneye	1%	1.3%	1
Bouvardia ternifolia	firecrackerbush	7%	3.7%	3
Eriogonum wrightii	bastardsage	5%	3.1%	3
Fallugia paradoxa	Apache plume	1%	1.3%	1
Fendlerella utahensis	Utah fendlerbush	3%	1.8%	2
Indigofera sphaerocarpa	Sonoran indigo	3%	2.7%	1
Rhus trilobata	skunkbush sumac	1%	1.3%	1
Trixis californica	American threefold	1%	1.3%	1
SUCCULENT				
Cylindropuntia spinosior	walkingstick cactus	9%	3.8%	5
Echinocereus fendleri	pinkflower hedgehog cactus	1%	1.3%	1
Echinocereus pectinatus	rainbow cactus	9%	3.3%	6
Opuntia chlorotica	dollarjoint pricklypear	3%	2.7%	1
Opuntia engelmannii	cactus apple	15%	7.9%	3
Sarcoyucca schottii	Schott's yucca	1%	1.3%	1
Yucca elata	soaptree yucca	1%	1.3%	1
TREE				
Pinus leiophylla	Chihuahuan pine	1%	1.3%	1
VINE				
Clematis sp.	leather flower	3%	2.7%	1
Cucurbita foetidissima	Missouri gourd	1%	1.3%	1

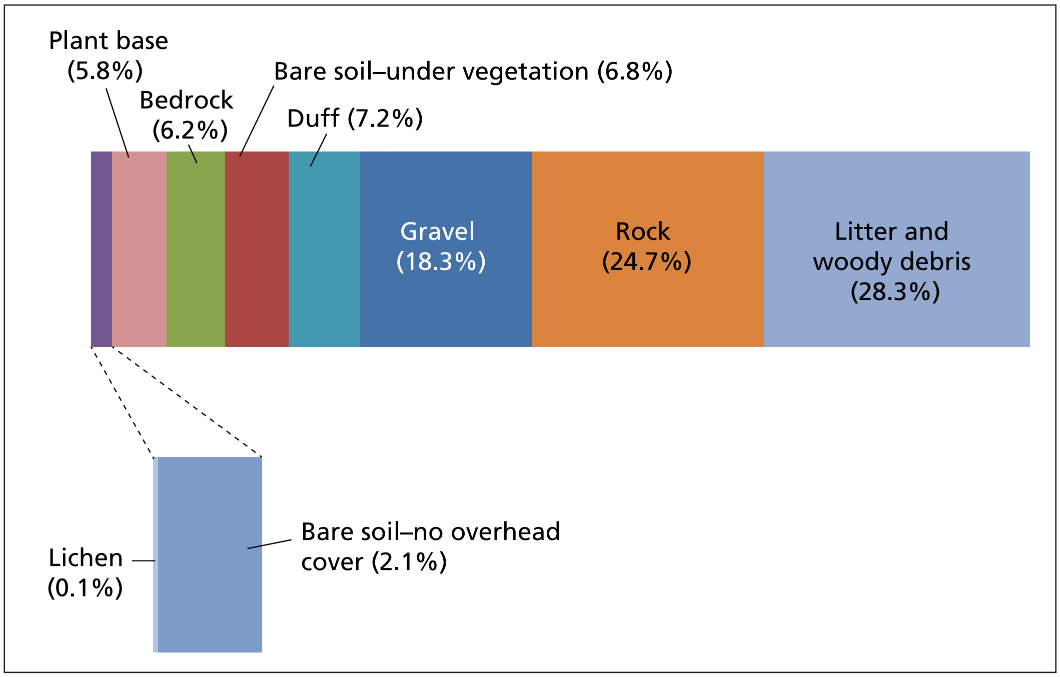


Figure 3-4. Soil surface cover (% by category) for sites in the rocky, mid-mountain (402) stratum, Chiricahua National Monument, 2007–2010. All categories met our statistical power criteria. (Duff=partially decomposed organic material, Gravel=2–75 mm diameter; Rocks=76–600 mm diameter)

Table 3-3. Vegetation and soils data for sites in the rocky, mid-mountain (402) stratum in the context of proposed management assessment points, Chiricahua National Monument, 2007–2010.

Issue	Management assessment point	Mean ± SE	Recommendation
Erosion hazard	Bare ground (with no overhead vegetation) >20%	**2.1% ± 0.3**	**Continue monitoring**
	Surface soil aggregate stability (with no overhead canopy) <Class 3	**3.0 ± 0.3**	**Meet and consider**
Plant community resilience	Annual plant cover: total plant cover >1:4 (field)	6.8%	Continue monitoring
	Percent cover of perennial grasses < 25% (field)	31.3% ± 8.1	Continue monitoring
	Tree + shrub cover > 50% (subcanopy)	19.0% ± 3.4	Continue monitoring
Exotic plant dispersal	**Extent of exotic plants > 50%**	**80% (12 of 15 sites)**	**Meet and consider**
Exotic plant invasion	Total exotic plant cover >10% (field)	4.8% ± 1.2	Continue monitoring
	Exotic plant cover: total plant cover >1:4 (field)	8.6%	Continue monitoring
Fire hazard	Litter + duff >50%	35.2% ± 3.9	Continue monitoring
	Percent cover of dead plants >5% (field)	**9.8% ± 2.5**	Meet and consider
	Percent cover of dead plants >5% (subcanopy)	3.4% ± 0.9	Continue monitoring

Red, bolded parameters exceeded our management assessment points.

3.3 Non-rocky, high-mountain (501) stratum

Restricted to relatively small areas around Cochise's Head (NE boundary) and the base of Sugarloaf Mountain (center of monument), sites in the non-rocky, high-mountain (501) stratum (see Table 2-3 for strata descriptions) comprised only about 6% of Chiricahua NM (Figure 3-5; figures and tables begin on page 33). This stratum is only occasionally found in other mountain ranges of the American Southwest. The only other nearby national park with this unusual stratum is Guadalupe Mountains NP. See Appendix A for photographs.

3.3.1 Vegetation formations and lifeforms

Two of the three sites in this stratum were forests. The third (501_V03) was a tree savanna (Figure 3-6). The dominance of trees is reflected in the nearly 60% total vegetation cover of the canopy layer, in contrast to the subcanopy and, to a greater extent, field layers (Figure 3-6; see Table 2-1 for layer descriptions).

With the exception of vines and ferns, all major lifeforms were encountered on non-rocky, high-mountain monitoring plots, with the greatest lifeform diversity occurring in the field layer (Figure 3-6). Perennial bunchgrasses dominated the field layer and were relatively abundant in the subcanopy, although small trees comprised the bulk of the latter. Snags (standing dead vegetation) were somewhat common, particularly in the field layer (Figure 3-6).

3.3.2 Cover and extent of perennial plant species

Monitoring plots on non-rocky, high-mountain sites were dominated by the trees, border pinyon pine, Arizona white oak, and alligator juniper (*Juniperus deppeana*), with the former having by far the greatest cover of any species in any stratum that we sampled at Chiricahua NM (see Tables 3-1, 3-4, 3-7, and 3-10). Alderleaf mountain mahogany (*Cercocarpus montanus*) also contributed substantial cover in the canopies of this stratum (Table 3-4). Subcanopies were dominated by juveniles or lower branches of the trees, as well as the shrub, Wright's silktassel (Table 3-4). Dense native bunchgrasses comprised the bulk of field vegetative cover, with bullgrass, sideoats grama, and cliff muhly being the most abundant species.

Several species were ubiquitous across non-rocky, high-mountain sites. The trees, border pinyon pine, Arizona white oak, alligator juniper, and alderleaf mountain mahogany, were detected on all three plots—as was the shrub, Wright's silktassel; the subshrubs, beargrass and gumhead (*Gymnosperma glutinosum*); and several species of perennial bunchgrasses (Table 3-5). Plot-specific results are provided in Appendix B.

3.3.3 Frequency and extent of uncommon plant species

Twenty-four uncommon plant species were detected only on the frequency subplots of non-rocky, high-mountain plots (Table 3-5). The grass, cane bluestem (*Bothriochloa barbinodis*); the forb, dentate false pennyroyal (*Hedeoma dentata*), and the cactus, kingcup cactus (*Echinocereus triglochidiatus*), were the only species with at least 20% subplot frequency across non-rocky, high-mountain sites. Cane bluestem and tulip pricklypear (*Opuntia phaeacantha*) were the only uncommon plants found on more than one plot (Table 3-5). Plot-specific results are provided in Appendix B.

3.3.4 Cover and frequency of exotic species

Two non-native plants were detected on non-rocky, high-mountain transects, both at less than 1% foliar cover (see Table 3-4): the bunchgrass, Lehmann lovegrass; and the annual grass, field brome (*Bromus arvensis*). Each exotic plant species was detected on one of the three non-rocky, high-monitoring sites (501_V01 and 501_V02, respectively). No additional exotic species were detected on frequency subplots (see Table 3-5). Plot-specific results are provided in Appendix B.

3.3.5 Soil cover, biological soil crusts, and stability

Soil substrate cover was dominated by plant litter, duff, and, to a lesser extent, gravel and rocks (Figure 3-7). Less than 2% of the soil surface was bare soil without vegetative cover. Biological soil crusts were nearly absent. Moss was the only biocrust morphological group detected; it covered less than 0.2% of the soil surface (Figure 3-7). We did not meet our statistical power criteria for gravel and duff cover; we estimate that we can detect only a 15% and 26% change, respectively. All other soil cover types met or exceeded our statistical power criteria (see Sections 2.6 and 2.7).

Surface soil aggregate stability under vegetation canopies was 4.7 ± 0.1 (stable). Values for samples without overhead canopy cover were comparable, at 4.2 ± 1.0 (moderately stable). The high variance for the latter was due to the relatively low stability of samples from plot 501_V01, which was only "somewhat unstable" at 2.7, and the high stability of samples from plot 501_V02 at 6.0 (very stable) (see Table 2-2).

3.3.6 Management assessment points

Our results for non-rocky, high-mountain sites in the context of management assessment points (see Section 2.2.4) indicated a few potential issues for management consideration (Table 3-6).

The measurements for the erosion hazard, plant community resilience, and exotic plant invasion indicators were all well below their corresponding management assessment points (Table 3-6). However, exotic plants were detected on two of the three non-rocky, high-mountain sites, suggesting that exotic plants are not dispersal-limited from colonizing these areas of the monument. Although the stratum met the management assessment point for soil aggregate stability, plot 501_V01 was "somewhat unstable" (2.7).

As with the rocky, mid-mountain (402) stratum, the fire hazard indicators for non-rocky, high-mountain sites foreshadowed the Horseshoe II Fire to follow in 2011 (Table 3-6). Whereas litter and duff accumulations were only slightly above the management assessment point, the cover of dead plants in the field layer was nearly twice the assessment point. In combination, both plant litter and dead standing plants provided the dense fine fuels required for landscape-scale fire.

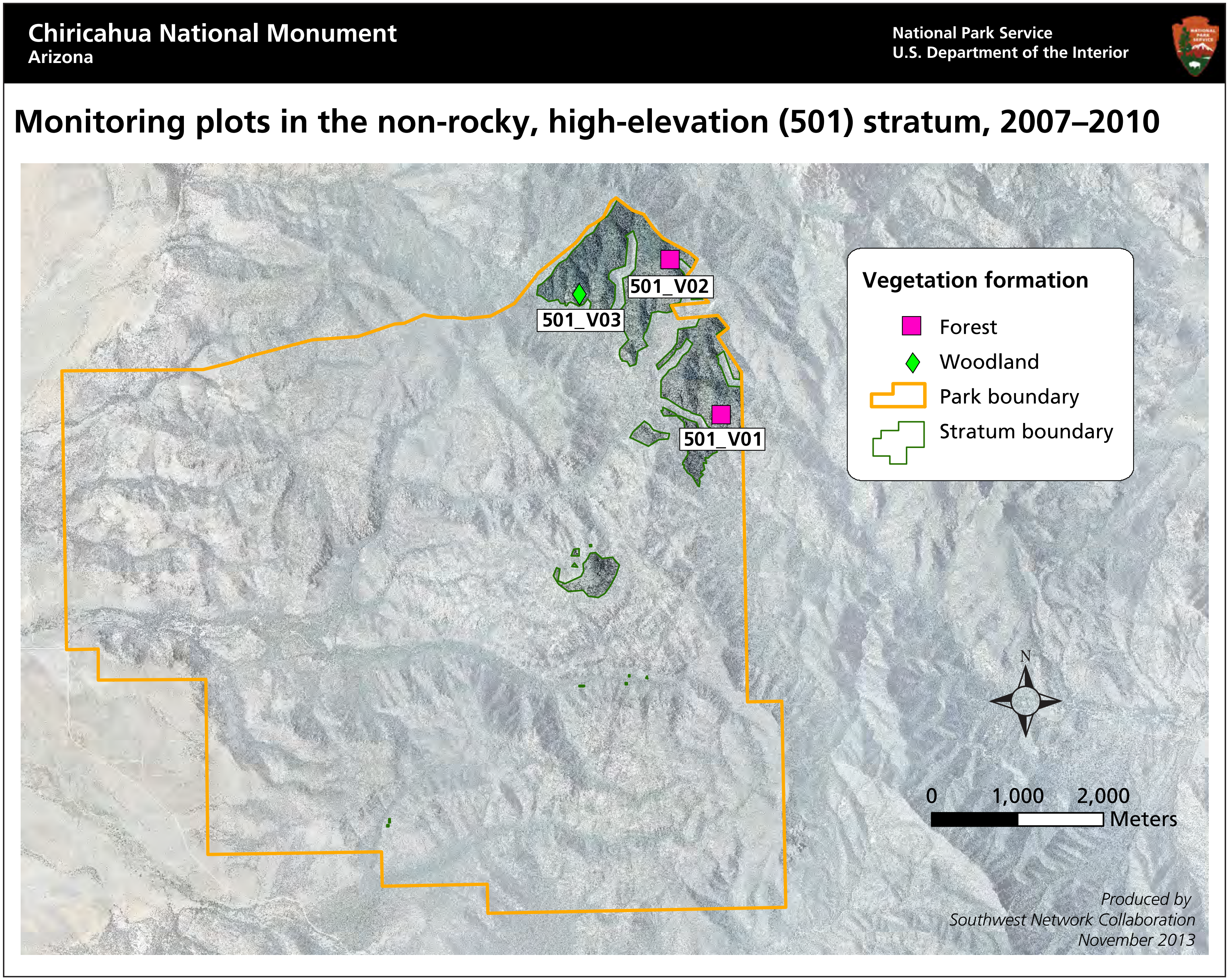


Figure 3-5. Locations of monitoring plots, by formation type, within the non-rocky, high-elevation (501) stratum, Chiricahua National Monument, 2007–2010. See Table 2-3 for strata descriptions.

Sonoran Desert Network
Arizona and New Mexico

National Park Service
U.S. Department of the Interior

Percent Cover of Lifeforms in Non-rocky, High-mountain (501) Plots, Chiricahua National Monument, 2007–2010

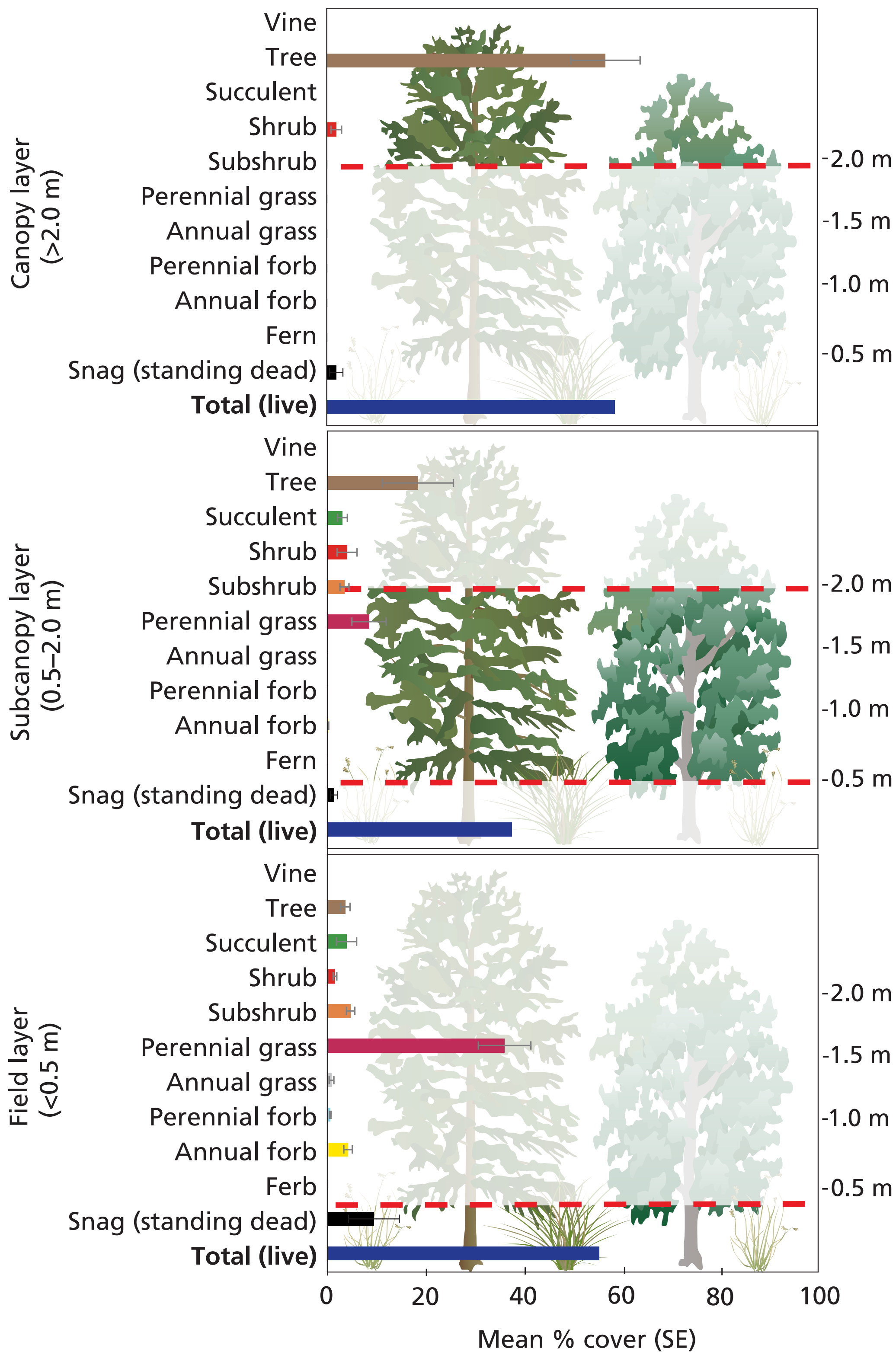


Figure 3-6. Lifeform cover in monitoring plots in the non-rocky, high-mountain (501) stratum, Chiricahua National Monument, 2007–2010.

Table 3-4. Percent cover for perennial and non-native annual species (by lifeform) measured in the field, subcanopy, and canopy layers of sites in the non-rocky, high-mountain (501) stratum, Chiricahua National Monument, 2007–2010.

		Field (<0.5 m)			Subcanopy (0.5–2.0 m)			Canopy (>2.0 m)			Extent
Scientific name	Common name	AVG	SE	MDC	AVG	SE	MDC	AVG	SE	MDC	(of 3)
FORB/HERB											
Galium microphyllum	bracted bedstraw	0.28%	0.28%	5%	---	---	---	---	---	---	1
Galium sp.	bedstraw	0.14%	0.14%	5%	---	---	---	---	---	---	2
Symphyotrichum sp.	aster	0.14%	0.14%	5%	---	---	---	---	---	---	1
GRASS											
Aristida schiedeana	single threeawn	1.25%	0.72%	5%	0.28%	0.28%	5%	---	---	---	2
Aristida ternipes	spidergrass	0.28%	0.28%	5%	0.28%	0.28%	5%	---	---	---	1
Bouteloua curtipendula	sideoats grama	11.39%	2.23%	5%	2.92%	1.05%	5%	---	---	---	3
***Bromus arvensis*[a]**	**field brome**	**0.28%**	**0.28%**	**5%**	**---**	**---**	**---**	**---**	**---**	**---**	**1**
Bromus sp.	brome	0.14%	0.14%	5%	0.14%	0.14%	5%	---	---	---	1
Eragrostis intermedia	plains lovegrass	1.11%	0.37%	5%	---	---	---	---	---	---	3
Eragrostis lehmanniana	**Lehmann lovegrass**	**0.28%**	**0.28%**	**5%**	**0.14%**	**0.14%**	**5%**	**---**	**---**	**---**	**1**
Eragrostis sp.	lovegrass	0.14%	0.14%	5%	---	---	---	---	---	---	1
Lycurus phleoides	common wolfstail	0.14%	0.14%	5%	---	---	---	---	---	---	1
Muhlenbergia alopecuroides	bristly wolfstail	0.28%	0.28%	5%	0.14%	0.14%	5%	---	---	---	3
Muhlenbergia emersleyi	bullgrass	11.67%	6.86%	15%	3.75%	2.60%	6%	---	---	---	3
Muhlenbergia polycaulis	cliff muhly	6.39%	5.19%	11%	0.69%	0.37%	5%	---	---	---	2
Piptochaetium fimbriatum	pinyon ricegrass	0.97%	0.50%	5%	---	---	---	---	---	---	3
Poa fendleriana	muttongrass	1.94%	1.94%	5%	---	---	---	---	---	---	1
Schizachyrium cirratum	Texas bluestem	0.14%	0.14%	5%	0.14%	0.14%	5%	---	---	---	2
SUBSHRUB											
Brickellia sp.	brickellbush	0.70%	0.50%	5%	---	---	---	---	---	---	2
Coleosanthus californicus	California brickellbush	0.14%	0.14%	5%	---	---	---	---	---	---	1
Ericameria laricifolia	turpentine bush	0.14%	0.14%	5%	0.42%	0.42%	5%	---	---	---	1
Gymnosperma glutinosum	gumhead	0.42%	0.24%	5%	0.42%	0.24%	5%	---	---	---	3
Nolina microcarpa	sacahuista	1.80%	0.28%	5%	1.53%	0.50%	5%	---	---	---	3
Viguiera dentata	toothleaf goldeneye	1.53%	1.53%	5%	1.11%	1.11%	5%	---	---	---	1
SHRUB											
Bouvardia ternifolia	firecrackerbush	0.56%	0.56%	5%	0.14%	0.14%	5%	---	---	---	2
Ceanothus greggii	desert ceanothus	0.14%	0.14%	5%	1.25%	1.25%	5%	0.56%	0.56%	5%	1
Fendlera rupicola	cliff fendlerbush	0.28%	0.28%	5%	0.69%	0.69%	5%	---	---	---	1
Garrya wrightii	Wright's silktassel	0.42%	0.42%	5%	1.80%	0.97%	5%	1.39%	0.69%	5%	3
Rhus trilobata	skunkbush sumac	0.14%	0.14%	5%	0.14%	0.14%	5%	---	---	---	1

Table 3-4. Percent cover for species (by lifeform) measured in the field, subcanopy, and canopy layers of sites in the non-rocky, high-mountain (501) stratum, Chiricahua National Monument, 2007–2010, cont.

		Field (<0.5 m)			Subcanopy (0.5–2.0 m)			Canopy (>2.0 m)			Extent
Scientific name	**Common name**	**AVG**	**SE**	**MDC**	**AVG**	**SE**	**MDC**	**AVG**	**SE**	**MDC**	**(of 3)**
SUCCULENT											
Agave palmeri	Palmer's century plant	0.83%	0.64%	5%	0.56%	0.56%	5%	---	---	---	3
Agave parryi	Parry's agave	0.28%	0.28%	5%	---	---	---	---	---	---	1
Cylindropuntia spinosior	walkingstick cactus	---	---	5%	0.28%	0.28%	5%	---	---	---	3
Opuntia engelmannii	cactus apple	0.14%	0.14%	5%	---	---	---	---	---	---	3
Yucca baccata	banana yucca	2.36%	2.36%	5%	1.39%	1.39%	5%	---	---	---	1
Yucca madrensis	yucca	0.28%	0.28%	5%	0.83%	0.48%	5%	---	---	---	2
TREE											
Cercocarpus montanus	alderleaf mountain mahogany	0.42%	---	5%	1.53%	0.77%	5%	3.47%	1.84%	5%	3
Juniperus deppeana	alligator juniper	0.14%	0.14%	5%	1.39%	0.60%	5%	8.75%	3.31%	7%	3
Pinus discolor	border pinyon	2.50%	0.64%	5%	12.22%	5.82%	13%	33.33%	12.08%	25%	3
Quercus arizonica	Arizona white oak	0.56%	0.37%	5%	3.19%	2.24%	5%	11.11%	3.70%	8%	3
Quercus emoryi	Emory oak	---	---	---	0.14%	0.14%	5%	0.14%	0.14%	5%	2
TOTALS BY LIFEFORM											
Annual Forb		4.17%	0.87%	5%	0.14%	0.14%	5%	---	---	---	
Annual Grass		0.83%	0.48%	5%	---	---	---	---	---	---	
Perennial Forb		0.56%	0.14%	5%	---	---	---	---	---	---	
Perennial Grass		36.11%	5.35%	12%	8.47%	3.47%	8%	---	---	---	
Fern		---	---	---	---	---	---	---	---	---	
Subshrub		4.72%	0.84%	5%	3.47%	0.91%	5%	---	---	---	
Shrub		1.53%	0.37%	5%	4.03%	2.04%	5%	**1.94%**	**1.08%**	5%	
Succulent		3.89%	2.04%	5%	3.06%	1.00%	5%	---	---	---	
Tree		3.62%	0.97%	5%	18.47%	7.24%	15%	**56.81%**	**7.07%**	15%	
Vine		---	---	---	---	---	---	---	---	---	
Snag		9.44%	5.18%	11%	1.39%	0.74%	5%	**1.94%**	**1.37%**	5%	
Total (live)		**55.43%**	**6.13%**	**13%**	**37.64%**	**6.86%**	**15%**	**58.75%**	**7.50%**	**16%**	

AVG = average, SE = standard error, MDC = minimum detectable change (% cover), Extent is the number of plots in which the species was detected (out of 3).
Non-native plants are bolded. Non-native annual plants are additionally marked with an "a". Species and lifeforms with MDC values shown in red and highlighted in yellow did not meet our statistical power criteria (MDC ≤ 10%).

Table 3-5. Within-plot frequency (%) and extent of uncommon plant species, by lifeform, sampled at sites in the non-rocky, high-mountain (501) stratum, Chiricahua National Monument, 2007–2010.

Scientific name	Common name	Within-plot frequency	SE	Extent (of 3)
FERN				
Pellaea sp.	cliffbrake	7%	6.7%	1
FORB/HERB				
Dalea albiflora	whiteflower prairie clover	7%	6.7%	1
Hedeoma dentata	dentate false pennyroyal	27%	26.7%	1
Heliomeris multiflora	showy goldeneye	7%	6.7%	1
Tragia ramosa	branched noseburn	13%	13.3%	1
GRASS				
Bothriochloa barbinodis	cane bluestem	27%	17.6%	2
Bouteloua gracilis	blue grama	7%	6.7%	1
Disakisperma dubium	green sprangletop	7%	6.7%	1
Elymus arizonicus	Arizona wheatgrass	7%	6.7%	1
Elymus elymoides	squirreltail	7%	6.7%	1
SUBSHRUB				
Ageratina herbacea	fragrant snakeroot	7%	6.7%	1
Brickellia lemmonii	Lemmon's brickellbush	7%	6.7%	1
Dalea formosa	featherplume	13%	13.3%	1
Penstemon pseudospectabilis	desert penstemon	13%	13.3%	1
Sphaeralcea sp.	globemallow	7%	6.7%	1
Trichostema arizonicum	Arizona bluecurls	7%	6.7%	1
SHRUB				
Fallugia paradoxa	Apache plume	7%	6.7%	1
Mimosa aculeaticarpa	catclaw mimosa	13%	13.3%	1
SUCCULENT				
Echinocereus triglochidiatus	kingcup cactus	20%	20.0%	1
Opuntia macrocentra	purple pricklypear	7%	6.7%	1
Opuntia phaeacantha	tulip pricklypear	13%	6.7%	2
Sarcoyucca schottii	Schott's yucca	13%	13.3%	1
TREE				
Quercus hypoleucoides	silverleaf oak	7%	6.7%	1
VINE				
Phaseolus sp.	bean	7%	6.7%	1

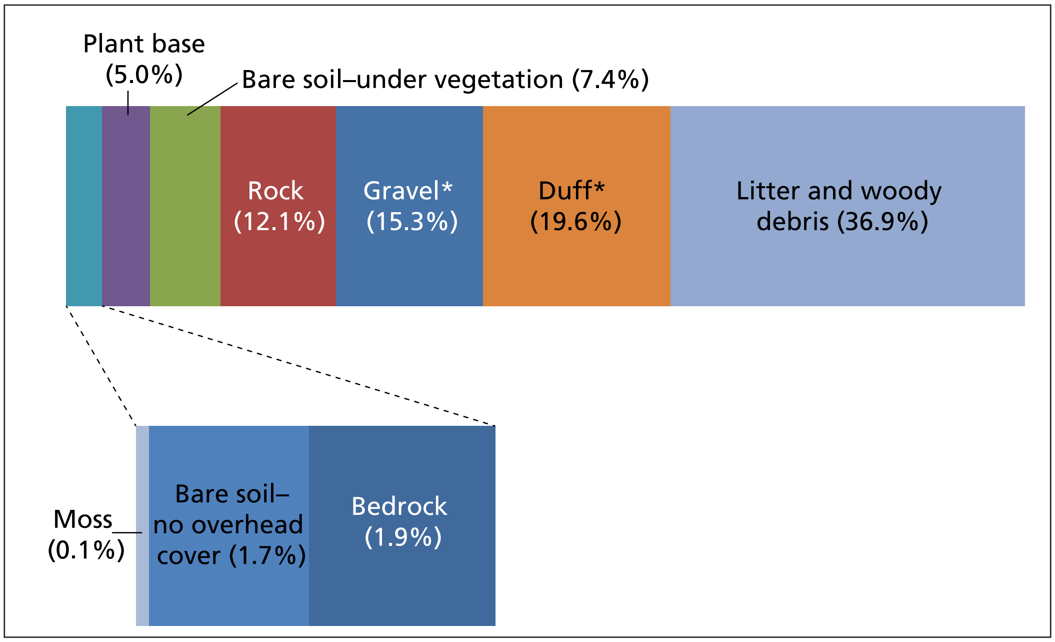


Figure 3-7. Soil surface cover (% by category) for sites in the non-rocky, high-mountain (501) stratum, Chiricahua National Monument, 2007–2010. Categories with an asterisk did not meet our statistical power criteria. (Duff=partially decomposed organic material, Gravel=2–75 mm diameter; Rocks=76–600 mm diameter)

Table 3-6. Vegetation and soils data for sites in the non-rocky, high-mountain (501) stratum in the context of proposed management assessment points, Chiricahua National Monument, 2007–2010.

Issue	Management assessment point	Mean ± SE	Recommendation
Erosion hazard	Bare ground (with no overhead vegetation) >20%	1.7% ± 1.1	Continue monitoring
	Surface soil aggregate stability (with no overhead canopy) <Class 3	4.2 ± 1.0	Continue monitoring
Plant community resilience	Annual plant cover: total plant cover >1:4 (field)	9.8%	Continue monitoring
	Percent cover of dead plants >5% (subcanopy)	1.4% ± 0.8	Continue monitoring
	Percent cover of dead plants >5% (canopy)	1.9% ± 1.1	Continue monitoring
Exotic plant dispersal	**Extent of exotic plants >50%**	**67% (2 of 3 plots)**	**Meet and consider**
Exotic plant invasion	Total exotic plant cover >10% (field)	0.55% ± 0.32	Continue monitoring
	Exotic plant cover: total plant cover >1:4 (field)	1.04%	Continue monitoring
Fire hazard	**Litter + duff >50%**	**56.5% ± 9.2**	**Meet and consider**
	Percent cover of dead plants >5% (field)	**9.4% ± 5.5**	**Meet and consider**

Red, bolded parameters exceeded our management assessment points.

3.4 Rocky, high-mountain (502) stratum

Comprising 29% of Chiricahua NM, sites in the rocky, high-mountain (502) stratum (see Table 2-3 for strata descriptions) occur extensively throughout the mountain tops and plateaus in the central and eastern portions of the monument (Figure 3-8; figures and tables begin on page 41). This stratum is the most common high-elevation type found in larger mountain ranges and "sky islands" of the American Southwest, including in parks such as Carlsbad Caverns, Guadalupe Mountains, and Saguaro national parks, Gila Cliff Dwellings and Organ Pipe Cactus national monuments, and Coronado NMem. See Appendix A for photographs.

3.4.1 Vegetation formations and lifeforms

Eight of the 12 rocky, high-mountain monitoring plots were forests or woodlands (see Figure 3-8). Plot 502_V02 was a shrub savanna, and plots 502_V07, V09, and V15 were wooded shrublands. The prevalence of forests is reflected in the relatively low lifeform diversity recorded within the rocky, high-mountain plots (Figure 3-9).

Trees and, to a much lesser extent, shrubs, dominated not only canopies and subcanopies of rocky, high-mountain sites, but also the field layers (Figure 3-9; see Table 2-1). Grasses, subshrubs, and succulents were common in field and subcanopy layers, whereas forbs and vines were nearly absent. Snags constituted a considerable amount of cover in field and (to a lesser extent) subcanopy vegetation.

Total vegetation cover was greatest in the subcanopy layer, reflecting the importance of short-statured trees (and relatively dense cover of low tree branches on even very tall trees) and large shrubs. The preponderance of small trees was also illustrated by the relatively low cover in the canopy, as few individual trees emerged beyond the subcanopy. The greatest lifeform diversity was found in the field layer (Figure 3-9).

3.4.2 Cover and extent of perennial plant species

Monitoring plots on rocky, high-mountain sites were dominated by scattered border pinyon pine canopy over a mixed Toumey oak or border pinyon pine subcanopy (Table 3-7). Seedlings and the bases of both trees were relatively common in the field layer, as well, occurring in a matrix of native perennial grasses, such as bullgrass, Texas bluestem (*Schizachyrium cirratum*), and pinyon ricegrass (*Piptochaetium fimbriatum*; Table 3-7). Pointleaf manzanita was relatively dense in both the field and subcanopy layers, as well (Table 3-7).

Pointleaf manzanita, Toumey oak, and border pinyon pine were found on all 12 rocky, high-mountain sites (Table 3-7). Other widespread species included the subshrub, beargrass (11 sites), and the perennial bunchgrasses, bullgrass (11 sites), bristly wolfstail (9 sites), and pinyon ricegrass (9 sites; Table 3-7). Plot-specific results are provided in Appendix B.

3.4.3 Frequency and extent of uncommon plant species

Thirty-nine plant species were observed only on frequency subplots of rocky, high-mountain monitoring sites, and we consider them uncommon species for this stratum (Table 3-8). The ferns, spiny cliffbrake (*Pellaea truncata*) and fairyswords, the shrub, firecrackerbush (*Bouvardia ternifolia*), and the succulents, Parry's agave (*Agave parryi*), kingcup cactus, and cactus apple, were the uncommon plant species with at least 10% within-plot frequency across the stratum (Table 3-8), and occurred on at least 25% of the rocky, high-elevation, monitoring sites. Plot-specific results are provided in Appendix B.

3.4.4 Cover and frequency of exotic species

One exotic plant species was detected on line-point transects on rocky, high-mountain sites: the exotic perennial grass, Lehmann lovegrass, although at <1% foliar cover. Lehmann lovegrass was detected on three of the 12 monitoring plots. Plot-specific results are provided in Appendix B.

We suspect that an annual *Echinochloa* we detected may have been the invasive nonnative, barnyardgrass (*Echinochloa crus-galli*) or the non-native, jungle rice (*Echinochloa colona*). Detected only on frequency subplots, the annual *Echinochloa* was the most frequent (within-plot frequency = 22%) and extensive (8 of 12 monitoring sites) uncommon plant (Table 3-8).

3.4.5 Soil cover, biological soil crusts, and stability

Soil cover was dominated by plant litter, duff, and, to a lesser extent, rocks and gravel (Figure 3-10). Bedrock was not uncommon, whereas bare soil without overhead vegetative cover was less than 2%, and biological soil crusts were nearly absent. Light cyanobacteria crust was the only biocrust morphological group detected, covering less than 0.3% of the soil surface. We met or exceeded our statistical power criteria for all soil substrate categories (see Sections 2.6 and 2.7).

Surface soil aggregate stability under vegetation canopies was 4.6 ± 0.4 (moderately stable), whereas stability for sample locations without overhead canopy cover were only 3.9 ± 0.5 (moderately stable). Plots 502_V03, V07, V09, and V13 had average stability index values of between 2 and 3 (unstable to somewhat unstable) for sample locations without canopy cover.

3.4.6 Management assessment points

Our results for rocky, high-mountain sites in the context of management assessment points (see Section 2.2.4) indicate one potential issue for management consideration: fire hazard (Table 3-10).

Here again, it is evident that fire hazard indicators for rocky, high-mountain sites foreshadowed the Horseshoe II Fire in 2011 (Table 3-10). Whereas litter and duff accumulations were only slightly above the management assessment point, the cover of dead plants (snags) in the field layer was nearly twice the assessment point. In combination, both plant litter and dead standing plants provided the dense fine fuels required for landscape-scale fire.

Erosion hazard, plant community resilience, exotic plant dispersal, and exotic plant invasion indicators were all well below their corresponding management assessment points (Table 3-10). However, Plot 502_V02 is potentially concerning, as locations both under vegetation and in the open had stabilities between 1 and 2 (unstable). However, most samples were collected beneath gravel, and the soil cover for plot 502_V02 was dominated by gravel, plant litter, and rock.

Chiricahua National Monument
Arizona

National Park Service
U.S. Department of the Interior

Monitoring plots in the rocky, high-mountain (502) stratum, 2007–2010

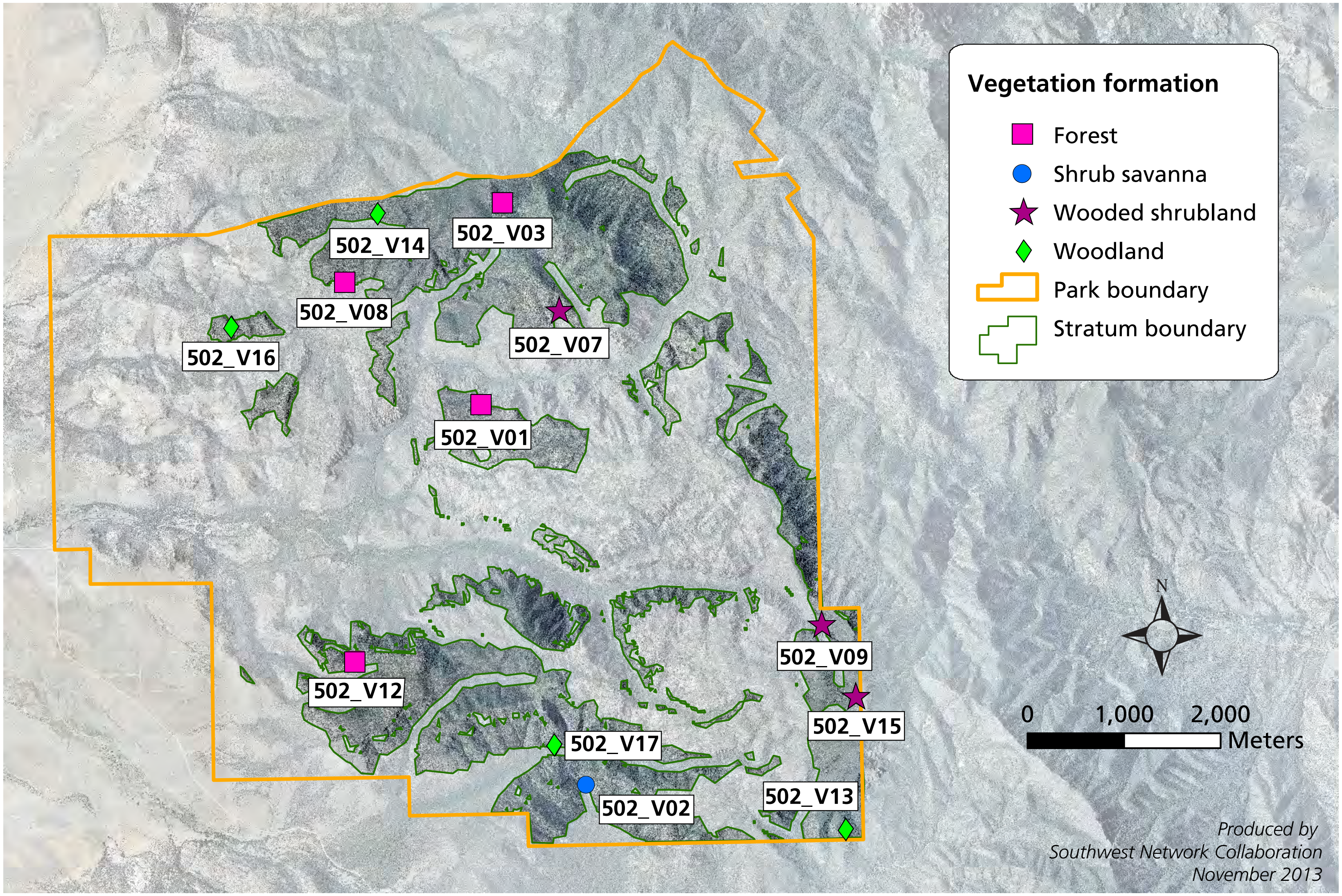


Figure 3-8. Locations of monitoring plots, by formation type, in the rocky, high-mountain (502) stratum, Chiricahua National Monument, 2007–2010. See Table 2-3 for strata descriptions.

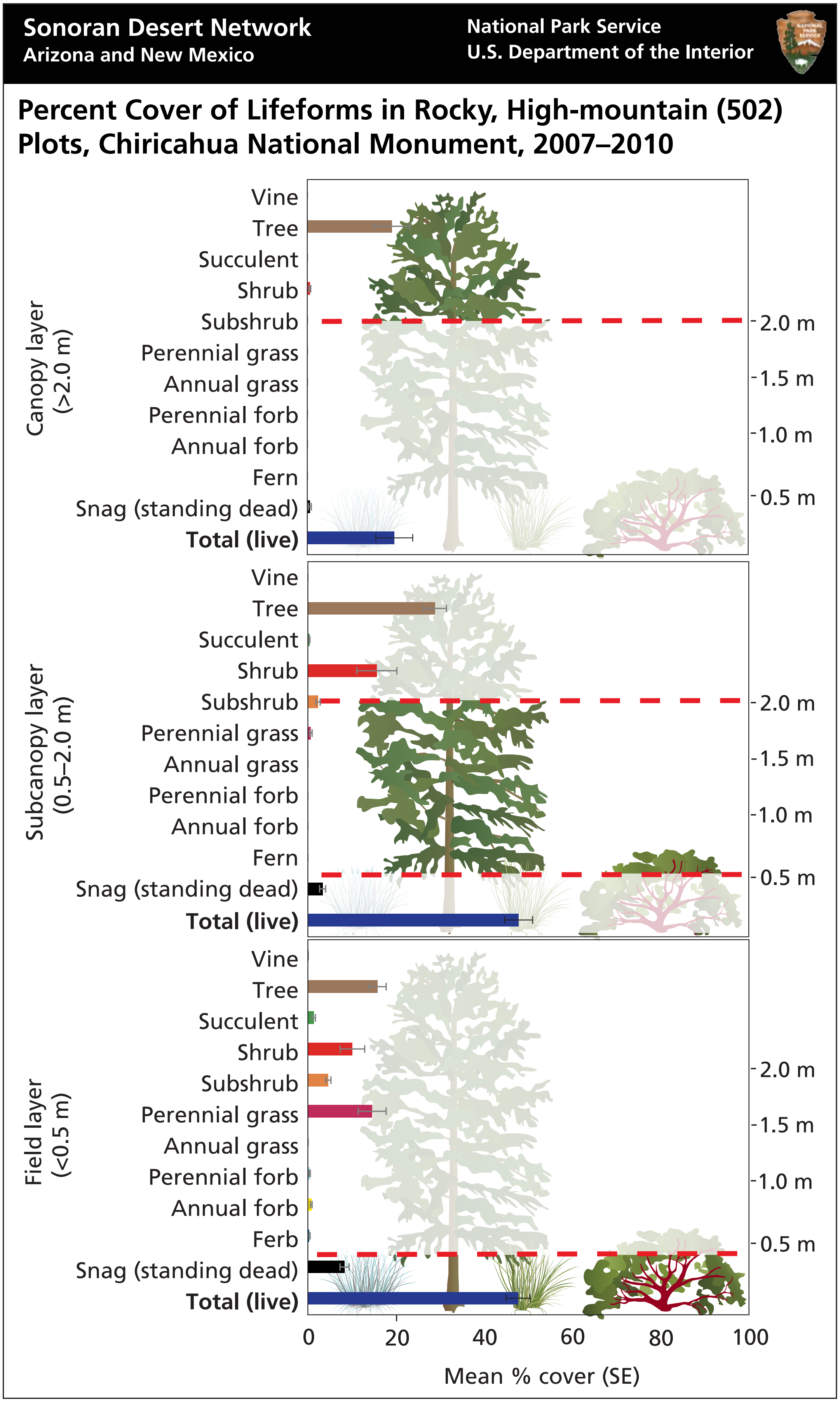


Figure 3-9. Lifeform cover in monitoring plots in the rocky, high-mountain (502) stratum, Chiricahua National Monument, 2007–2010.

Table 3-7. Percent cover for perennial and non-native annual species (by lifeform) measured in the field, subcanopy, and canopy layers of sites in the rocky, high-mountain (502 stratum), Chiricahua National Monument, 2007–2010.

Scientific name	Common name	Field (<0.5 m)			Subcanopy (0.5–2.0 m)			Canopy (>2.0 m)			Extent (of 12)
		AVG	SE	MDC	AVG	SE	MDC	AVG	SE	MDC	
FERN											
Bommeria hispida	copper fern	0.04%	0.04%	5%	---	---	---	---	---	---	1
Cheilanthes sp.	lipfern	0.21%	0.21%	5%	---	---	---	---	---	---	5
FORB/HERB											
Commelina tuberosa	birdbill dayflower	0.04%	0.04%	5%	---	---	---	---	---	---	3
Dalea sp.	prairie clover	0.04%	0.04%	5%	---	---	---	---	---	---	1
Erigeron sp.	fleabane	0.24%	0.18%	5%	---	---	---	---	---	---	5
Eriogonum sp.	buckwheat	0.04%	0.04%	5%	---	---	---	---	---	---	1
GRASS											
Aristida schiedeana	single threeawn	1.11%	0.47%	5%	0.14%	0.08%	5%	---	---	---	9
Bouteloua curtipendula	sideoats grama	0.28%	0.14%	5%	0.04%	0.04%	5%	---	---	---	5
Bouteloua gracilis	blue grama	0.04%	0.04%	5%	---	---	---	---	---	---	2
Bouteloua repens	slender grama	0.04%	0.04%	5%	---	---	---	---	---	---	1
Carex geophila	White Mountain sedge	0.04%	0.04%	5%	---	---	---	---	---	---	4
Carex vallicola	valley sedge	0.04%	0.04%	5%	---	---	---	---	---	---	1
Eragrostis intermedia	plains lovegrass	0.45%	0.24%	5%	0.04%	0.04%	5%	---	---	---	7
Eragrostis lehmanniana	**Lehmann lovegrass**	**0.04%**	**0.04%**	**5%**	**---**	**---**	**---**	**---**	**---**	**---**	**3**
Muhlenbergia alopecuroides	bristly wolfstail	0.45%	0.17%	5%	0.04%	0.04%	5%	---	---	---	9
Muhlenbergia emersleyi	bullgrass	6.01%	1.55%	5%	0.24%	0.10%	5%	---	---	---	11
Muhlenbergia longiligula	longtongue muhly	0.14%	0.14%	5%	---	---	---	---	---	---	1
Muhlenbergia polycaulis	cliff muhly	0.04%	0.04%	5%	---	---	---	---	---	---	3
Muhlenbergia rigida	purple muhly	0.59%	0.28%	5%	0.04%	0.04%	5%	---	---	---	5
Piptochaetium fimbriatum	pinyon ricegrass	2.19%	0.80%	5%	---	---	---	---	---	---	9
Schizachyrium cirratum	Texas bluestem	2.81%	1.47%	5%	0.17%	0.14%	5%	---	---	---	8
Schizachyrium sp.	little bluestem	0.17%	0.17%	5%	---	---	---	---	---	---	1
SUBSHRUB											
Ageratina herbacea	fragrant snakeroot	0.07%	0.07%	5%	---	---	---	---	---	---	5
Baccharis thesioides	Arizona baccharis	0.04%	0.04%	5%	---	---	---	---	---	---	4
Brickellia venosa	veiny brickellbush	0.07%	0.05%	5%	---	---	---	---	---	---	7
Brickellia californica	California brickellbush	0.24%	0.17%	5%	---	---	---	---	---	---	4
Dasylirion wheeleri	common sotol	0.97%	0.30%	5%	0.49%	0.13%	5%	---	---	---	10
Gutierrezia sp.	snakeweed	0.04%	0.04%	5%	---	---	5%	---	---	---	1

Table 3-7. Percent cover for species (by lifeform) measured in the field, subcanopy, and canopy layers of sites in the rocky, high-mountain (502 stratum), Chiricahua National Monument, 2007–2010, cont.

Scientific name	Common name	Field (<0.5 m)			Subcanopy (0.5–2.0 m)			Canopy (>2.0 m)			Extent (of 12)
		AVG	SE	MDC	AVG	SE	MDC	AVG	SE	MDC	
Gymnosperma glutinosum	gumhead	0.28%	0.15%	5%	0.04%	0.04%	5%	---	---	---	6
Nolina microcarpa	sacahuista	2.85%	0.67%	5%	1.77%	0.47%	5%	---	---	---	12
Trichostema arizonicum	Arizona bluecurls	0.07%	0.05%	5%	---	---	---	---	---	---	6
SHRUB											
Arctostaphylos pungens	pointleaf manzanita	9.24%	2.90%	6%	13.16%	4.67%	10%	0.10%	0.07%	5%	12
Garrya wrightii	Wright's silktassel	0.83%	0.30%	5%	2.47%	1.20%	5%	0.45%	0.22%	5%	12
SUCCULENT											
Agave palmeri	Palmer's century plant	0.87%	0.35%	5%	0.17%	0.11%	5%	---	---	---	12
Echinocereus sp.	hedgehog cactus	0.04%	0.04%	5%	---	---	---	---	---	---	2
Yucca baccata	banana yucca	0.07%	0.07%	5%	---	---	---	---	---	---	1
Yucca madrensis	yucca	0.31%	0.10%	5%	0.17%	0.08%	5%	---	---	---	10
TREE											
Cercocarpus montanus	alderleaf mountain mahogany	---	---	---	0.14%	0.11%	5%	---	---	---	2
Hesperocyparis arizonica	Arizona cypress	---	---	---	0.31%	0.25%	5%	0.24%	0.18%	5%	4
Juniperus deppeana	alligator juniper	0.04%	0.04%	5%	0.87%	0.28%	5%	0.77%	0.34%	5%	9
Mimosa aculeaticarpa	catclaw mimosa	0.07%	0.07%	5%	0.10%	0.10%	5%	---	---	---	2
Pinus discolor	border pinyon	1.70%	0.27%	5%	11.67%	2.01%	5%	16.01%	3.78%	8%	12
Quercus arizonica	Arizona white oak	0.28%	0.28%	5%	0.59%	0.46%	5%	0.35%	0.23%	5%	4
Quercus emoryi	Emory oak	0.04%	0.04%	5%	0.07%	0.05%	5%	---	---	---	2
Quercus hypoleucoides	silverleaf oak	0.31%	0.21%	5%	0.42%	0.42%	5%	0.14%	0.14%	5%	6
Quercus rugosa	netleaf oak	0.10%	0.07%	5%	0.21%	0.12%	5%	---	---	---	4
Quercus toumeyi	Toumey oak	12.99%	2.16%	5%	14.17%	2.01%	5%	1.67%	0.84%	5%	12
Quercus turbinella	Sonoran scrub oak	0.07%	0.07%	5%	0.07%	0.07%	5%	---	---	---	1
Rhus virens	evergreen sumac	0.17%	0.08%	5%	0.24%	0.14%	5%	---	---	---	5
VINE											
Ipomoea tenuiloba	spiderleaf	0.04%	0.04%	5%	---	---	---	---	---	---	1

Table 3-7. Percent cover for species (by lifeform) measured in the field, subcanopy, and canopy layers of sites in the rocky, high-mountain (502 stratum), Chiricahua National Monument, 2007–2010, cont.

Scientific name	Common name	Field (<0.5 m)			Subcanopy (0.5–2.0 m)			Canopy (>2.0 m)			Extent (of 12)
		AVG	SE	MDC	AVG	SE	MDC	AVG	SE	MDC	
TOTALS BY LIFEFORM											
Annual Forb		0.73%	0.20%	5%	---	---	---	---	---	---	
Annual Grass		---	---	---	---	---	---	---	---	---	
Perennial Forb		0.35%	0.18%	5%	---	---	---	---	---	---	
Perennial Grass		14.56%	3.17%	7%	0.70%	0.25%	5%	---	---	---	
Fern		0.24%	0.24%	5%	---	---	---	---	---	---	
Subshrub		4.62%	0.59%	5%	2.29%	0.48%	5%	---	---	---	
Shrub		10.07%	2.79%	6%	15.62%	4.55%	10%	0.56%	0.21%	5%	
Succulent		1.29%	0.39%	5%	0.35%	0.12%	5%	---	---	---	
Tree		15.76%	1.94%	5%	28.86%	2.55%	6%	19.17%	4.08%	9%	
Vine		0.04%	0.04%	5%	---	---	---	---	---	---	
Snag		8.30%	1.02%	5%	3.33%	0.69%	5%	0.56%	0.36%	5%	
Total (live)		**47.65%**	**2.76%**	**6%**	**47.82%**	**3.16%**	**7%**	**19.73%**	**4.17%**	**9%**	

AVG = average, SE = standard error, MDC = minimum detectable change (% cover), Extent is the number of sites in which the species was detected on either transects or subplots (out of 12). Non-native plants are bolded. All species exceeded our statistical power criteria (MDC ≤10%).

Table 3-8. Within-plot frequency (%) and extent of uncommon plant species, by lifeform, sampled at sites in the rocky, high-mountain (502) stratum, Chiricahua National Monument, 2007–2010.

Scientific name	Common name	Within-plot frequency	SE	Extent (of 12)
FERN				
Astrolepis sp.	cloakfern	2%	1.7%	1
Cheilanthes lendigera	nitbearing lipfern	3%	3.3%	1
Cheilanthes lindheimeri	fairyswords	10%	4.6%	4
Pellaea truncata	spiny cliffbrake	15%	8.2%	5
Pellaea wrightiana	Wright's cliffbrake	3%	3.3%	1
FORB/HERB				
Acourtia sp.	desertpeony	3%	3.3%	1
Comandra umbellata	bastard toadflax	2%	1.7%	1
Erigeron flagellaris	trailing fleabane	2%	1.7%	1
Erigeron oreophilus	chaparral fleabane	7%	5.1%	2
Galium sp.	bedstraw	5%	3.6%	2
Hedeoma dentata	dentate false pennyroyal	5%	5.0%	1
Hedeoma oblongifolia	oblongleaf false pennyroyal	3%	2.2%	2
Ipomoea sp.	morning-glory	2%	1.7%	1
Lasianthaea podocephala	San Pedro daisy	5%	3.6%	2
Linum neomexicanum	New Mexico yellow flax	3%	3.3%	1
Tragia ramosa	branched noseburn	2%	1.7%	1
GRASS				
Bouteloua hirsuta	hairy grama	3%	2.2%	2
Cyperus sp.	flatsedge	2%	1.7%	1
Elionurus barbiculmis	woolyspike balsamscale	3%	3.3%	1
Muhlenbergia tricholepis	pine dropseed	5%	5.0%	1
Poa fendleriana	muttongrass	2%	1.7%	1
Zuloagaea bulbosa	bulb panicgrass	2%	1.7%	1
SUBSHRUB				
Brickellia grandiflora	tasselflower brickellbush	2%	1.7%	1
Brickellia lemmonii	Lemmon's brickellbush	2%	1.7%	1
Carphochaete bigelovii	Bigelow's bristlehead	5%	3.6%	2
Gutierrezia sarothrae	broom snakeweed	8%	8.3%	1
SHRUB				
Bouvardia ternifolia	firecrackerbush	10%	5.8%	3
Fendlerella utahensis	Utah fendlerbush	7%	6.7%	1
Phoradendron villosum	Pacific mistletoe	3%	2.2%	2
Rhus aromatica	fragrant sumac	2%	1.7%	1
Rhus trilobata	skunkbush sumac	2%	1.7%	1
Trixis californica	American threefold	2%	1.7%	1
SUCCULENT				
Agave parryi	Parry's agave	12%	7.2%	3
Echinocereus pectinatus	rainbow cactus	2%	1.7%	1
Echinocereus triglochidiatus	kingcup cactus	12%	6.3%	3
Opuntia chlorotica	dollarjoint pricklypear	7%	3.8%	3
Opuntia engelmannii	cactus apple	12%	5.2%	5
Opuntia phaeacantha	tulip pricklypear	7%	2.8%	4

Table 3-8. Within-plot frequency (%) and extent of uncommon plant species, by lifeform, sampled at sites in the rocky, high-mountain (502) stratum, Chiricahua National Monument, 2007–2010, cont.

Scientific name	Common name	Within-plot frequency	SE	Extent (of 12)
VINE				
Phaseolus sp.	bean	2%	1.7%	1

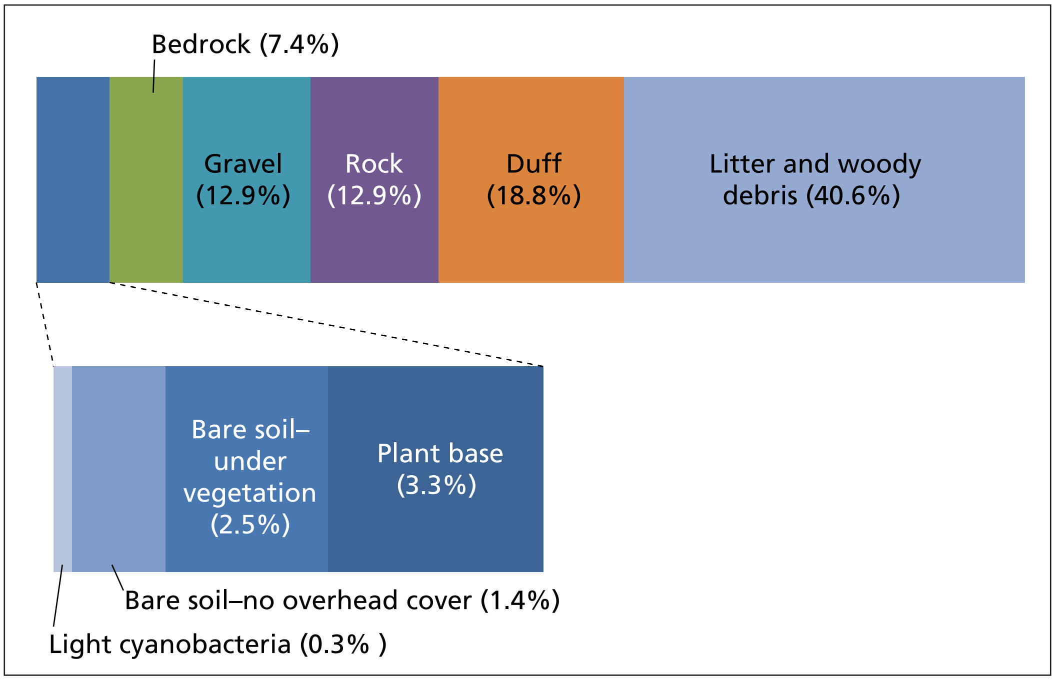


Figure 3-10. Soil surface cover (% by category) for sites in the rocky, high-mountain (502) stratum, Chiricahua National Monument, 2007–2010. All categories met or exceeded our statistical power criteria. (Duff=partially decomposed organic material, Gravel=2–75 mm diameter; Rocks=76–600 mm diameter)

Table 3-9. Vegetation and soils data for sites in the rocky, high-mountain (502) stratum in the context of proposed management assessment points, Chiricahua NM, 2007–2010.

Issue	Management assessment point	Mean ± SE	Recommendation
Erosion hazard	Bare ground (with no overhead vegetation) >20%	1.4% ± 0.4	Continue monitoring
	Surface soil aggregate stability (with no overhead canopy) <Class 3	3.9 ± 0.5	Continue monitoring
Plant community resilience	Annual plant cover: total plant cover >1:4 (field)	1.7%	Continue monitoring
	Percent cover of dead plants >5% (subcanopy)	3.3% ± 1.0	Continue monitoring
	Percent cover of dead plants >5% (canopy)	0.6% ± 0.2	Continue monitoring
Exotic plant dispersal	Extent of exotic plants >50%	25% (3 of 12 plots)	Continue monitoring
Exotic plant invasion	Total exotic plant cover >10% (field)	0.94% ± 0.3	Continue monitoring
	Exotic plant cover: total plant cover >1:4 (field)	2.0%	Continue monitoring
Fire hazard	**Litter + duff > 50%**	**59.3% ± 4.0**	**Meet and consider**
	Percent cover of dead plants > 5% (field)	**8.3% ± 2.4**	**Meet and consider**

Red, bolded parameters exceeded our management assessment points.

3.5 High-mountain rock outcrop (503) stratum

Comprising nearly 21% of the terrestrial uplands of Chiricahua NM, high-mountain rock outcrops include the "hoodoo" (rock pinnacle) formations for which the monument is renowned. Although localized rock outcrops are scattered throughout the monument, extensive areas are found in and around the major canyon systems and across a broad extent of the southern boundary (Figure 3-11; figures and tables begin on page 51). Although actual hoodoos are much rarer, this stratum (503; see Table 2-3 for strata descriptions) is found in many other large mountains ranges and "sky islands" of the American Southwest, including in Coronado NMem, Gila Cliff Dwellings and Organ Pipe Cactus national monuments, and Saguaro NP. See Appendix A for photographs.

3.5.1 Vegetation formations and lifeforms

All but two high-mountain rock outcrop monitoring plots were forests or woodlands. Plot 503_V08 was a shrubland, and plot 503_V04 was a wooded shrubland (see Figure 3-11).

As on rocky, high-mountain sites (see Section 3.4), the preponderance of small-statured trees dominated canopy, subcanopy, and even field layers (Figure 3-12; see Table 2-1 for layer descriptions). Relatively small shrubs were co-dominant in field layers and of secondary importance in the subcanopies. Vines and perennial forbs were nearly absent at all heights. Grasses, subshrubs, annual forbs, and succulents occurred at very low cover, primarily in the field layer. Snags comprised approximately 10% cover in the field, and smaller (but sizeable) values in the subcanopy and canopy (Figure 3-12).

As with the rocky, high-mountain sites, total vegetation cover was greatest in the subcanopy, despite the preponderance of trees. All lifeforms, except annual grass, were observed in the field layer (Figure 3-12).

3.5.2 Cover and extent of perennial plant species

Monitoring plots located on high-mountain rock outcrops were dominated by relatively dense pointleaf manzanita in field and subcanopy layers (see Figure 3-12). Subdominants included border pinyon and the short-statured evergreen oaks, Toumey oak, netleaf oak (*Quercus rugosa*), and, to a lesser extent, silverleaf oak (*Q. hypoleucoides*). Border pinyon pine was the primary tree in the canopy, with Arizona cypress (*Cupressus arizonica*) as a common associate (Table 3-10).

In addition to being dominant plants within high-mountain rock outcrop monitoring sites, pointleaf manzanita, Toumey oak, and border pinyon pine were detected on all eight sites. Silverleaf oak was detected on seven sites, and netleaf oak on six (Table 3-10). Other extensive species included the perennial bunchgrass, bullgrass, and the subshrub, beargrass, which were widespread but never dominant (Table 3-10). Plot-specific results are provided in Appendix B.

3.5.3 Frequency and extent of uncommon plant species

An additional 31 plant species were observed only on frequency subplots of high-mountain rock outcrop sites (Table 3-11). For analysis and interpretation purposes, we consider these species "uncommon" across this stratum. The cactus, hedgehog cactus (*Echinocereous* sp.); the subshrub, Lemmon's brickellbush (*Brickellia lemmonii*); the grass cliff muhly; and the sedge, Fendler's flatsedge (*Cyperus fendlerianus*) were the only uncommon species detected with at least 10% within-plot frequency across this stratum, and at least 25% (2 of 8) of the high-mountain, rock outcrop monitoring sites (Table 3-11). Plot-specific results are provided in Appendix B.

3.5.4 Cover and frequency of exotic species

One exotic plant species was detected on line-point transects at high-mountain rock outcrop sites: the perennial bunchgrass, Lehmann lovegrass (although only on plot 503_V03, at about 2% cover; see Table 3-10). One potential additional exotic grass was detected on frequency subplots within this stratum: an annual *Echinochloa* sp., likely barnyardgrass or jungle rice (see Table 3-11). Plot-specific results are provided in Appendix B.

3.5.5 Soil cover, biological soil crusts, and stability

Soil cover was dominated by plant litter (often over bedrock), duff, bedrock, rock, and gravel (Figure 3-13). Total bare soil was <2% of the substrate cover, and the only biological soil crusts were traces of lichen and moss (Figure 3-13). We did not meet our statistical power criteria for plant litter, for which we estimated a change detection of 12%. We met our statistical power criteria for all other soil cover categories.

Surface soil aggregate stability under vegetation canopies was 4.3 ± 0.4 (moderately stable). Values for samples without overhead canopy cover were comparable, at 4.2 ± 0.4.

3.5.6 Management assessment points

Our results for high-mountain, rock outcrop sites in the context of management assessment points (see Section 2.2.4) indicated one potential issue for management consideration (Table 3-12): fire hazard.

As with all other strata, the fire hazard indicators for high-mountain, rock outcrop sites foreshadowed the Horseshoe II Fire in 2011 (Table 3-12). Whereas litter and duff accumulations were only slightly above the management assessment point, the cover of dead plants in the field layer was more than twice the assessment point. In combination, both plant litter and dead standing plants provided the dense fine fuels required for landscape-scale fire.

Erosion hazard, plant community resilience, exotic plant dispersal, and exotic plant invasion indicators were all well below their corresponding management assessment points (Table 3-12).

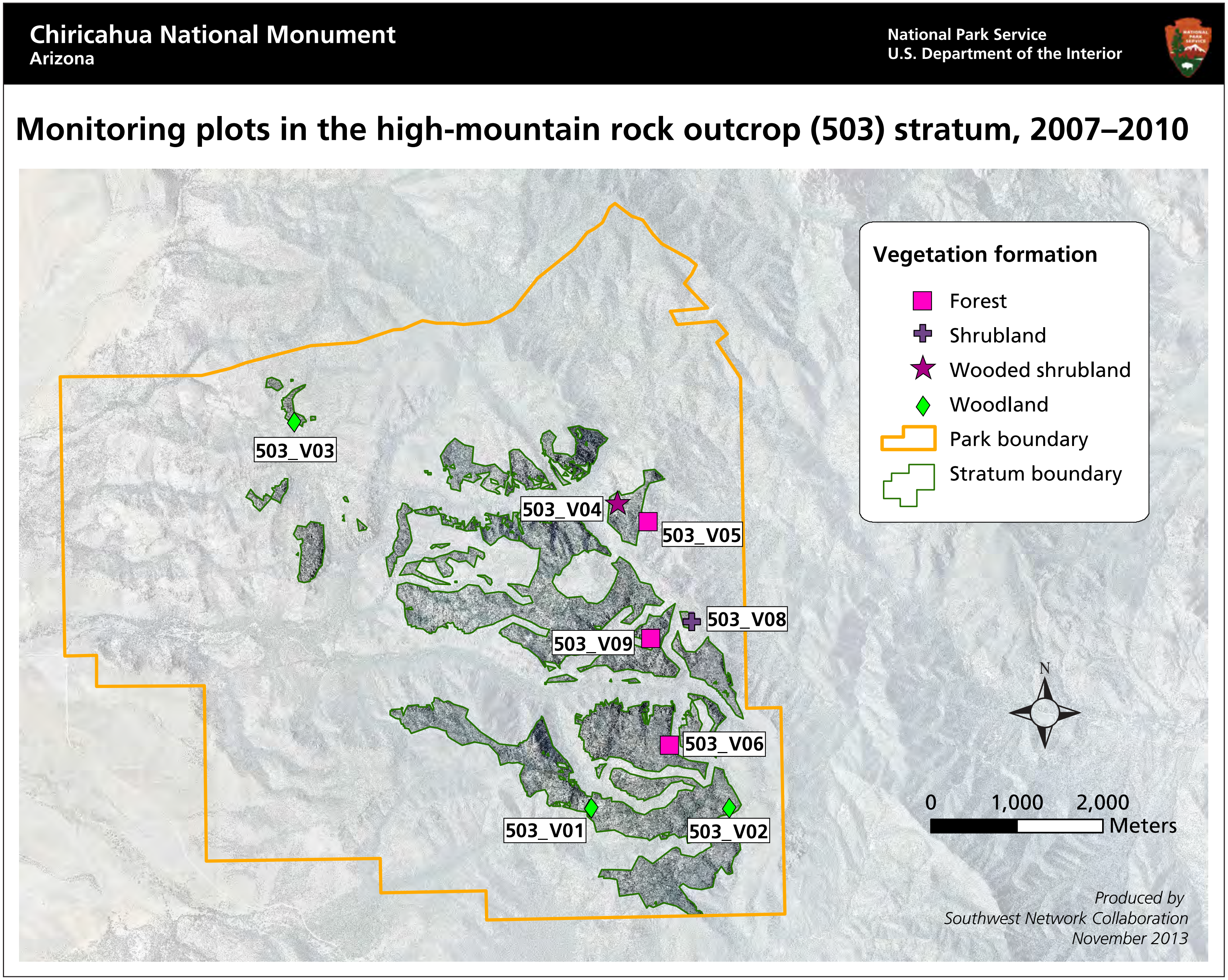


Figure 3-11. Locations of monitoring plots, by formation type, in the high-mountain rock outcrop (503) stratum, Chiricahua National Monument, 2007–2010. See Table 2-3 for strata descriptions.

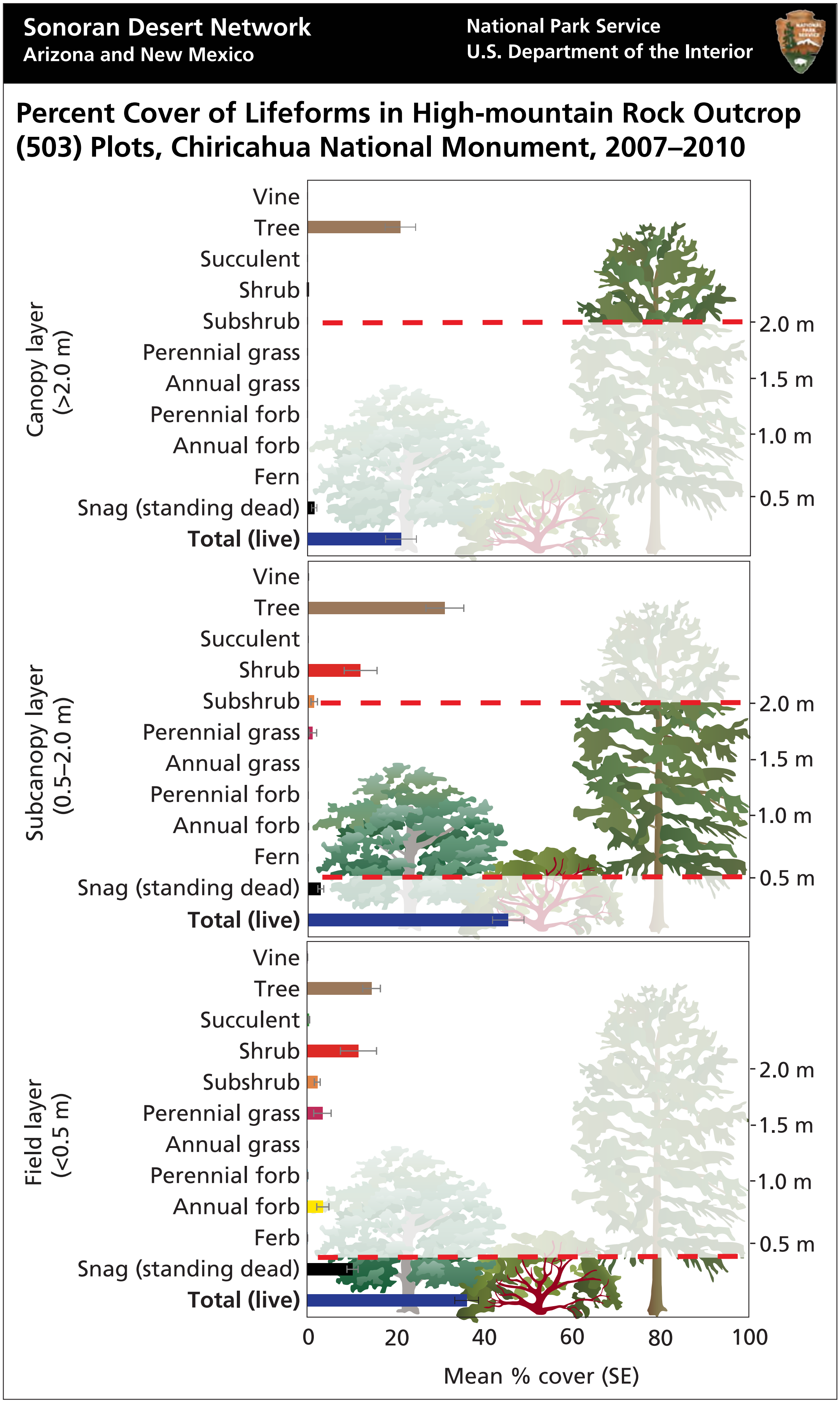


Figure 3-12. Lifeform cover in monitoring plots in the high-mountain rock outcrop (503) stratum, Chiricahua National Monument, 2007–2010.

Table 3-10. Percent cover for perennial and non-native annual species (by lifeform) measured in the field, subcanopy, and canopy layers of sites in the high-mountain rock outcrop (503) stratum, Chiricahua National Monument, 2007–2010.

		Field (<0.5 m)			Subcanopy (0.5–2.0 m)			Canopy (>2.0 m)			Extent
Scientific name	Common name	AVG	SE	MDC	AVG	SE	MDC	AVG	SE	MDC	(of 8)
FERN											
Cheilanthes sp.	lipfern	0.05%	0.05%	5%	---	---	---	---	---	---	5
FORB/HERB											
Galium sp.	bedstraw	0.05%	0.05%	5%	---	---	---	---	---	---	1
Stachys coccinea	scarlet hedgenettle	0.05%	0.05%	5%	---	---	---	---	---	---	1
GRASS											
Aristida schiedeana	single threeawn	0.05%	0.05%	5%	0.05%	0.05%	5%	---	---	---	4
Aristida ternipes	spidergrass	0.05%	0.05%	5%	---	---	---	---	---	---	3
Bouteloua curtipendula	sideoats grama	0.05%	0.05%	5%	---	---	---	---	---	---	1
Eragrostis intermedia	plains lovegrass	0.47%	0.47%	5%	0.26%	0.21%	5%	---	---	---	2
Eragrostis lehmanniana	**Lehmann lovegrass**	**0.26%**	**0.26%**	**5%**	**0.16%**	**0.16%**	**5%**	**---**	**---**	**---**	**1**
Muhlenbergia alopecuroides	bristly wolfstail	0.11%	0.07%	5%	---	---	---	---	---	---	4
Muhlenbergia emersleyi	bullgrass	1.20%	0.64%	5%	0.37%	0.31%	5%	---	---	---	6
Piptochaetium fimbriatum	pinyon ricegrass	0.57%	0.29%	5%	0.10%	0.10%	5%	---	---	---	4
Schizachyrium cirratum	Texas bluestem	0.11%	0.07%	5%	0.05%	0.05%	5%	---	---	---	2
Setaria leucopila	streambed bristlegrass	0.42%	0.42%	5%	0.05%	0.05%	5%	---	---	---	1
SUBSHRUB											
Baccharis thesioides	Arizona baccharis	0.10%	0.10%	5%	---	---	---	---	---	---	2
Coleosanthus californicus	California brickellbush	0.21%	0.21%	5%	---	---	---	---	---	---	1
Dasylirion wheeleri	common sotol	0.37%	0.24%	5%	0.31%	0.22%	5%	---	---	---	2
Gymnosperma glutinosum	gumhead	0.05%	0.05%	5%	---	---	---	---	---	---	1
Nolina microcarpa	sacahuista	1.56%	0.59%	5%	1.04%	0.67%	5%	---	---	---	6
SHRUB											
Arctostaphylos pungens	pointleaf manzanita	11.56%	4.09%	9%	11.56%	3.82%	8%	0.06%	0.06%	5%	8
Bouvardia ternifolia	firecrackerbush	0.05%	0.05%	5%	---	---	---	---	---	---	1
Garrya wrightii	Wright's silktassel	---	---	---	0.21%	0.16%	5%	0.06%	0.06%	5%	6
Philadelphus microphyllus	littleleaf mock orange	---	---	---	0.10%	0.10%	5%	---	---	---	1
SUCCULENT											
Agave palmeri	Palmer's century plant	0.21%	0.14%	5%	---	---	---	---	---	---	4
Agave parryi	Parry's agave	0.11%	0.07%	5%	---	---	---	---	---	---	2
Yucca baccata	banana yucca	0.11%	0.07%	5%	---	---	---	---	---	---	4

Table 3-10. Percent cover for species (by lifeform) measured in the field, subcanopy, and canopy layers of sites in the high-mountain rock outcrop (503) stratum, Chiricahua National Monument, 2007–2010, cont.

		Field (<0.5 m)			Subcanopy (0.5–2.0 m)			Canopy (>2.0 m)			Extent
Scientific name	**Common name**	**AVG**	**SE**	**MDC**	**AVG**	**SE**	**MDC**	**AVG**	**SE**	**MDC**	**(of 8)**
TREE											
Hesperocyparis arizonica	Arizona cypress	0.05%	0.05%	5%	1.51%	0.88%	5%	3.87%	1.38%	5%	4
Juniperus deppeana	alligator juniper	---	---	---	0.10%	0.10%	5%	---	---	---	2
Pinus discolor	border pinyon	1.04%	0.38%	5%	7.66%	1.72%	5%	14.11%	1.95%	5%	8
Quercus arizonica	Arizona white oak	0.16%	0.16%	5%	0.57%	0.57%	5%	0.12%	0.11%	5%	2
Quercus emoryi	Emory oak	---	---	---	---	---	---	0.12%	0.11%	5%	1
Quercus hypoleucoides	silverleaf oak	2.45%	0.94%	5%	3.85%	1.88%	5%	0.60%	0.56%	5%	7
Quercus rugosa	netleaf oak	3.80%	2.23%	5%	6.46%	4.17%	9%	1.25%	1.11%	5%	6
Quercus toumeyi	Toumey oak	6.87%	2.00%	5%	10.42%	2.91%	7%	0.95%	0.25%	5%	8
Quercus turbinella	Sonoran scrub oak	0.05%	0.05%	5%	0.10%	0.10%	5%	---	---	---	1
Rhus virens	evergreen sumac	0.16%	0.16%	5%	0.26%	0.26%	5%	---	---	---	1
VINE											
Galactia wrightii	Wright's milkpea	0.05%	0.05%	5%	0.05%	0.05%	5%	---	---	---	2
TOTALS BY LIFEFORM											
Annual Forb		3.54%	1.38%	5%	0.05%	0.05%	5%	---	---	---	
Annual Grass		---	---	---	---	---	---	---	---	---	
Perennial Forb		0.11%	0.11%	5%	---	---	---	---	---	---	
Perennial Grass		3.44%	1.98%	5%	1.04%	0.87%	5%	---	---	---	
Fern		0.05%	0.05%	5%	---	---	---	---	---	---	
Subshrub		2.29%	0.67%	5%	1.36%	0.74%	5%	---	---	---	
Shrub		11.62%	4.07%	9%	11.88%	3.72%	8%	0.12%	0.07%	5%	
Succulent		0.42%	0.16%	5%	---	---	---	---	---	---	
Tree		14.58%	1.99%	5%	30.94%	4.28%	9%	21.01%	3.44%	8%	
Vine		0.05%	0.05%	5%	0.05%	0.05%	5%	---	---	---	
Snag		10.26%	1.26%	5%	2.87%	0.67%	5%	1.49%	0.60%	5%	
Total (live)		**36.10%**	**2.69%**	**6%**	**45.32%**	**3.55%**	**8%**	**21.13%**	**3.49%**	**8%**	

AVG = average, SE = standard error, MDC = minimum detectable change (% cover), Extent is the number of sites in which the species was detected on either transects or subplots (out of 8). Non-native plants are bolded. All species exceeded our statistical power criteria (MDC ≤10%).

Table 3-11. Within-plot frequency (%) and extent of uncommon plant species, by lifeform, sampled at sites in the high-mountain rock outcrop (503) stratum, Chiricahua National Monument, 2007–2010.

Scientific name	Common name	Within-plot frequency	SE	Extent (of 8)
FERN				
Astrolepis sp.	cloakfern	3%	2.5%	1
Bommeria hispida	copper fern	3%	2.5%	1
Pellaea atropurpurea	purple cliffbrake	8%	7.5%	1
FORB/HERB				
Heuchera sanguinea	coralbells	5%	5.0%	1
Symphyotrichum sp.	aster	3%	2.5%	1
GRASS				
Bouteloua gracilis	blue grama	3%	2.5%	1
Cyperus fendlerianus	Fendler's flatsedge	10%	7.6%	2
Disakisperma dubium	green sprangletop	3%	2.5%	1
Muhlenbergia polycaulis	cliff muhly	33%	10.0%	6
Poa fendleriana	muttongrass	3%	2.5%	1
Zuloagaea bulbosa	bulb panicgrass	3%	2.5%	1
SUBSHRUB				
Brickellia lemmonii	Lemmon's brickellbush	13%	5.3%	4
Brickellia venosa	veiny brickellbush	5%	3.3%	2
Carphochaete bigelovii	Bigelow's bristlehead	3%	2.5%	1
Trichostema arizonicum	Arizona bluecurls	3%	2.5%	1
SHRUB				
Apacheria chiricahuensis	apachebush	5%	5.0%	1
Arctostaphylos pringlei	Pringle manzanita	3%	2.5%	1
Cercocarpus montanus	alderleaf mountain mahogany	5%	5.0%	1
Fallugia paradoxa	Apache plume	3%	2.5%	1
Fendlerella utahensis	Utah fendlerbush	3%	2.5%	1
Fouquieria splendens	ocotillo	5%	5.0%	1
Prunus virginiana	chokecherry	5%	5.0%	1
SUCCULENT				
Echinocereus sp.	hedgehog cactus	25%	11.8%	5
Opuntia chlorotica	dollarjoint pricklypear	3%	2.5%	1
Opuntia engelmannii	cactus apple	3%	2.5%	1
Opuntia phaeacantha	tulip pricklypear	5%	5.0%	1
Yucca madrensis	yucca	3%	2.5%	1

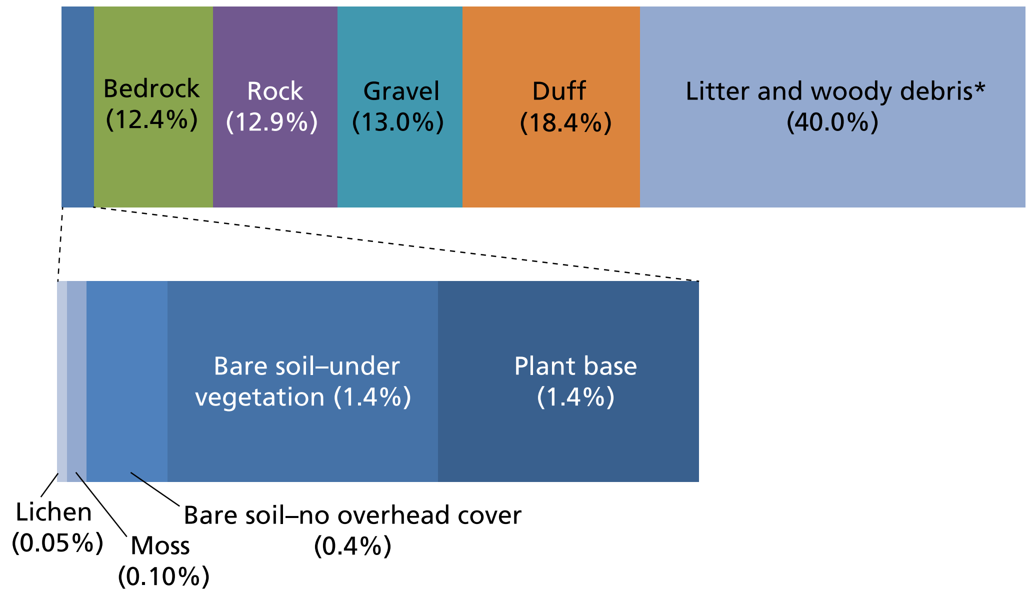


Figure 3-13. Soil surface cover (% by category) for sites in the high-mountain rock outcrop (503) stratum, Chiricahua National Monument, 2007–2010. Categories with an asterisk did not meet our statistical power criteria. (Duff=partially decomposed organic material, Gravel=2–75 mm diameter; Rocks=76–600 mm diameter)

Table 3-12. Vegetation and soils data for sites in the high-mountain rock outcrop (503) stratum in the context of proposed management assessment points, Chiricahua National Monument, 2007–2010.

Issue	Management assessment point	Mean ± SE	Recommendation
Erosion hazard	Bare ground (with no overhead vegetation) >20%	0.4% ± 0.2	Continue monitoring
	Surface soil aggregate stability (with no overhead canopy) <Class 3	4.2 ± 0.4	Continue monitoring
Plant community resilience	Annual plant cover: total plant cover >1:4 (field)	9.8%	Continue monitoring
	Percent cover of dead plants >5% (subcanopy)	2.9% ± 1.0	Continue monitoring
	Percent cover of dead plants >5% (canopy)	1.5% ± 0.5	Continue monitoring
Exotic plant dispersal	Extent of exotic plants > 50%	13% (1 of 8 plots)	Continue monitoring
Exotic plant invasion	Total exotic plant cover >10% (field)	0.05% ± 0.02	Continue monitoring
	Exotic plant cover: total plant cover >1:4 (field)	0.14%	Continue monitoring
Fire hazard	**Litter + duff >50%**	**58.4% ± 4.1**	**Meet and consider**
	Percent cover of dead plants >5% (field)	**10.3% ± 3.6**	**Meet and consider**

Red, bolded parameters exceeded our management assessment points.

4 Discussion

4.1 The role of elevation and soil in governing vegetation communities

Analysis of the data presented in this report reveals a complex montane landscape in which both elevation and soil characteristics govern vegetation communities (Figure 4-1).

Sites below 6,000' are characterized by semi-desert grasslands and savannas (somewhat similar to nearby Fort Bowie NHS; see Hubbard et al. 2010), composed primarily of drought-tolerant, diverse perennial bunchgrasses; hardy, short-statured Toumey oak trees (a scrubby evergreen oak that sprouts vigorously following disturbance); and scattered, drought-tolerant shrubs and succulents, such as pointleaf manzanita, beargrass, and sotol (rocky, mid-mountain [402] stratum, Figure 4-2).

Grass cover diminishes, and Toumey oak is joined by border pinyon pine in the canopies, on similar soils above 6,000' (rocky, high-mountain [502] stratum, Figure 4-3). Dense pointleaf manzanita thickets underlie the woodland canopies, which contain substantial quantities of dead standing trees and shrubs.

Lower proportions of surface-soil rock fragments on sites above 6,000' result in relatively dense, tall forests of border pinyon pine and alligator juniper (non-rocky, high-mountain [501] stratum, Figure 4-4). Toumey oak is replaced by the less drought-tolerant Arizona white oak. Grass and forb cover drops under the more shaded canopies. Dead trees and shrubs are common.

Overall vegetation cover is lowest on rock outcrop sites above 6,000'—sites where the characteristic "hoodoos" or rock pinnacles are found. Here, Toumey oak is joined by silverleaf oak and, to a lesser extent, netleaf oak (shrubby evergreen oaks that are highly drought-resistant) in a sparse, open woodland (high-mountain rock outcrop [503] stratum, Figure 4-5). These trees, as well as small border pinyon pine and pointleaf manzanita, are rooted in cracks and small, disjunct pockets of shallow soil scattered among the rock outcrops and bedrock of these rock-dominated sites. Annual forbs and other herbs are uncommon. As with other high-elevation sites, dead trees and shrubs are common.

4.2 The central role of available soil moisture

The striking partitioning of the Chiricahua NM landscape by elevation and soil is likely due to the important effects these elements exert on the most limiting factor for plant growth in these ecosystems: soil moisture availability for germination, growth, and persistence.

Increasing elevation enhances available soil moisture via increases in precipitation. Decreased air pressure reduces air temperature with increasing elevation (Strahler 2013). Moist air masses cool as they rise over the Chiricahua Mountains. Water vapor then condenses and falls as rain during warm-season thunderstorms, or as snow during cool-season storms (Ingram 2000; Larcher 2003). This results in sharp increases in precipitation on the high-elevation "sky island" mountain systems, as compared to the surrounding desert "seas" (Dimmitt 2000; Figure 4-6). For every 1,000-foot (305-m) increase in elevation, annual precipitation increases approximately 3–5" (7.62–12.7 cm; Sellers 2008).

It is this combination of cooler air temperatures and higher effective soil moisture that drives the occurrence of mixed conifer forests (more representative of the Rocky Mountains) atop elevation gradients of woodlands, grasslands, and savannas above subtropical desert valleys. These are the "sky island" mountain systems of the American Southwest (Marshall 1957; Figure 4-7).

Rock fragments in surface soils also have important effects on available soil moisture. Increasing proportions of rock fragments result in fewer fine pores for water movement and storage in a soil profile (Brady and Weil 2002). In combination, soil rock-fragment content and the effects of elevation on local climate result in an aridity gradient ranging from effectively drier mid-mountain, rocky sites through more mesic high-mountain, non-rocky sites. Our data support this view, as more drought-adapted species and lifeforms are replaced by more productive, less-tolerant woodland and forest species with increasing elevation and decreasing rockiness of surface soil. Overall vegetative cover also generally increases along this gradient (see Tables 3-1, 3-4, 3-7, 3-10).

Rock outcrop sites somewhat defy this trend. Unlike the more homogenous rocky and non-

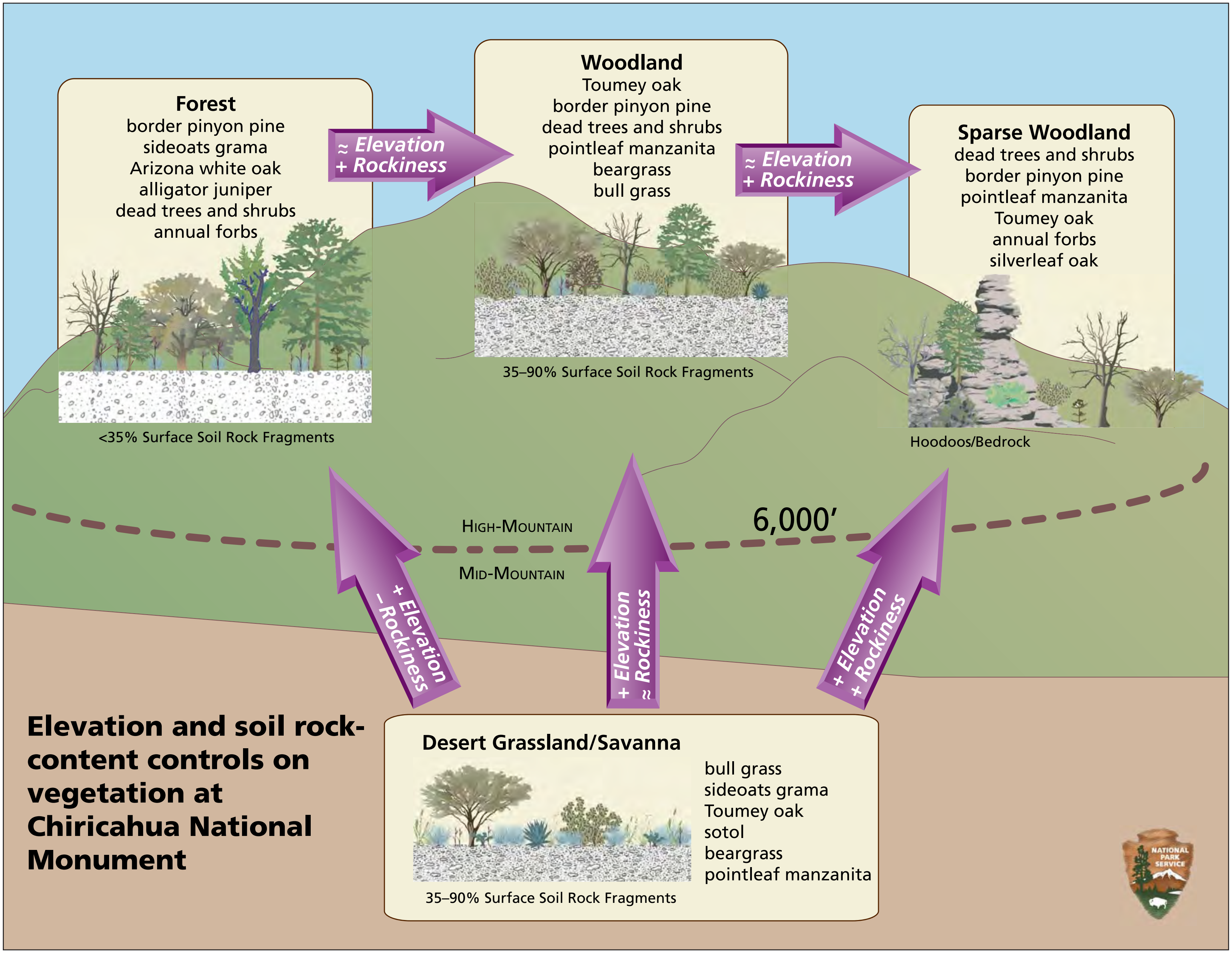


Figure 4-1. Elevation and soil effects on plant communities at Chiricahua National Monument.

NPS/A. HUBBARD

Figure 4-2. Shrub savanna typical of rocky sites below 6,000' elevation (402 stratum), Chiricahua National Monument.

NPS/S. STUDD

Figure 4-3. Woodland typical of rocky sites above 6,000' elevation (502 stratum), Chiricahua National Monument.

NPS

Figure 4-4. Forest typical of non-rocky sites above 6,000' elevation (501 stratum), Chiricahua National Monument.

NPS

Figure 4-5. Sparse woodland typical of bedrock "hoodoo" sites above 6,000' elevation (503 stratum), Chiricahua National Monument.

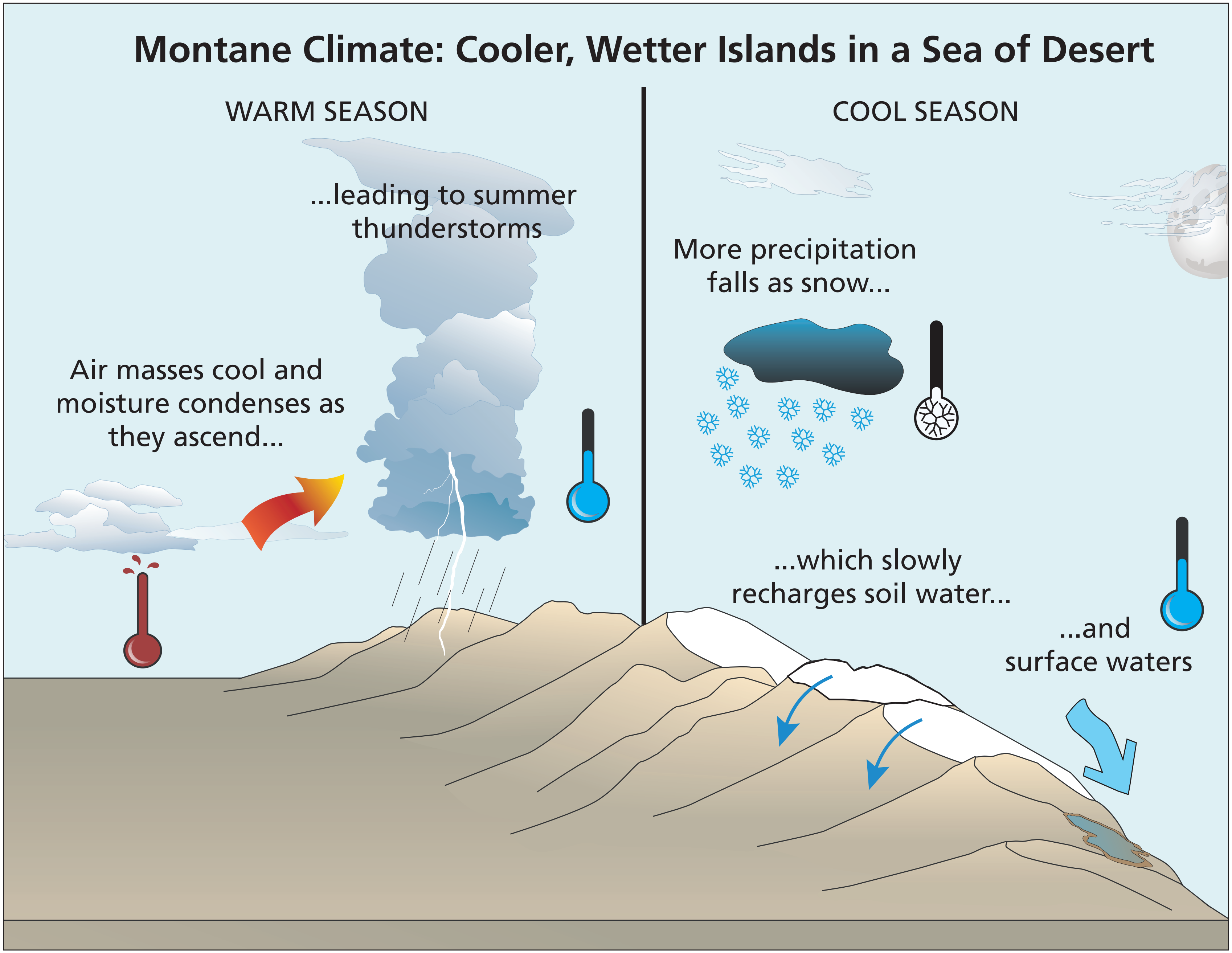


Figure 4-6. Increasing elevation strongly enhances available soil moisture for “sky island” mountains in a desert “sea.” Air masses cool and moisture condenses as they ascend, leading to increased precipitation during both summer thunderstorms and winter snowstorms. More precipitation falls as snow during cold months, resulting in snowpack which slowly recharges soil water and feeds surface waters (Strahler and Strahler 1986).

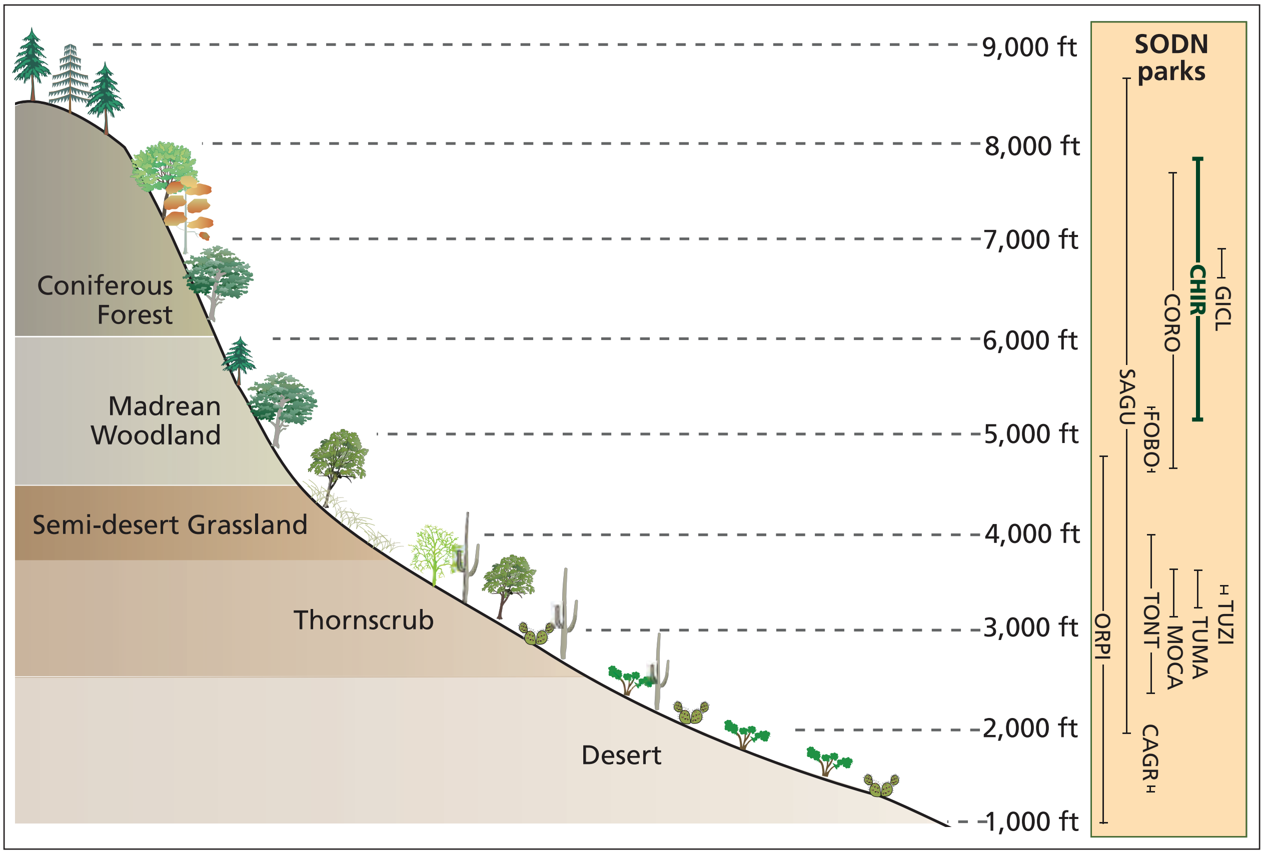


Figure 4-7. Arrangement of life zones along sky-island elevation gradients of Sonoran Desert Network parks (c.f. Marshall 1957).

CAGR=Casa Grande Ruins NM, CHIR=Chiricahua NM, CORO=Coronado NMem, FOBO=Fort Bowie NHS, GICL=Gila Cliff Dwellings NM, MOCA=Montezuma Castle NM, ORPI=Organ Pipe Cactus NM, SAGU=Saguaro NP, TONT=Tonto NM, TUMA=Tumacácori NHP, TUZI=Tuzigoot NM

rocky sites, rock outcrop sites can be thought of as a dual-type system in which largely impermeable bedrock and hoodoos predominate over cracks and small patches of soil that act as islands in a sea of barren rock. Although some precipitation puddles and evaporates, much of it runs off from the rock faces and accumulates in these fissures and small (often shallow) soil patches (Figure 4-8). The result is a large catchment for each small soil patch or crack that might support vegetation. As a consequence, rock outcrop vegetation is more abundant than we might expect, as the productivity of these relatively well-watered microsites is enhanced by localized geology.

4.3 Exotic invasive plants

Exotic plant encroachment typically occurs in two phases. Phase I is 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. Phase II is domination, which occurs when asymmetrical competition (often mediated through disturbance) allows the new species to become a common or even dominant plant in the plant community, often with negative consequences for ecosystem structure and function. It is important to note that the second phase often requires a specific set of ecological triggers or conditions that may, in fact, never occur; this is why many exotic species are relatively innocuous under some environmental conditions. The success of management strategies and effectiveness of monitoring designs in a given area is strongly linked to which phase (colonization or domination) has occurred.

Our data indicate that one exotic grass, Lehmann lovegrass, has completed the colonization phase on rocky, mid-mountain (402) sites (Table 3-1). This warm-season, South African bunchgrass was detected on 12 of our 15 monitoring sites (Figure 4-9), suggesting that it is not dispersal-limited from suitable habitats within the park. Many sites that are likely to be colonized have been colonized. This is not the case for other exotic species, or for Lehmann lovegrass on high-mountain (>6,000') sites. The other detected exotic species (the annual grass, field brome) was both sparse

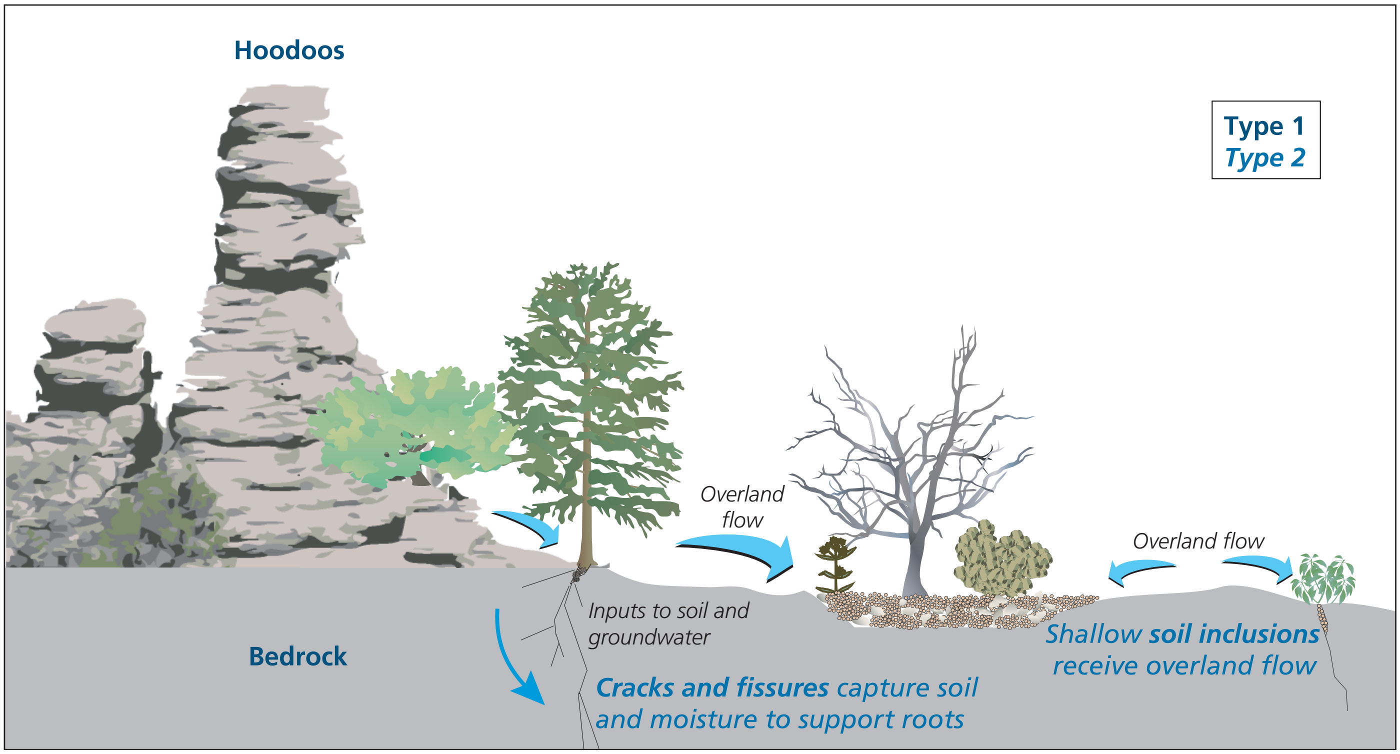


Figure 4-8. In this dual-type system, impervious bedrock helps channel moisture to soil and rock-crack microhabitats on rock outcrop and "hoodoo" sites (503 stratum), Chiricahua National Monument.

and localized.

Although Lehmann lovegrass does not currently dominate mid-mountain sites, it is one of the three most common grasses in this stratum (at 4.8% ± 1.2 vegetative cover) and has the potential to increase in abundance following drought or disturbance (Abbott and Roundy 2003), making it a leading concern following the Horseshoe II Fire of 2011.

We will continue to monitor the distribution and abundance of Lehmann lovegrass and other non-native plants, and we 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.

4.4 Site stability and erosion

Site stability is the resistance of a site to localized wind and water erosion of soils. Site stability has 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 1999), 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 Chiricahua NM.

Both static and dynamic factors determine the vulnerability of a site to water erosion (Herrick et al. 2005a). Static factors, which include soil texture, depth and parent material, slope, aspect, and climate, are generally not affected by management actions and (Herrick et al. 2005a). Static factors set the range of erosion potential within which dynamic factors may be influenced by disturbance and management action to determine actual erosion.

Dynamic factors affecting water erosion include soil disturbance, soil structure, total cover, and plant basal cover. The total amount of soil cover is the single most-important dynamic factor affecting water erosion (Herrick et al. 2005a). Most soil loss occurs in "unprotected" areas; that is, bare soils without vegetative cover (Davenport et al. 1998). 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).

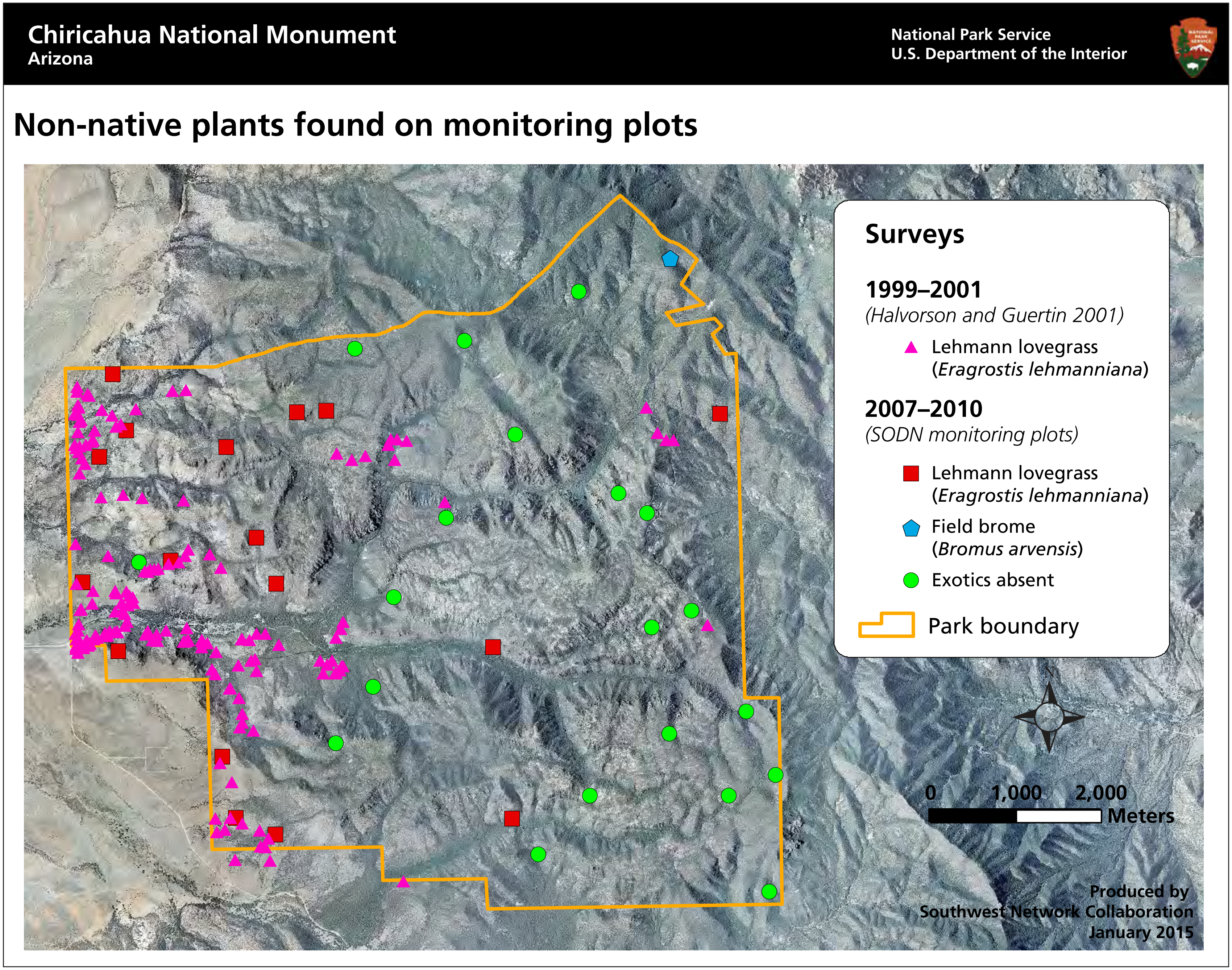


Figure 4-9. Non-native plants found on monitoring plots at Chiricahua National Monument, 2007–2010, and distribution of Lehmann lovegrass (*Eragrostis lehmanniana*), 1999–2001 (Halvorson and Guertin 2003).

Our data indicate that soils at Chiricahua NM are currently very well armored, with less than 2% of the soil surface consisting of exposed, bare-mineral soil (see Figures 3-4, 3-7, 3-10, 3-13). However, for each stratum, the majority of the resistant soil cover was composed of vegetation, leaf litter, and duff—materials that could be rapidly lost following wildfire or prolonged drought, such was experienced in the years leading up to the Horseshoe II Fire of 2011.

In addition, the stability of surface soil aggregates (an indicator of soil structure) not under vegetative cover was below our proposed management assessment point for rocky mid-mountain (≤6,000') sites (see Table 3-3), indicating the potential for soil erosion if soil cover is lost. This area also contains the bulk of the known cultural resource sites in the monument. In many cases, these sites contain finite archaeological resources at or near the soil surface. As a result, soil stability in the rocky, mid-mountain areas of the monument is a concern for management of both natural and cultural resources.

In the high-mountain strata (501, 502, 503), all stability values were well above 3 (somewhat unstable), and generally above 4 (moderately stable). This was likely due to the increased soil organic matter resulting from higher productivity in these high-elevation forests and woodlands. Soil stability and cover results suggest a degree of resistance to erosion, although a few sites appear to have localized susceptibility to soil loss.

Although pre-fire soil loss appears to have been moderate and localized, we emphasize the potential impacts that the Horseshoe II Fire and prolonged drought may have on critical soil resources at Chiricahua NM, due to inherent site instability, particularly on sites below 6,000'.

4.5 Foreshadowing the 2011 Horseshoe II Fire

A review of the management assessment points for fire hazard provides a foreshadowing of the massive Horseshoe II Fire of 2011. The vegetative cover of dead plants was consistently about twice the assessment point for every stratum, indicating the large volume of potential fuel across the Chiricahua landscape. Fine fuels (litter and duff) were continuous and abundant, particularly on the three high-mountain sites, where they comprised more than half of the soil surface cover.

The legacy of fire suppression and drought are evident in the 2007–2010 vegetation and soils data, and illustrate a fire-prone system primed for landscape-scale fire. We will explore the consequences of fuel loading and the Horseshoe II Fire in subsequent analyses of post-fire data.

4.6 Implications for terrestrial vegetation and soils monitoring

This effort comprised the first complete round of terrestrial vegetation and soils monitoring at Chiricahua NM. Much of our focus was, therefore, 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 (e.g., initial plot layout, permanent marking and mapping, and collection of in situ soil and landscape parameters). Travel time is often extensive at Chiricahua NM, due to steep terrain and dense vegetation (especially pointleaf manzanita).

The occurrence of Horseshoe II Fire in 2011, a few months before our fifth season of sampling, poses challenges to our initial revisit design. The fire likely “reset” the system, and dramatic vegetation changes can be expected over the first several years of recovery.

Our large-park revisit design, in which one-fifth of the plots are sampled annually over a five-year period, will likely miss some important changes early in the recovery, and pooling the data over five years may increase the short-term temporal variability of our results. Instead, we will migrate this park to our small-park design, in which all plots are sampled in the same year at five-year intervals.

With support from the Burned Area Emergency Rehabilitation (BAER) program, we were able to resample all of the existing terrestrial vegetation and soils monitoring plots in 2012, effectively resetting our design for revisits in 2017.

The stratification design worked very well. All four strata effectively partitioned variability in vegetation, and well-represented the landscape diversity noted by previous research (e.g., Taylor 2004).

The combination of sampling intensity and stratification generally yielded very good statistical power to detect trends in most parameters of interest. However, we plan to add two additional sites in the non-rocky, high-mountain (501) stratum to improve power in this diverse and undersampled stratum. We could reduce sampling intensity in the rocky, mid-mountain (402) and rocky, high-mountain (502) strata to save time and money without compromising our monitoring objectives. However, the effects of the fire on power and species detectability are unknown, so we will postpone any possible reductions in sampling intensity for now.

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

Dynamic soil function attributes probably are within the range of natural variability, although historic and prehistoric information is nearly absent. The combination of rugged topography, intense and often localized precipitation events, and generally underdeveloped soils results in relatively common flooding and occasional mass wasting and debris flows under current or past conditions.

By contrast, terrestrial vegetation at Chiricahua NM (at least before the 2011 Horseshoe II Fire) appeared to diverge from long-term conditions. When our results are taken in the context of historical research on vegetation and fire ecology at the monument, it appears that pre-fire terrestrial vegetation was outside the range of natural variability—particularly, outside the fire regimes and consequent vegetation structure and composition that was predominant before Euro-American settlement in the late 19th century.

Taylor (2004) documented sharp increases in woody plant cover from 1937 to 1993, with the greatest increases coming from fire-sensitive species, such as border pinyon pine and pointleaf manzanita. Our data confirm the predominance of these species throughout the monument, and the vegetation cover values for shrubs and trees combined were some of the highest we had recorded in SODN parks to date.

Relatively common ground fire and occasional extensive canopy fire were the norm in prehistory, as documented from tree-ring analysis by Swetnam and others (1989) and Baisan and Morino (2000). This is a common pattern seen throughout montane systems of the American Southwest (Covington and Moore 1994). The consequences of such fires for vegetation would include more open-canopied woodlands, savannas, and, at lower elevations (our rocky, mid-mountain sites), desert grassland than we found during our 2007–2010 sampling.

Whether the Horseshoe II Fire restores pre-settlement conditions or sends vegetation on a new trajectory should become apparent as long-term monitoring and fire research continue. Interactions between fire effects and climate change may yield novel fire regimes and vegetation responses.

5 Literature Cited

Abbott, L. B., and B. A. Roundy. 2003. Available water influences field germination and recruitment of seeded grasses. Journal of Range Management 56(1):56–64.

Aber, J., and J. Melillo. 1991. Terrestrial ecosystems. Philadelphia: Saunders College Publishing.

Bailey, R. G. 1998. Ecoregions: The ecosystem geography of the oceans and continents. New York: Springer-Verlag Inc.

Baisan, C. H., and K. A. Morino. 2000. Fire history in Chiricahua National Monument. Laboratory of Tree-Ring Research, University of Arizona, Tucson, Arizona.

Barton, A. M. 1993. Factors controlling plant distributions: Drought, competition, and fire in montane pines in Arizona. Ecological Monographs 63:367–397.

——. 1996. The impact of fire on Arizona pine populations in Rhyolite Canyon, Chiricahua National Monument. Final report to the Southwest Parks and Monuments Association.

——. 1999. Pines versus oaks: Effects of fire on the composition of Madrean forests in Arizona. Forest Ecology and Management 120:143–156.

Barton, A. M., T. W. Swetnam, and C. H. Baisan. 2001. Arizona pine (*Pinus arizonica*) stand dynamics: Local and regional factors in a fire-prone Madrean gallery forest of Southeast Arizona, USA. Landscape Ecology 16:351–369.

Belnap, J., S. L. Phillips, L. E. Herrick, and J. R. Johansen. 2007. Wind erodibility of soils at Fort Irwin, California (Mojave Desert), USA, before and after trampling disturbance: Implications for land management. Earth Surface Processes and Landforms 32:75–84.

Bennetts, R. E., J. E. Gross, K. Cahill, C. L. McIntyre, B. B. Bingham, J. A. Hubbard, L. Cameron, and S. L. Carter. 2007. Linking monitoring to management and planning: Assessments points as a generalized approach. The George Wright Forum 24(2):59–77.

Bingham, B. B., R. E. Bennetts, and J. A. Hubbard. 2007. Integrating science and management: the road to Rico-Chico. Pp. 21-25 in Integrating Science and Management. The George Wright Forum 24(2):21–25.

Bonham, C. D. 1989. Measurements for terrestrial vegetation. New York: Wiley-Interscience.

Brady, N. C., and R. R. Weil. 2002. The nature and properties of soils. 13th edition. Upper Saddle River, N.J.: Prentice Hall.

Brown, J., and S. Archer. 1999. Shrub invasion of grassland: Recruitment is continuous and not regulated by herbaceous biomass or density. Ecology 80(7):2385–2396.

Clarke, K. R., and R. M. Warwick. 2001. Change in marine communities: An approach to statistical analysis and interpretation, 2nd edition. Plymouth, U.K.: PRIMER-E.

Covington, W. W., and M. M. Moore. 1994. Southwest ponderosa pine forest structure changes since Euro-American settlement. Journal of Forestry 89:39–47.

D'Antonio, C., and P. Vitousek. 1992. Biological invasions by exotic grasses, the grass/fire cycle, and global change. Annual Review of Ecology and Systematics 23:63–87.

Davenport, D. W., D. D. Breshears, B. P. Wilcox, and C. D. Allen. 1998. Viewpoint: Sustainability of pinyon-juniper ecosystems—a unifying perspective of soil erosion thresholds. Journal of Range Management 51(2):231–232.

Davey, C. A., K. T. Redmond, and D. B. Simeral. 2007. Weather and climate inventory, National Park Service, Sonoran Desert Network. Natural Resource Technical Report NPS/SODN/NRTR—2007/044. National Park Service, Fort Collins, Colorado.

Denney, D. W., and C. R. Peacock. 2000. Soil survey of Chiricahua National Monument, Arizona. U.S. Geological Survey, Sonoran Desert Field Station Technical Report No. 65. Tucson, Arizona.

Dimmitt, M. A. 2000. Biomes and communities of the Sonoran Desert Region. Pages 3–18 *in* S. J. Phillips and P. W. Comus, eds., A natural history of the Sonoran Desert. Berkeley: University of California Press.

Dimmitt, M. A., R. C. Brusca, K. Krebbs, C. L. McIntyre, J. Viers, C. Filippone, and A. Berry. 2011. Natural resource condition assessment: Chiricahua National Monument, Coronado National Memorial, and Fort Bowie National Historic Site. Arizona-Sonora Desert Museum and Sonoran Institute, Tucson, Arizona.

Elzinga, C. L., D. W. Salzer, and J. W. Willoughby. 1998. Measuring and monitoring plant populations. BLM Technical Reference 1730-1, Bureau of Land Management, Denver, Colorado.

Gori, D. F., and C. A. F. Enquist. 2003. An assessment of the spatial extent and condition of grasslands in central and southern Arizona, southwestern New Mexico, and northern Mexico. Prepared by The Nature Conservancy, Arizona Chapter.

Graham, J. 2009. Chiricahua National Monument geologic resources inventory report. Natural Resource Report NPS/NRPC/GRD/NRR-2009/081. National Park Service, Denver, Colorado.

Halvorson, W. L., and P. Guertin. 2003. USGS weeds of the West: Status of introduced plants in southern Arizona parks. http://sdfsnet.srnr.arizona.edu/index.php?page=datamenu&lib=2sublib=13. Last accessed December 1, 2014.

Herrick, J. E., J. W. Van Zee, K. M. Havstad, L. M. Burkett, and W. G. Whitford. 2005a. Monitoring manual for grassland, shrubland and savanna ecosystems. Volume 1: Quick start. USDA-ARS Jornada Experimental Range.

——. 2005b. Monitoring manual for grassland, shrubland, and savanna ecosystems. Volume II: Design, supplementary methods, and interpretation. Tucson: University of Arizona Press.

Hubbard, J. A., C. L. McIntyre, S. E. Studd, T. W. Nauman, D. Angell, K. Beaupré, B. Vance, and M. K. Connor. 2012. Terrestrial vegetation and soils monitoring protocol and standard operating procedures: Sonoran Desert and Chihuahuan Desert networks, Version 1.1. Natural Resource Report NPS/SODN/NRR—2012/509. National Park Service, Fort Collins, Colorado.

Hubbard, J. A., S. Studd, and C. McIntyre. 2010. Terrestrial vegetation and soils monitoring at Fort Bowie National Historic Site: 2008 status report. Natural Resource Technical Report NPS/SODN/NRTR—2010/368. National Park Service, Fort Collins, Colorado.

Ingram, M. 2000. Desert storms. Pages 41–59 *in* S. J. Phillips and P.W. Comus, eds., A natural history of the Sonoran Desert. Berkeley: University of California Press.

Intergovernmental Panel on Climate Change (IPCC). 2007. Fourth assessment report. Available at http://www.ipcc.ch/index.htm#.UhPGaZO1Hy0.

Keddy, P. A. 2007. Plants and vegetation: Origins, processes, and consequences. Cambridge, U.K.: Cambridge University Press.

Krebbs, K. 2013. Bat species richness and abundance at the Chiricahua National Monument and Fort Bowie National Historic Site. Annual Report to the National Park Service.

Larcher, W. 2003. Physiological plant ecology. 4th edition. New York: Springer.

Marshall, J. T. 1957. Birds of the pine-oak woodland in southern Arizona and adjacent Mexico. Cooper Ornithological Society, Berkeley, California.

McAuliffe, J. R. 1999. The Sonoran Desert: Landscape complexity and ecological diversity. Pages 68–114 *in* R. H. Robichaux, ed., Ecology of Sonoran Desert plants and plant communities. Tucson: University of Arizona Press.

National Park Service (NPS). 2005. Sonoran Desert Network monitoring plan. National Park Service, Sonoran Desert Network, Tucson, Arizona.

——. 2009. Strategic plan for natural resource inventories: FY 2008–FY 2012. Natural Resource Report NPS/NRPC/NRR—2009/094. National Park Service, Fort Collins, Colorado.

Powell, B. F., E. W. Albrecht, W. L. Halvorson, C. A. Schmidt, K. Docherty, and P. Anning. 2008. Vascular plant and vertebrate inventory of Chiricahua National Monument. USGS OFR 2005-1187. USGS Southwest Biological Science Center, Sonoran Desert Research Station, University of Arizona, Tucson, Arizona.

Overpeck, J., G. Garfin, A. Jardine, D. E. Busch, D. Cayan, M. Dettinger, E. Fleishman, A. Gershunov, G. MacDonald, K. T. Redmond, W. R. Travis, and B. Udall. 2013. Summary for decision makers. Pages 1–20 *in* G. Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy, eds., Assessment of climate change in the southwest United States: A report prepared for the National Climate Assessment. Washington, DC: Island Press.

Roseberry, R. D., and N. E. Dole. 1939. The vegetation type survey of Chiricahua National Monument. Report to the U.S. Department of the Interior, National Park Service, Branch of Forestry. O.P. 705-3-5. San Francisco, California. https://irma.nps.gov/App/Reference/Profile/133236.

Scarborough, R. 2000. The geologic origin of the Sonoran Desert. Pages 71–85 *in* S. J. Phillips and P. W. Comus, eds., A natural history of the Sonoran Desert. Tucson, Az.: Arizona-Sonora Desert Museum Press.

Sellers, W. D. 2008. Climate. Pages 26–39 in P. F. Ffolliott and O.K. Davis, eds., Natural environments of Arizona: From deserts to mountains. Tucson: University of Arizona Press.

Shinneman, D. J., and W. L.Baker. 2009. Historical fire and multi-decadal drought as context for pinon-juniper woodland restoration in western Colorado. Ecological Applications 19:1231–1245.

Shreve, F. 1951. Vegetation of the Sonoran Desert. Washington, D.C.: Carnegie Institution of Washington Publication no. 591.

Stehman, S. V. 1999. Basic probabilistic sampling for thematic mapper accuracy assessment. International Journal of Remote Sensing 20:2347–2366.

Stevens, D. L., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association 99:262–278.

Strahler, A. 2013. Introduction to Physical Geography. 6th edition. Somerset, N.J.: Wiley.

Strahler, A. N., and A. H. Strahler. 1986. Elements of physical geography, 3rd edition. New York: John Wiley and Sons.

Studd, S. E., S. Drake, M. Villarreal, E. Fallon, and L. L. Crumbacher. 2013. Vegetation inventory, mapping, and classification report, Fort Bowie National Historic Site. Natural Resource Report NPS/SODN/NRR—2013/673. National Park Service, Fort Collins, Colorado.

Swetnam, T. W., C. H. Baisan, P. M. Brown, and A. C. Caprio. 1989. Fire history of Rhyolite Canyon, Chiricahua National Monument. NPS Cooperative Park Studies Unit Technical Report No. 32, University of Arizona, Tucson, Arizona.

Taylor, A. H. 2004. Vegetation change in Chiricahua National Monument, Arizona, Phase II. Final Report to USDI National Park Service.

The Nature Conservancy (TNC). 1999. Ecoregional conservation analysis of the Arizona–New Mexico Mountains. The Nature Conservancy, Santa Fe, New Mexico.

Theobald, D. M., D. L. Steves, Jr., D. White, N. S. Urquart, A. R. Olsen, and J. B. Norman. 2007. Using GIS to generate spatially balanced designs for natural resource applications. Environmental Management 40:134–146.

Weiss, J. L., C. L. Castro, and J. T. Overpeck. 2009. Distinguishing pronounced droughts in the southwestern United States: Seasonality and effects of warmer temperatures. Journal of Climate 22:5918–5932.

Whittaker, R. H. 1975. Communities and ecosystems. Indianapolis, In.: MacMillan.

Appendix A. Repeat Photos and Plot Locations

Figures begin on next page.

Chiricahua National Monument
Arizona

National Park Service
U.S. Department of the Interior

Uplands Plot 402_V01 in 2008

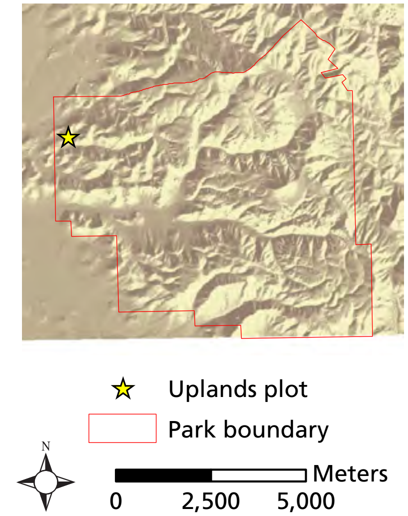
Photo point 2 (0m, 20m corner): 55 degrees

Photo point 3 (50m, 20m corner): 150 degrees

Photo point 1 (0m, 0m corner): 339 degrees

Photo point 4 (50m, 0m corner): 230 degrees

Plot Location



Plot Layout

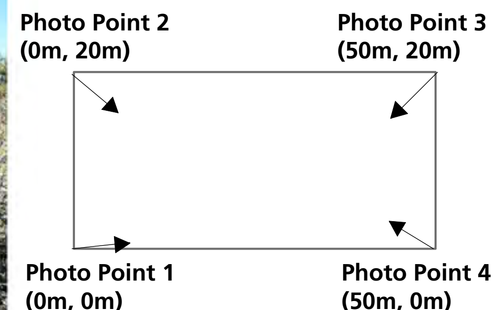


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner. Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Uplands Plot 402_V02 in 2008

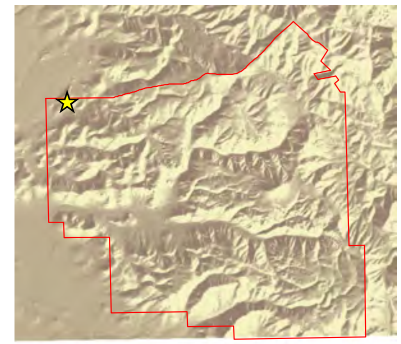
Photo point 2 (0m, 20m corner): 304 degrees

Photo point 3 (50m, 20m corner): 68 degrees

Photo point 1 (0m, 0m corner): 240 degrees

Photo point 4 (50m, 0m corner): 160 degrees

Plot Location



Uplands plot
Park boundary
N
Meters
0 2,500 5,000

Plot Layout

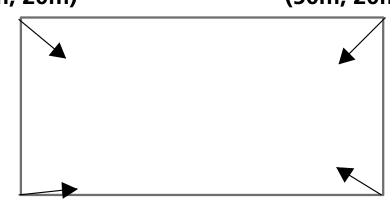


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Chiricahua National Monument
Arizona

National Park Service
U.S. Department of the Interior

Uplands Plot 402_V05 in 2008

Photo point 2 (0m, 20m corner): 306 degrees

Photo point 3 (50m, 20m corner): 200 degrees

Plot Location

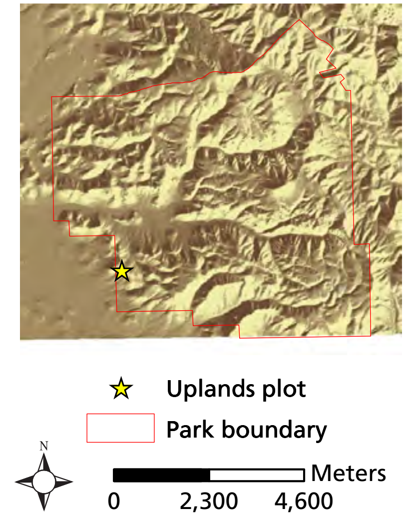


Photo point 1 (0m, 0m corner): 38 degrees

Photo point 4 (50m, 0m corner): 118 degrees

Plot Layout

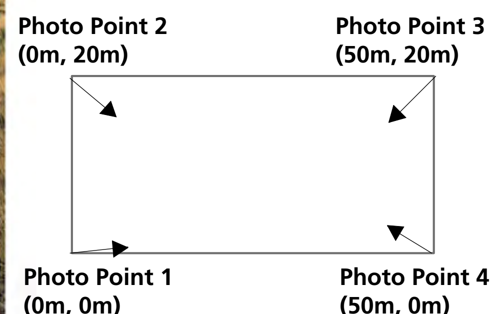


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Uplands Plot 402_V06 in 2008

Photo point 2 (0m, 20m corner): 170 degrees

Photo point 3 (50m, 20m corner): 250 degrees

Plot Location

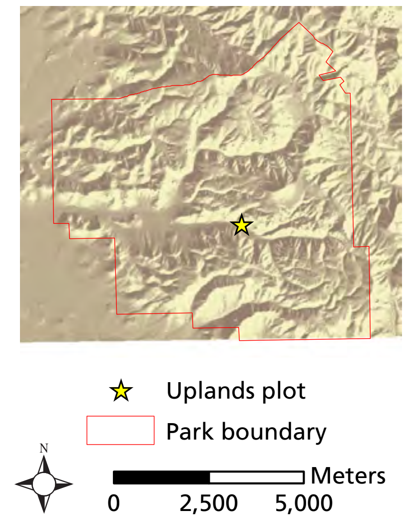


Photo point 1 (0m, 0m corner): 70 degrees

Photo point 4 (50m, 0m corner): 320 degrees

Plot Layout

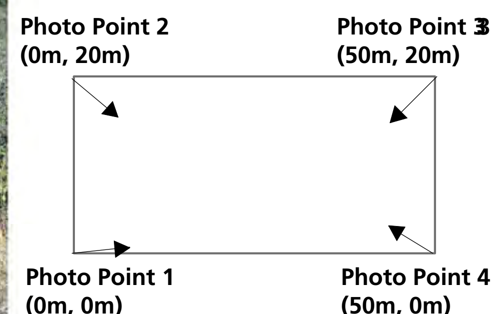


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Uplands Plot 402_V07 in 2008

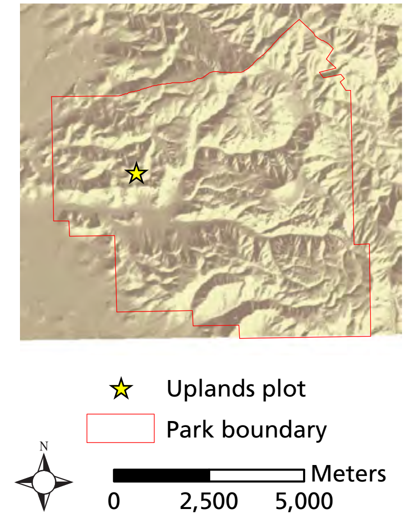
Photo point 2 (0m, 20m corner): 70 degrees

Photo point 3 (50m, 20m corner): 171 degrees

Photo point 1 (0m, 0m corner): 344 degrees

Photo point 4 (50m, 0m corner): 244 degrees

Plot Location



Plot Layout

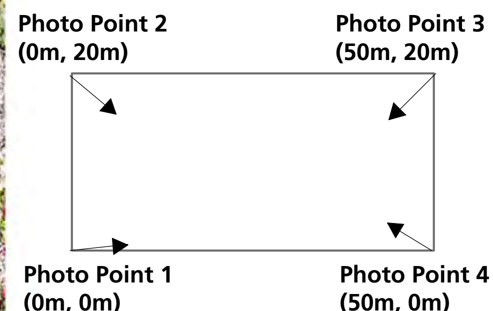


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Uplands Plot 402_V08 in 2008

Photo point 2 (0m, 20m corner): 222 degrees

Photo point 3 (50m, 20m corner): 278 degrees

Plot Location

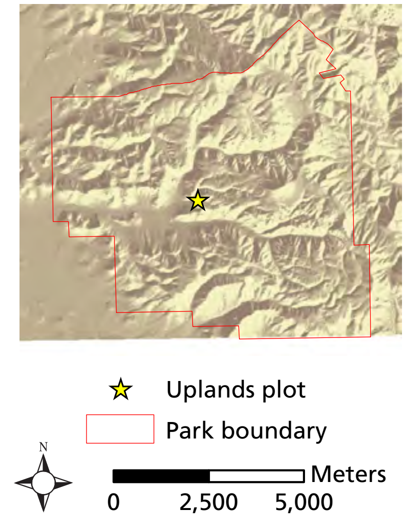


Photo point 1 (0m, 0m corner): 144 degrees

Photo point 4 (50m, 0m corner): 22 degrees

Plot Layout

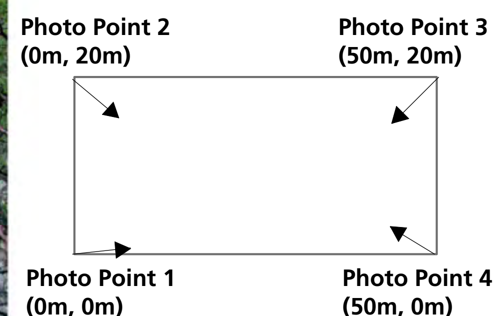


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Chiricahua National Monument
Arizona

National Park Service
U.S. Department of the Interior

Uplands Plot 402_V09 in 2008

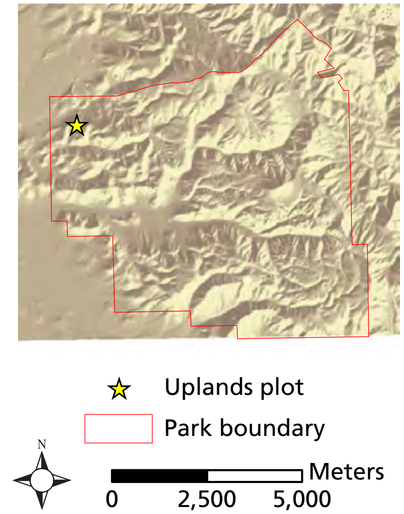
Photo point 2 (0m, 20m corner): 122 degrees

Photo point 3 (50m, 20m corner): 224 degrees

Photo point 1 (0m, 0m corner): 0 degrees

Photo point 4 (50m, 0m corner): 288 degrees

Plot Location



Plot Layout

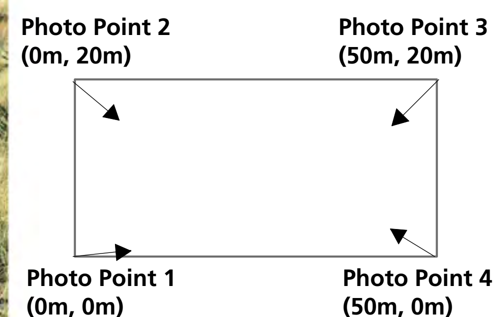


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Chiricahua National Monument
Arizona

National Park Service
U.S. Department of the Interior

Uplands Plot 402_V10 in 2008

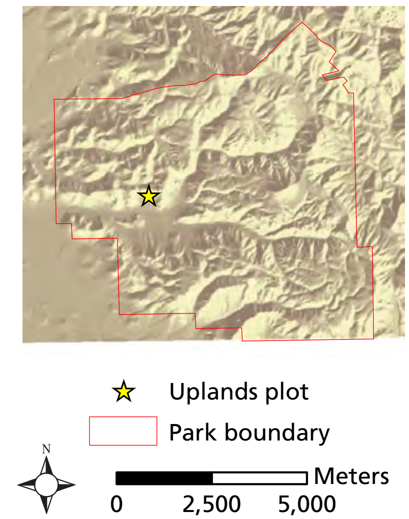
Photo point 2 (0m, 20m corner): 258 degrees

Photo point 3 (50m, 20m corner): 330 degrees

Photo point 1 (0m, 0m corner): 140 degrees

Photo point 4 (50m, 0m corner): 80 degrees

Plot Location



Plot Layout

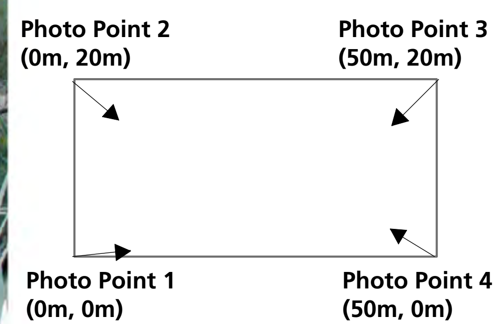


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Uplands Plot 402_V11 in 2008

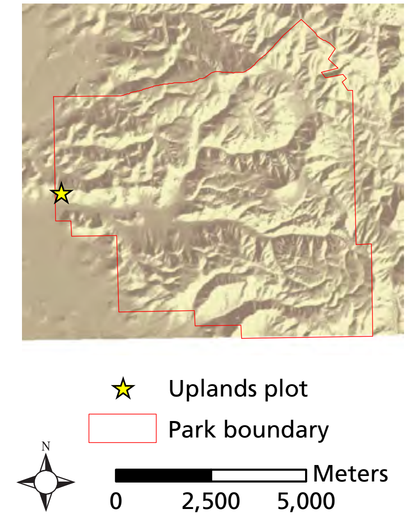
Photo point 2 (0m, 20m corner): 172 degrees

Photo point 3 (50m, 20m corner): 270 degrees

Photo point 1 (0m, 0m corner): 90 degrees

Photo point 4 (50m, 0m corner): 336 degrees

Plot Location



Plot Layout

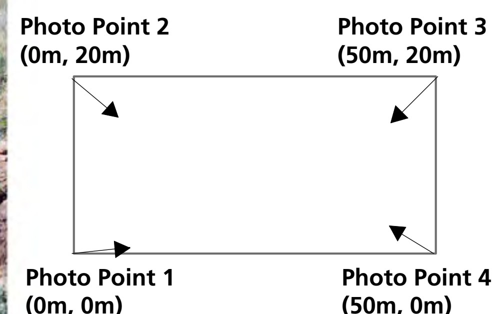


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Uplands Plot 402_V13 in 2008

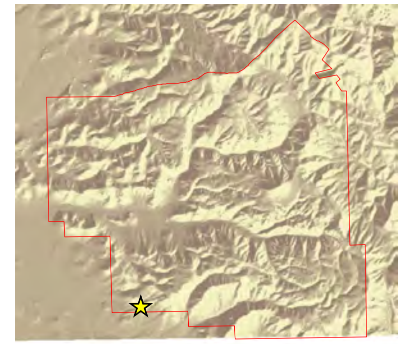
Photo point 2 (0m, 20m corner): 162 degrees

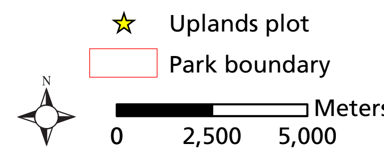
Photo point 3 (50m, 20m corner): 268 degrees

Photo point 1 (0m, 0m corner): 86 degrees

Photo point 4 (50m, 0m corner): 340 degrees

Plot Location





Plot Layout

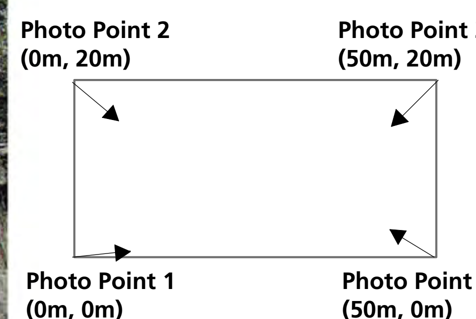


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Uplands Plot 402_V14 in 2008

Photo point 2 (0m, 20m corner): 326 degrees

Photo point 3 (50m, 20m corner): 32 degrees

Plot Location

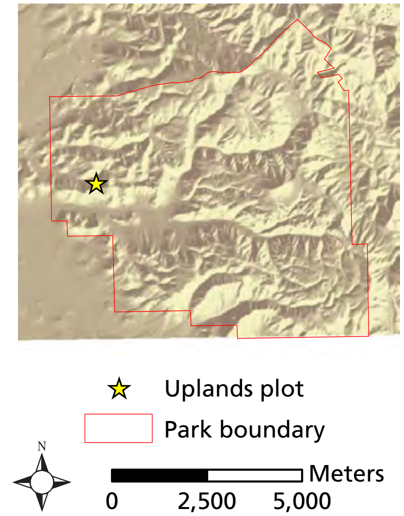


Photo point 1 (0m, 0m corner): 262 degrees

Photo point 4 (50m, 0m corner): 112 degrees

Plot Layout

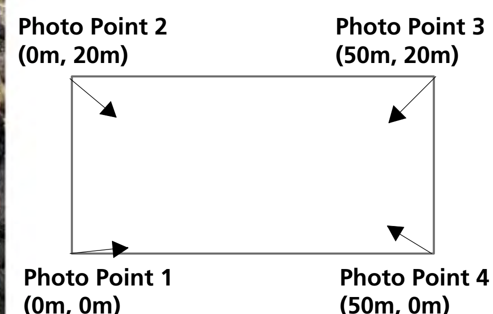


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Uplands Plot 402_V15 in 2008

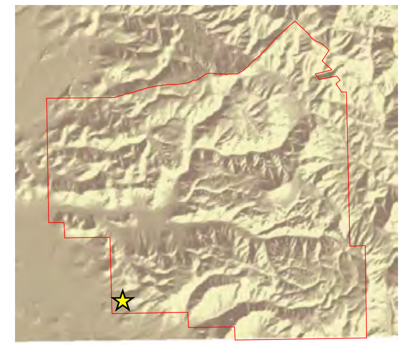
Photo point 2 (0m, 20m corner): 198 degrees

Photo point 3 (50m, 20m corner): 300 degrees

Photo point 1 (0m, 0m corner): 150 degrees

Photo point 4 (50m, 0m corner): 14 degrees

Plot Location



☆ Uplands plot
Park boundary
N
Meters
0 2,500 5,000

Plot Layout

Photo Point 2 (0m, 20m)
Photo Point 3 (50m, 20m)

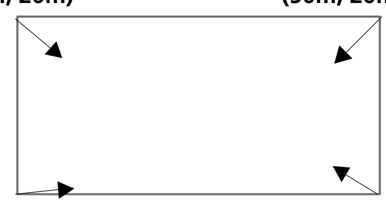


Photo Point 1 (0m, 0m)
Photo Point 4 (50m, 0m)

Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Chiricahua National Monument
Arizona

National Park Service
U.S. Department of the Interior

Uplands Plot 402_V17 in 2008

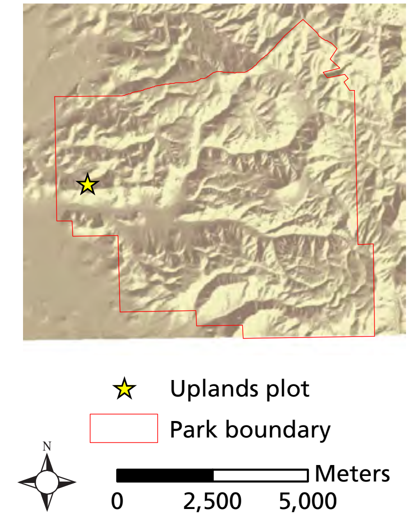
Photo point 2 (0m, 20m corner): 247 degrees

Photo point 3 (50m, 20m corner): 344 degrees

Photo point 1 (0m, 0m corner): 168 degrees

Photo point 4 (50m, 0m corner): 80 degrees

Plot Location



Plot Layout

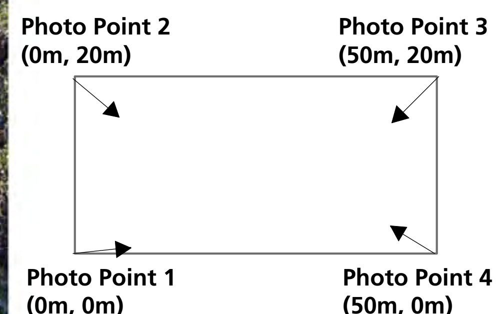


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Uplands Plot 501_V01 in 2008

Photo point 2 (0m, 20m corner): 220 degrees

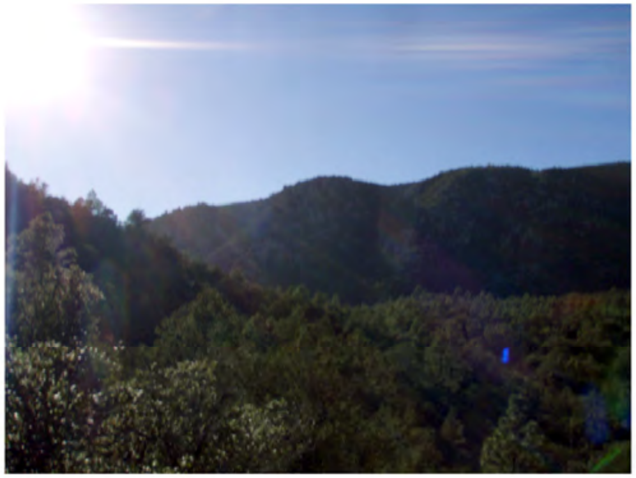
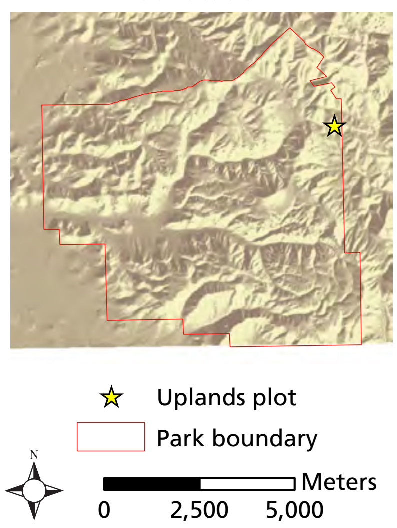


Photo point 3 (50m, 20m corner): 320 degrees

Photo point 1 (0m, 0m corner): 140 degrees

Photo point 4 (50m, 0m corner): 60 degrees

Plot Location



Plot Layout

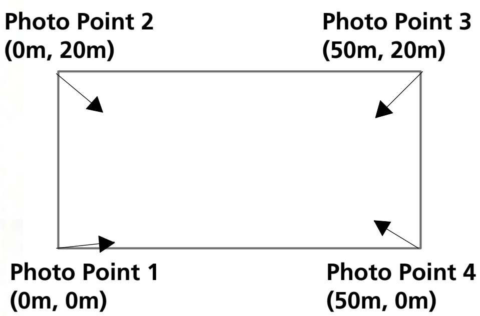


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Chiricahua National Monument
Arizona

National Park Service
U.S. Department of the Interior

Uplands Plot 501_V02 in 2008

Photo point 2 (0m, 20m corner): 20 degrees

Photo point 3 (50m, 20m corner): 90 degrees

Plot Location

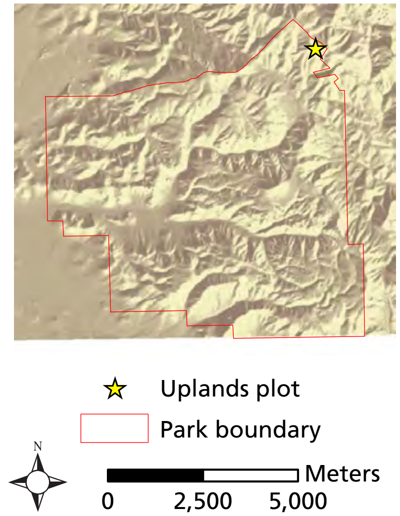


Photo point 1 (0m, 0m corner): 279 degrees

Photo point 4 (50m, 0m corner): 192 degrees

Plot Layout

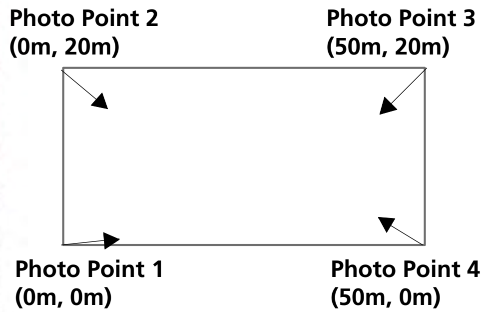


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Uplands Plot 501_V03 in 2008

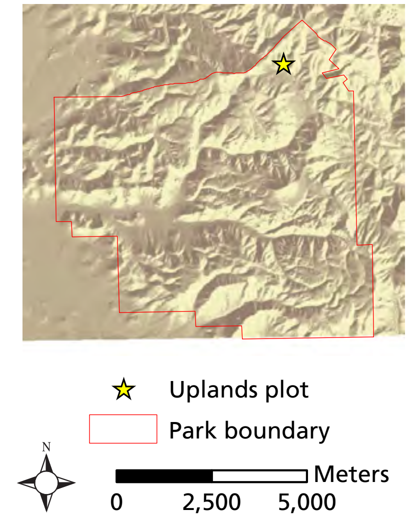
Photo point 2 (0m, 20m corner): 70 degrees

Photo point 3 (50m, 20m corner): 160 degrees

Photo point 1 (0m, 0m corner): 350 degrees

Photo point 4 (50m, 0m corner): 270 degrees

Plot Location



Plot Layout

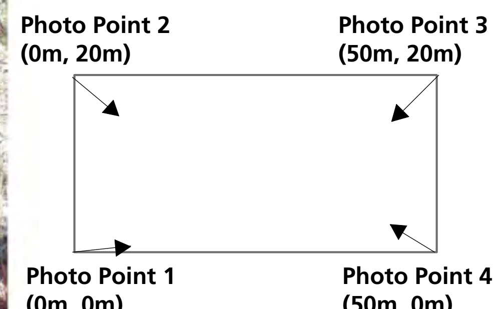


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Uplands Plot 502_V01 in 2008

Photo point 2 (0m, 20m corner): 320 degrees

Photo point 3 (50m, 20m corner): 54 degrees

Plot Location

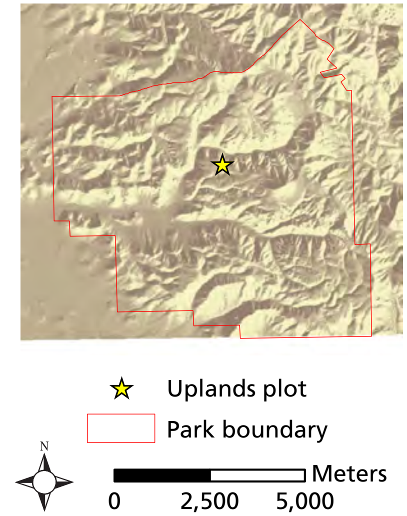


Photo point 1 (0m, 0m corner): 270 degrees

Photo point 4 (50m, 0m corner): 138 degrees

Plot Layout

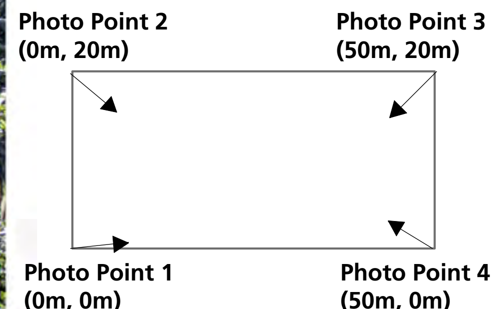


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Uplands Plot 502_V02 in 2008

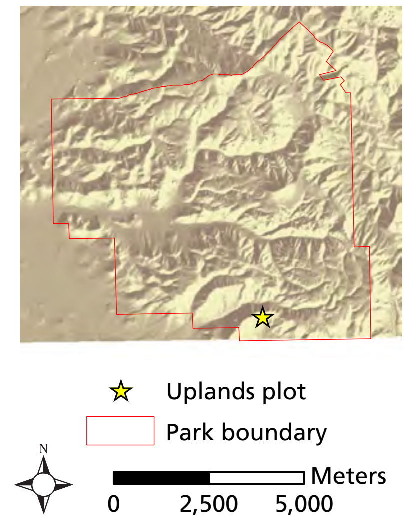
Photo point 2 (0m, 20m corner): 320 degrees

Photo point 3 (50m, 20m corner): 242 degrees

Photo point 1 (0m, 0m corner): 54 degrees

Photo point 4 (50m, 0m corner): 146 degrees

Plot Location



Plot Layout

Photo Point 2 (0m, 20m)

Photo Point 3 (50m, 20m)

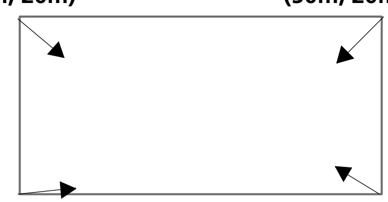


Photo Point 1 (0m, 0m)

Photo Point 4 (50m, 0m)

Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Chiricahua National Monument
Arizona

National Park Service
U.S. Department of the Interior

Uplands Plot 502_V03 in 2008

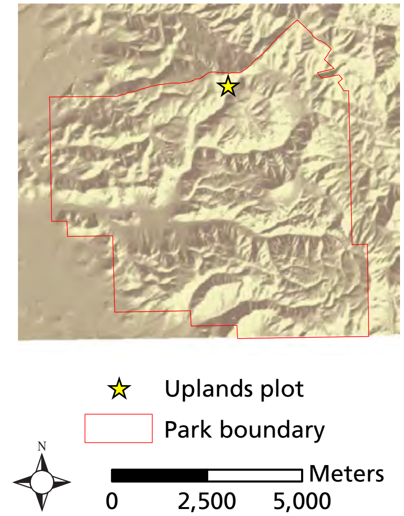
Photo point 2 (0m, 20m corner): 50 degrees

Photo point 3 (50m, 20m corner): 164 degrees

Photo point 1 (0m, 0m corner): 326 degrees

Photo point 4 (50m, 0m corner): 234 degrees

Plot Location



Plot Layout

Photo Point 2 (0m, 20m)

Photo Point 3 (50m, 20m)

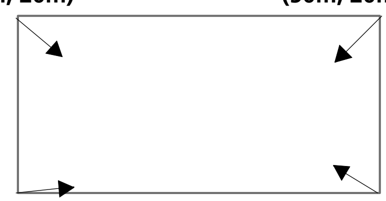


Photo Point 1 (0m, 0m)

Photo Point 4 (50m, 0m)

Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Uplands Plot 502_V07 in 2008

Photo point 2 (0m, 20m corner): 200 degrees

Photo point 3 (50m, 20m corner): 304 degrees

Plot Location

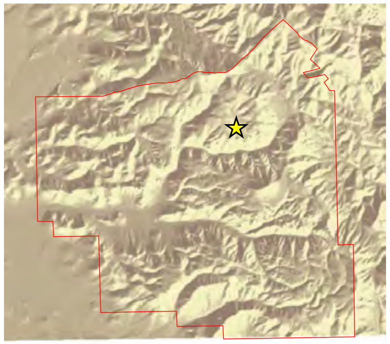


Photo point 1 (0m, 0m corner): 108 degrees

Photo point 4 (50m, 0m corner): 20 degrees

Plot Layout

Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner. Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Chiricahua National Monument
Arizona

National Park Service
U.S. Department of the Interior

Uplands Plot 502_V08 in 2008

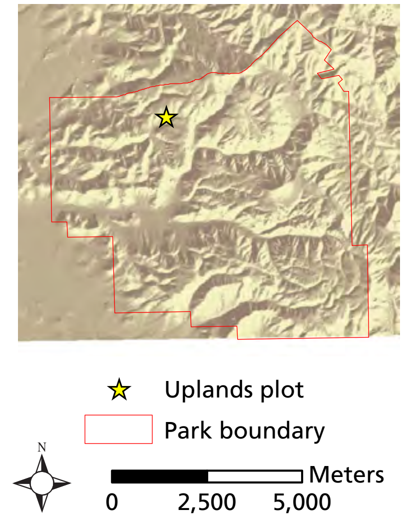
Photo point 2 (0m, 20m corner): 130 degrees

Photo point 3 (50m, 20m corner): 236 degrees

Photo point 1 (0m, 0m corner): 60 degrees

Photo point 4 (50m, 0m corner): 340 degrees

Plot Location



Plot Layout

Photo Point 2 (0m, 20m)

Photo Point 3 (50m, 20m)

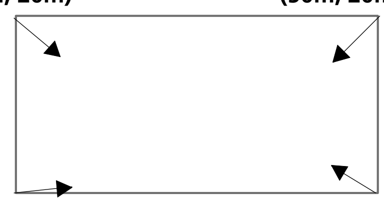


Photo Point 1 (0m, 0m)

Photo Point 4 (50m, 0m)

Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Uplands Plot 502_V09 in 2008

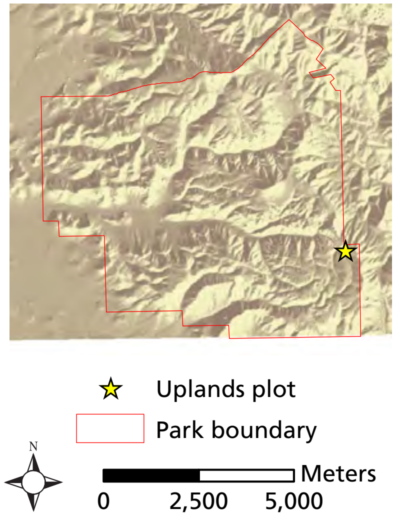
Photo point 2 (0m, 20m corner): 160 degrees

Photo point 3 (50m, 20m corner): 258 degrees

Photo point 1 (0m, 0m corner): 88 degrees

Photo point 4 (50m, 0m corner): 330 degrees

Plot Location



Plot Layout

Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Chiricahua National Monument
Arizona

National Park Service
U.S. Department of the Interior

Uplands Plot 502_V12 in 2008

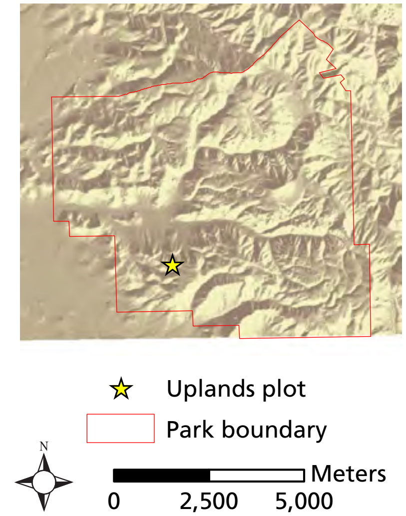
Photo point 2 (0m, 20m corner): 296 degrees

Photo point 3 (50m, 20m corner): 60 degrees

Photo point 1 (0m, 0m corner): 248 degrees

Photo point 4 (50m, 0m corner): 100 degrees

Plot Location



Plot Layout

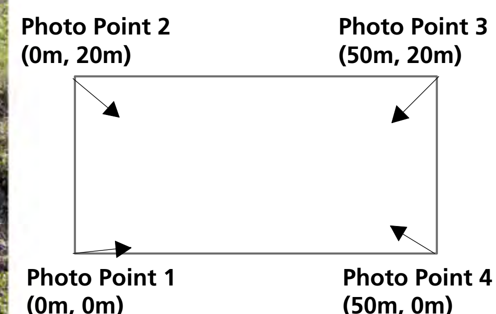


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Chiricahua National Monument
Arizona

National Park Service
U.S. Department of the Interior

Uplands Plot 502_V13 in 2008

Photo point 2 (0m, 20m corner): 50 degrees

Photo point 3 (50m, 20m corner): 168 degrees

Plot Location

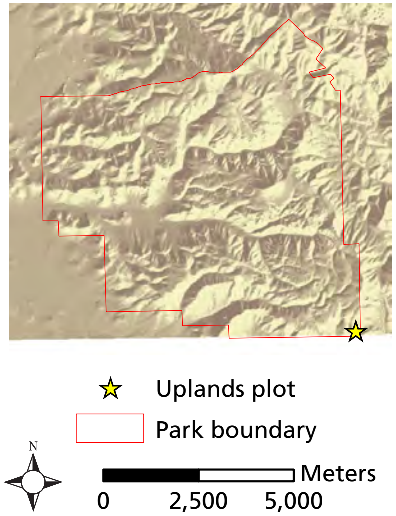


Photo point 1 (0m, 0m corner): 10 degrees

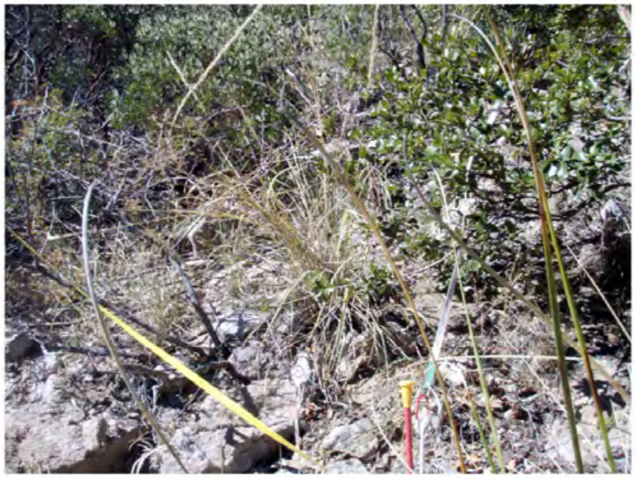


Photo point 4 (50m, 0m corner): 260 degrees

Plot Layout

Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Chiricahua National Monument
Arizona

National Park Service
U.S. Department of the Interior

Uplands Plot 502_V14 in 2008

Photo point 2 (0m, 20m corner): 212 degrees

Photo point 3 (50m, 20m corner): 280 degrees

Plot Location

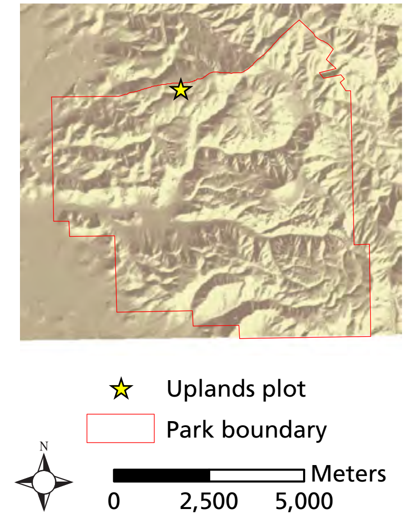


Photo point 1 (0m, 0m corner): 152 degrees

Photo point 4 (50m, 0m corner): 18 degrees

Plot Layout

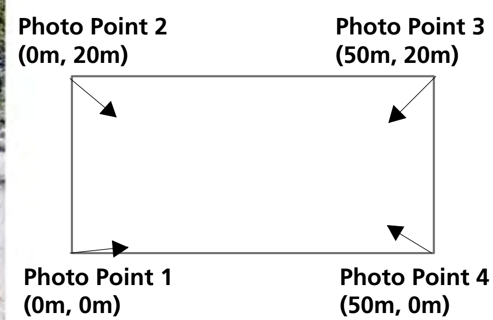


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Uplands Plot 502_V15 in 2008

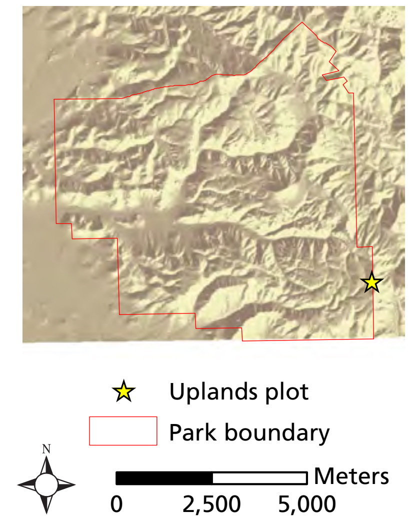
Photo point 2 (0m, 20m corner): 220 degrees

Photo point 3 (50m, 20m corner): 330 degrees

Photo point 1 (0m, 0m corner): 180 degrees

Photo point 4 (50m, 0m corner): 22 degrees

Plot Location



Plot Layout

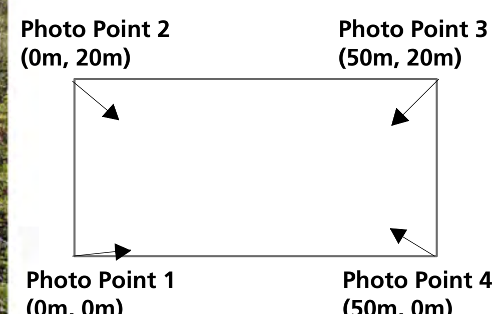


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Chiricahua National Monument
Arizona

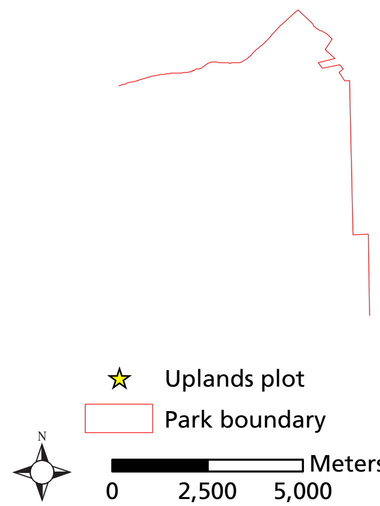
National Park Service
U.S. Department of the Interior

Uplands Plot 502_V16 in 2008

Photo point 2 (0m, 20m corner): 322 degrees

Photo point 3 (50m, 20m corner): 72 degrees

Plot Location



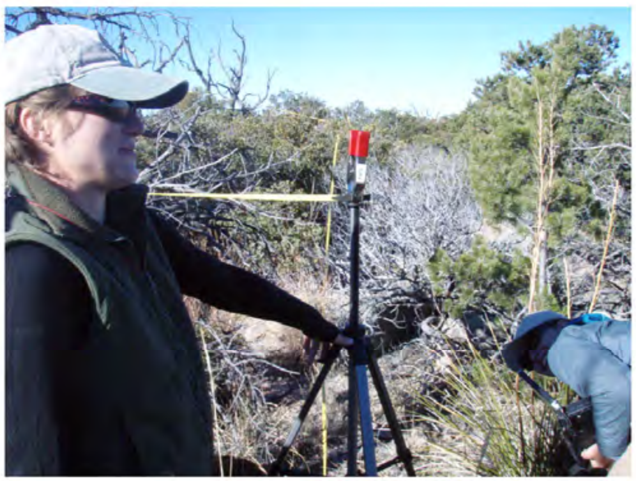


Photo point 1 (0m, 0m corner): 278 degrees

Photo point 4 (50m, 0m corner): 148 degrees

Plot Layout

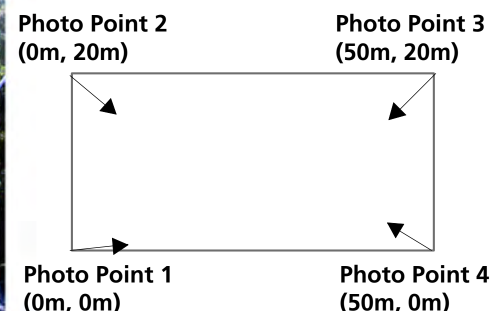


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Uplands Plot 502_V17 in 2008

Photo point 2 (0m, 20m corner): 160 degrees

Photo point 3 (50m, 20m corner): 208 degrees

Plot Location

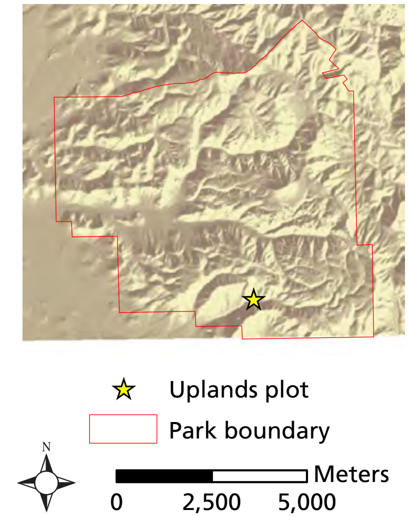


Photo point 1 (0m, 0m corner): 78 degrees

Photo point 4 (50m, 0m corner): 323 degrees

Plot Layout

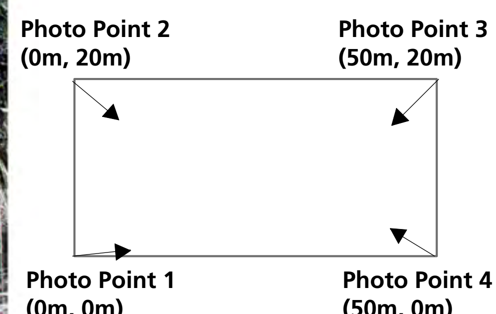


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Chiricahua National Monument
Arizona

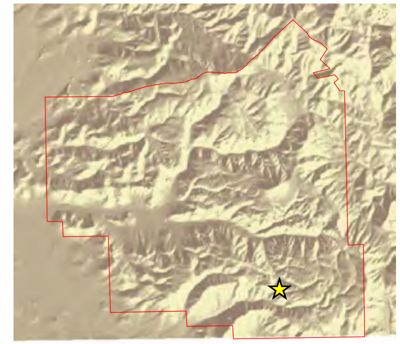
National Park Service
U.S. Department of the Interior

Uplands Plot 503_V01 in 2008

Photo point 2 (0m, 20m corner): 110 degrees

Photo point 3 (50m, 20m corner): 180 degrees

Plot Location



Uplands plot
Park boundary
N
Meters
0 2,500 5,000

Photo point 1 (0m, 0m corner): 8 degrees

Photo point 4 (50m, 0m corner): 266 degrees

Plot Layout

Photo Point 2 (0m, 20m)
Photo Point 3 (50m, 20m)

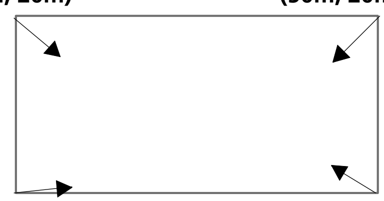


Photo Point 1 (0m, 0m)
Photo Point 4 (50m, 0m)

Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Uplands Plot 503_V02 in 2008

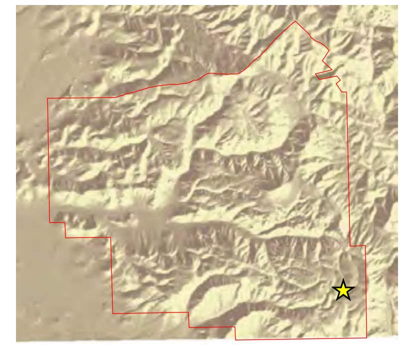
Photo point 2 (0m, 20m corner): 49 degrees

Photo point 3 (50m, 20m corner): 323 degrees

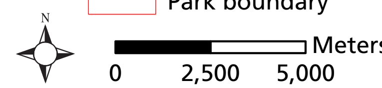
Photo point 1 (0m, 0m corner): 127 degrees

Photo point 4 (50m, 0m corner): 228 degrees

Plot Location



Uplands plot
Park boundary



Plot Layout

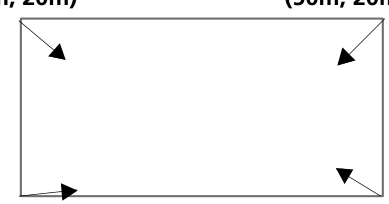


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Chiricahua National Monument
Arizona

National Park Service
U.S. Department of the Interior

Uplands Plot 503_V03 in 2008

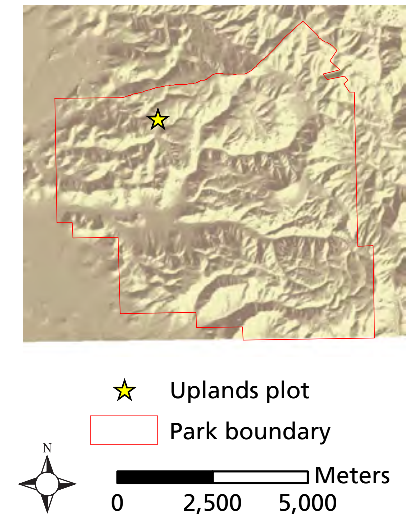
Photo point 2 (0m, 20m corner): 145 degrees

Photo point 3 (50m, 20m corner): 279 degrees

Photo point 1 (0m, 0m corner): 63 degrees

Photo point 4 (50m, 0m corner): 322 degrees

Plot Location



Plot Layout

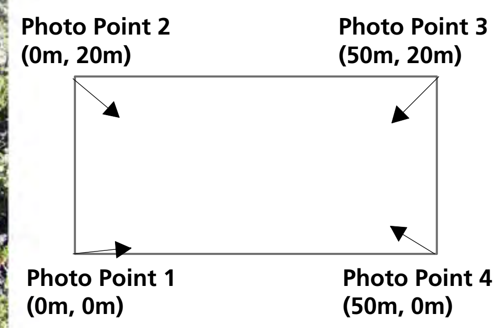


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Uplands Plot 503_V04 in 2008

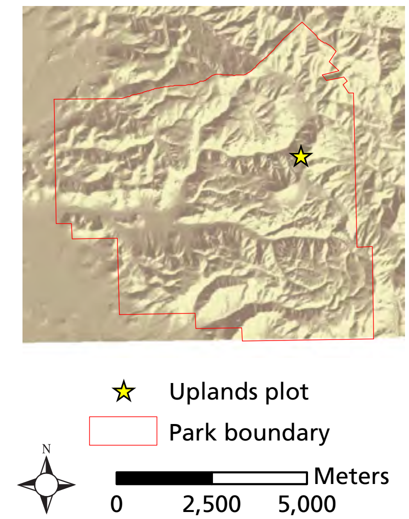
Photo point 2 (0m, 20m corner): 193 degrees

Photo point 3 (50m, 20m corner): 257 degrees

Photo point 1 (0m, 0m corner): 77 degrees

Photo point 4 (50m, 0m corner): 13 degrees

Plot Location



Plot Layout

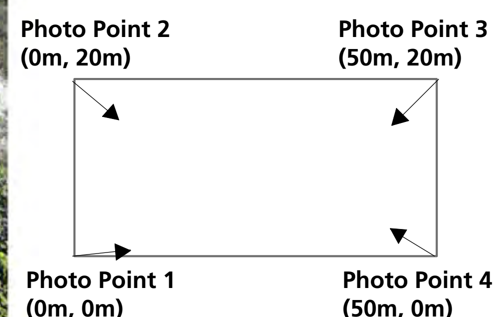


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Chiricahua National Monument
Arizona

National Park Service
U.S. Department of the Interior

Uplands Plot 503_V05 in 2008

Photo point 2 (0m, 20m corner): 356 degrees

Photo point 3 (50m, 20m corner): 102 degrees

Plot Location

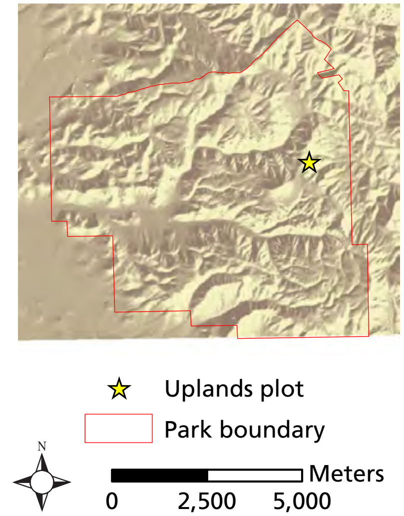


Photo point 1 (0m, 0m corner): 242 degrees

Photo point 4 (50m, 0m corner): 196 degrees

Plot Layout

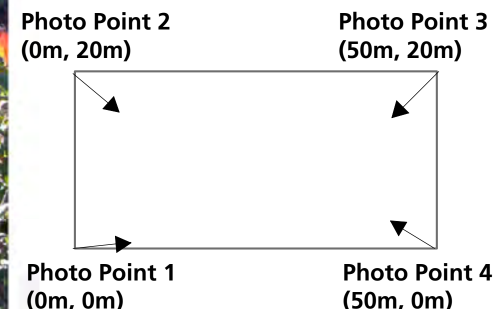


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

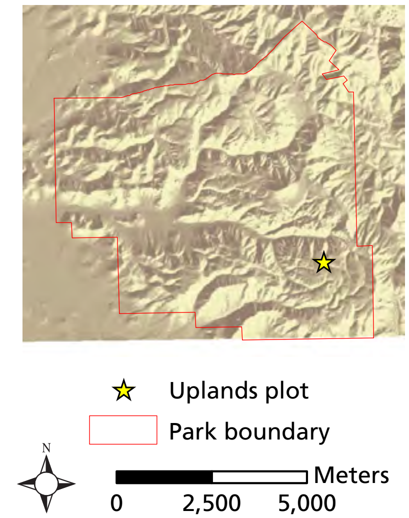
Produced by Sonoran Desert Network
October 2013

Uplands Plot 503_V06 in 2008

Photo point 2 (0m, 20m corner): 326 degrees

Photo point 3 (50m, 20m corner): 18 degrees

Plot Location



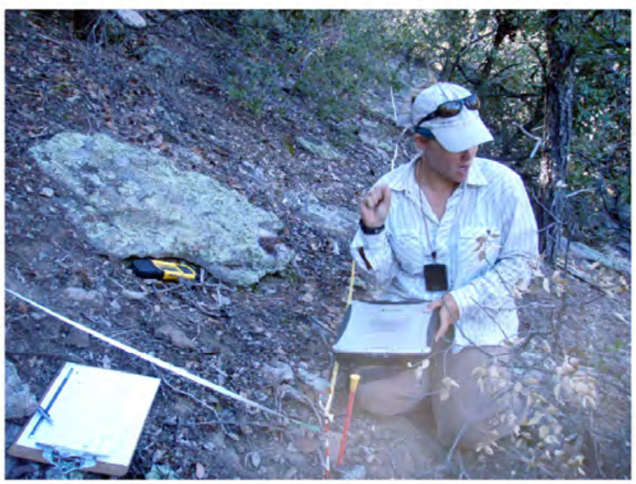


Photo point 1 (0m, 0m corner): 268 degrees

Photo point 4 (50m, 0m corner): 168 degrees

Plot Layout

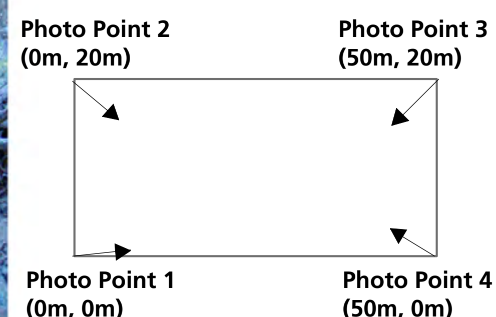


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Chiricahua National Monument
Arizona

National Park Service
U.S. Department of the Interior

Uplands Plot 503_V08 in 2008

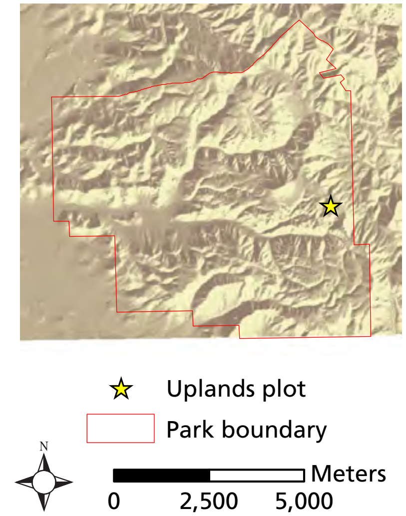
Photo point 2 (0m, 20m corner): 359 degrees

Photo point 3 (50m, 20m corner): 188 degrees

Photo point 1 (0m, 0m corner): 268 degrees

Photo point 4 (50m, 0m corner): 101 degrees

Plot Location



Plot Layout

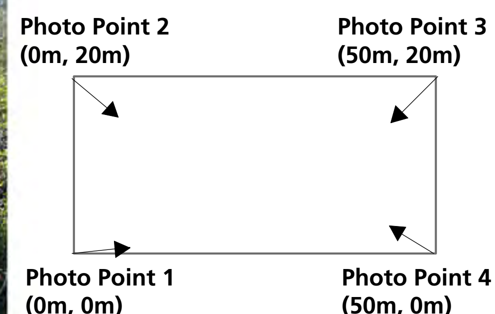


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Uplands Plot 503_V09 in 2008

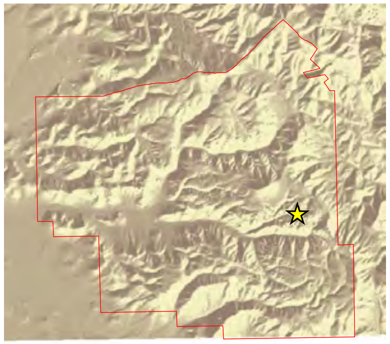
Photo point 2 (0m, 20m corner): 264 degrees

Photo point 3 (50m, 20m corner): 190 degrees

Photo point 1 (0m, 0m corner): 356 degrees

Photo point 4 (50m, 0m corner): 90 degrees

Plot Location



☆ Uplands plot
Park boundary
N
Meters
0 2,500 5,000

Plot Layout

Photo Point 2
(0m, 20m)

Photo Point 3
(50m, 20m)

Photo Point 1
(0m, 0m)

Photo Point 4
(50m, 0m)

Photo points are located at each of the four plot corners. Meter marks (e.g., 0m, 20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher-resolution photos are available from the Sonoran Desert Network.

Produced by Sonoran Desert Network
October 2013

Appendix B. Plot-specific Data

See electronic appendix.

NPS 145/130531, November 2015

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oak Ridge Drive, Suite 150
Fort Collins, Colorado 80525

www.nature.nps.gov

EXPERIENCE YOUR AMERICA™