



Terrestrial Vegetation and Soils Monitoring at Fort Davis National Historic Site

Status Report

Natural Resource Technical Report NPS/CHDN/NRTR—2013/753



ON THE COVER

Vegetation and soils monitoring at Fort Davis NHS (with Fort Davis in the background).
Photograph courtesy of Chihuahuan Desert Network.

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Executive Summary

This report summarizes results of the Chihuahuan Desert Network's first season of terrestrial vegetation and soils monitoring in upland areas of Fort Davis National Historic Site (NHS), on the southeastern edge of the Davis Mountains in Texas. Ten permanent field-monitoring sites were established and sampled in 2011. Our objectives were to determine the status of and detect trends, over five-year intervals, in vegetation cover, vegetation frequency, soil cover (including bare ground), biological soil crusts, and surface soil stability.

The majority of our plots are representative of desert shrublands or "sotol grasslands;" however, one plot is dominated by herbaceous vegetation (plot 401_003) and two plots appear to be shrub steppe communities or at the ecotone between shrubland and semi-desert grasslands (plots 403_002 and 403_005). Across all ten plots, vegetation cover was always greatest in the field height category (<0.5 m) and averaged nearly 50%. Vegetative cover in the field height category ranged from 22% to 88% among individual plots. In contrast, vegetation cover in the canopy height category (>2 m) was generally less than 5% and only five species were recorded in the canopy height category. The plots were sampled several months after the April 2011 Rock House Fire burned in the Davis Mountains and portions of Fort Davis NHS. Approximately 100 acres within Fort Davis NHS were affected with low to moderate severity burns. Although plots within the burned area may have some vegetation differences due to the effects of the recent burn, these differences were not statistically significant. No exotic plant species were recorded within the ten plots; however, it is possible that non-native species do occur on the plots but were undetected during the 2011 sampling effort.

Previous studies of vegetation change at Fort Davis NHS (Nelson 1981, Haynie 2000) expressed concerns about shrub encroachment into grasslands and associated loss of semi-desert grassland. Our data suggest that vegetation at Fort Davis NHS is currently fairly stable, consisting of semi-desert grasslands and shrub savannas, but that brush encroachment could become an issue in the future. All plots had the greatest overall cover in the field layer, and with the exception of three "true" shrubland sites, all others have two to three times as much native perennial grass and forb cover as they do shrub and succulent cover; however, mesquite is present in all but two plots. Although the within-plot frequency of mesquite is low (typically found in two or fewer of the five subplots), the park-wide extent of mesquite is high, which indicates that mesquite is well distributed. Although mesquite distribution in the northeastern grasslands of the park represents a deviation from the historical landscape of the 1800s, mesquite does not seem to have substantially increased in the three decades since Nelson's 1981 study.

Upland areas of the park, as a whole, appear to be well-protected from soil erosion, although a few sites had reduced soil surface aggregate stability and relatively high proportions of exposed bare ground. Three plots had an average stability value of less than three ("somewhat stable;" plots 401_001, 401_004, 403_005). On average, less than 10% of the soil surface was unprotected, due to high cover of vegetation and the abundance of gravel and bedrock on the soil surface; however, three sites had 20-24% of the soil surface as unprotected (plots 401_003, 401_004, and 401_005). None of the ten plots met our management assessment point of having exposed bare ground cover of 30% or more. Although six plots showed evidence of erosion, the overall amount of rills, gullies, and sheet erosion were modest. Plots 401_001 and 403_010 had the most evidence of erosion among the plots sampled.

We conclude that the terrestrial vegetation and soils in uplands of Fort Davis NHS are within the historic range of natural variability. The grassland systems appear to be in good condition with high overall vegetative cover, a high ratio of perennial to annual species, and a near lack of non-native grasses. Soil and site stability is relatively high, suggesting the park is fairly resistant to erosion or altered water and nutrient cycles. Because conversion from grassland to mesquite shrubland/woodland has been reported extensively elsewhere in the southwest (Van Auken 2000, Brown and Archer 1999) and expressed as a concern for Fort Davis NHS, we encourage managers to remain vigilant to potential increases in mesquite and other brush species. The Chihuahuan Desert Network will continue to monitor terrestrial vegetation and soils at Fort Davis NHS and will revisit the ten plots in 2016.

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List of Acronyms

AVG	average
ANOSIM	analysis of similarities
CHDN	Chihuahuan Desert Network
FODA	Fort Davis National Historic Site
GRTS	Generalized Random Tessellation Stratified
I&M	Inventory and Monitoring
MDC	minimum detectable change
MDS	multi-dimensional scaling
n	number
NHS	National Historic Site
NPS	National Park Service
RRQRR	Reversed Randomized Quadrant-Recursive Raster
SBS	spatially balanced sample
SD	standard deviation
Sdiff	standard deviation of the differences
SE	standard error
SIMPER	similarity of percentage contributions
SODN	Sonoran Desert Network

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 American Southwest, vegetation composition, distribution, and production are highly influenced by edaphic factors such as soil texture, mineralogy depth, and landform type (McAuliffe 1999). Especially as they relate to water, these influences are magnified at local scales, as described by pioneering desert ecologist Forrest Shreve:

The profound influence of soil upon desert vegetation is to be attributed to its strong control of the amount, availability, and continuity of the water supply. This fundamental requisite in plants is the most effective single factor in the differentiation of desert communities (Shreve 1951:29).

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

The Chihuahuan Desert Network (CHDN), as part of the National Park Service's Inventory and Monitoring (I&M) Program, identified terrestrial vegetation and dynamic soil functional attributes as important ecosystem monitoring parameters, or "vital signs" (NPS 2010a) that provide key insights into the integrity of terrestrial ecosystems at Fort Davis National Historic Site (NHS; Figure 1-1). Indicators of terrestrial vegetation integrity include vegetation



Figure 1-1. Terrestrial vegetation at Fort Davis National Historic Site.

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 soil cover (including bare ground), biological soil crusts, and the stability of surface soil aggregates.

1.2 Goals and Objectives

The overall goal of the CHDN 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 CHDN terrestrial vegetation and soils monitoring (Hubbard et al. 2012) at Fort Davis NHS are to determine the status of and detect trends in (over five-year intervals):

1. Terrestrial vegetation cover for common ($\geq 10\%$ 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. Basal cover and frequency of biological soil crusts by lichen growth form and morphological group.

1.3 Scope of this Report

This document reports and interprets the results of the first round of terrestrial vegetation and soils monitoring at Fort Davis NHS. Our focus is necessarily on current status, with trend evaluations to commence after the next sampling period in 2016. We do, however, contrast these current results with those from previous studies and interpret the information in the context

of management objectives and ecological considerations.

1.4 Overview of Terrestrial Ecosystems at Fort Davis NHS

1.4.1 Park Establishment and Purpose

Fort Davis NHS was authorized on September 8, 1961 and established on July 4, 1963. In its presently preserved condition, this site symbolizes the era of westward migration and the essence of the late 19th century U. S. Army. Fort Davis NHS covers 220 ha (516 acres) of the southeastern edge of the Davis Mountains (Figure 1-2). The park preserves 110 historic buildings, ruins, and foundations and the landscape associated with two forts (active from 1854-1862 and 1867-1891).

1.4.2 Biogeographic and Physiographic Context

Fort Davis NHS is located within the Chihuahuan Desert ecoregion in the Trans-Pecos region of West Texas. The site is bordered to the northwest by Davis Mountain State Park and by private land on the other sides. The town of Fort Davis, Texas, is adjacent to the park. The Nature Conservancy's Davis Mountain Preserve is a neighbor in close proximity, as is the McDonald Observatory and the

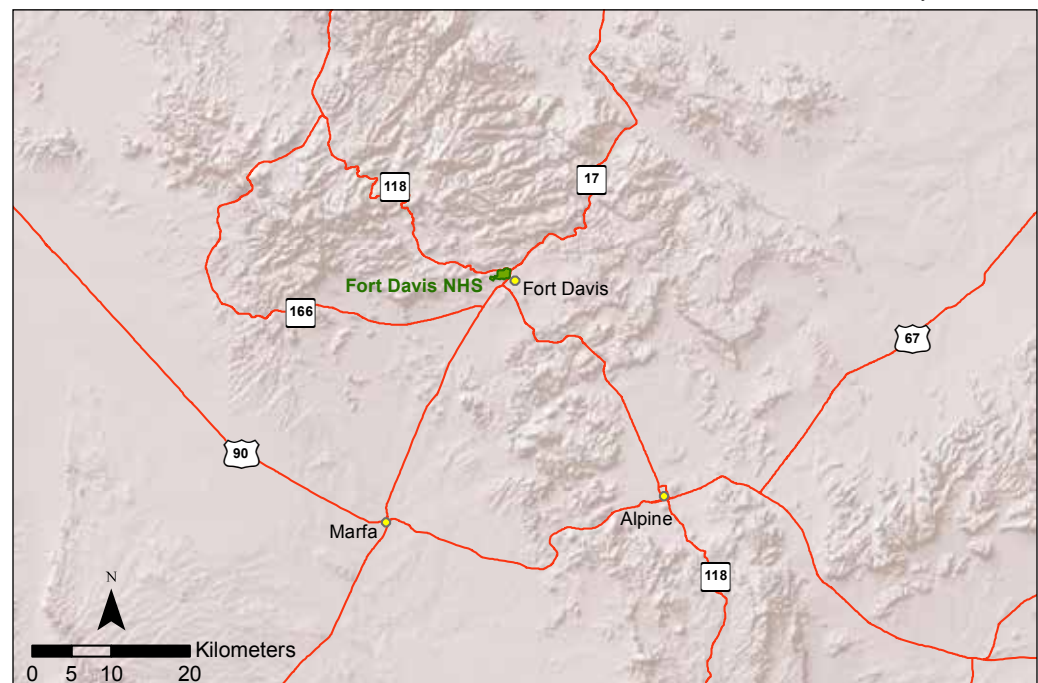


Figure 1-2. General map of Fort Davis NHS.

Chihuahuan Desert Research Institute. The elevation at Fort Davis NHS ranges from approximately 1,487 m (4,880 ft) at the fort to approximately 1,591 m (5,220 ft) in the Davis Mountains. Overall change in elevation is approximately 104 m (340 ft). The fort is located in the middle of an alluvial floodplain and natural drainages run through the site.

1.4.3 Local Geology and Soils

The Davis Mountains were formed by volcanic eruptions that occurred during the Tertiary geologic period, which began approximately 65 million years ago. Behind the main fort area rise the volcanic cliff walls of Hospital Canyon and a rugged steep escarpment running north-south that forms the prominent backdrop view from the lower elevations. The Sleeping Lion Mountains form the southern ridge of the site. Both the North Ridge Mountains and the Sleeping Lion Mountains are composed of a low-silica rhyolite lava flow that has distinctive exposed columnar jointing patterns commonly referred to as hoodoos. These formations create rugged and boulder-strewn cliffs with strong north and south aspects that influence vegetation patterns through modifying soil water availability and aspect-driven variation in solar radiation (Muldavin et al. 2012).

The valley bottom of Hospital Canyon and the lower elevation flats of the fort site have been described as Quaternary alluvial fan deposits. Soil properties of these four distinct areas have been summarized by Haynie (2000) based on soil survey data collected in 1969 and 1971 for Jeff Davis county (Turner and Jaco 1969, Turner 1977). Soils of both mountain ranges are said to have low water-holding capacity and high rock content, whereas the deeper soils of the military grounds and Hospital Canyon have high water-holding capacities.

According to the Natural Resource Conservation Service, however, the county-level soil map (Turner and Jaco 1969, Turner 1971) of the site may not be the appropriate scale for inferring soil types across Fort Davis NHS (NRCS 2012). The Jeff Davis soil survey was mapped at 1:31,680 (NRCS 2012), whereas a scale of 1:5,000 is probably more appropriate for the small extent of Fort Davis NHS. Therefore, the placement of the boundaries between soil map units may not be either precise or accurate at the “zoomed in” scale. In addition, the soil map does not show small areas of soil inclusions within a given soil map unit (NRCS 2012), however, the survey is the best available soil data for the site at the present (Figure 1-3).

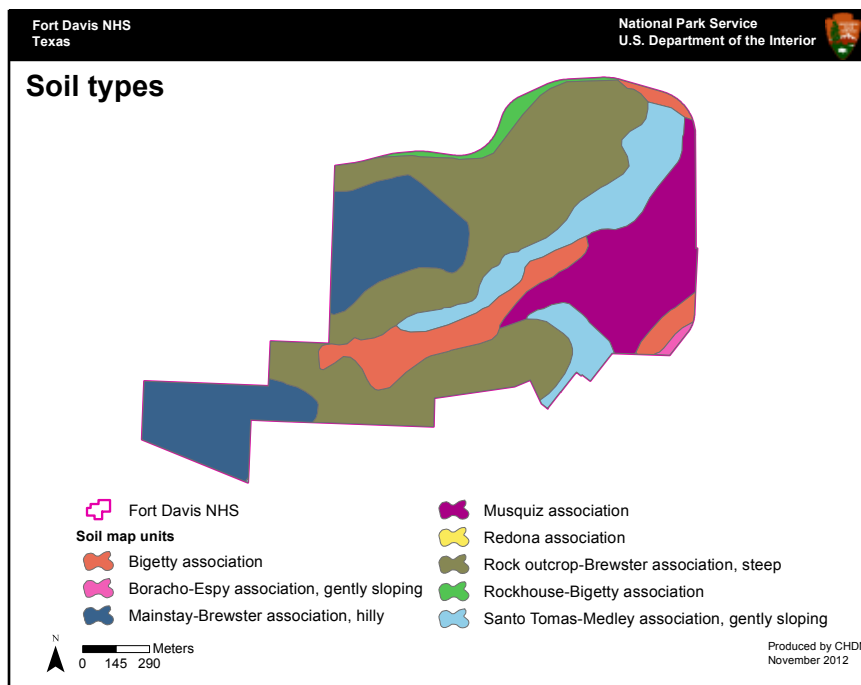


Figure 1-3. Soil map units at Fort Davis National Historic Site.

1.4.3.1 Biological Soil Crusts

Open spaces on the soils in the Chihuahuan Desert, are typically covered by biological soil crusts, a community of cyanobacteria, algae, lichens, and bryophytes. Lichens are a composite, symbiotic organism composed of a fungus and either a cyanobacteria or a green algae. Bryophytes are small, non-vascular plants, including mosses and liverworts.

Biological soil crusts provide key ecosystem functions, such as increasing water and wind erosion resistance, contributing organic matter, and fixing atmospheric nitrogen. Cyanobacteria weave through the upper few millimeters of soil, binding together soil particles by secreting polysaccharides. In addition to reducing water erosion, the polysaccharides contribute to soil aggregate structure, which is directly correlated with soil erosion resistance (Belnap et al. 2003, Herrick et al. 2005a). Mosses and lichens have small, anchoring structures that help them protect the soil surface (Belnap et al. 2003). On most soils, biological soil crusts increase infiltration; however, on sandy soils cyanobacteria-dominated biological soil crusts tend to reduce infiltration rates (Warren 2003).

Biological soil crusts contribute fixed carbon to soil through decaying and leaching processes (Lange 2003). Cyanobacteria and cyanolichens have the ability to fix atmospheric nitrogen. This process reduces atmospheric nitrogen (N_2) to ammonia (NH_4^+), which is usable by vascular plants (Belnap 2003). Biological soil crusts can be the dominant source of nitrogen for desert ecosystems. The distribution and species composition of biological soil crusts is influenced by soil chemistry and disturbance (Belnap et al. 2001).

In general, lichens with the same growth form have similar ecological functions. Squamulose lichens provide the most protection of the soil from water erosion, followed by crustose, foliose, and fruticose lichens. Gelatinous lichens provide the least protection from water erosion. Having some vertical growth allows lichens to provide additional protection from wind erosion by increasing surface roughness and decreasing the erosive power of wind. Crustose and

gelatinous lichens are effective at resisting detachment, but do not provide as much resistance to wind erosion as other growth forms. All gelatinous lichens fix nitrogen, whereas nitrogen fixation is species-dependent for the other growth forms.

1.4.3.2 Site and Soil Stability

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

Soil factors mediate water relations for plants in semi-arid environments (McAuliffe 1999), thereby controlling patch-scale ecological composition and net primary productivity (Herrick et al. 2005b). As recovery of disturbed soils is particularly slow in dry and seasonally dry environments (Aber and Melillo 1991), avoiding erosion is of paramount importance for effective natural resource management in CHDN parks, including Fort Davis NHS.

Static and dynamic factors determine the vulnerability of a site to water erosion (Herrick et al. 2005b). Static factors are generally not affected by management actions and include soil texture and rock fragment content, depth and parent material, slope, aspect, and climate (Herrick et al. 2005b). These factors can be combined to estimate site erosion potential (Davenport et al. 1998). 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 that affect water erosion include soil disturbance, soil structure, total cover, and plant basal cover. The amount of total cover (soil cover and vegetation cover) is the single most important dynamic factor affecting water erosion (Herrick et al. 2005b). Most soil loss occurs in “unprotected” areas with uncovered bare soils (Davenport et al. 1998), whereas rock, gravel, vegetation, biological soil crusts, and even plant debris (litter and duff) can “armor” the soil, slowing the flow of water and permitting increased infiltration of water into the soil profile (Belnap et al. 2007).

1.4.5 Climate

The climate of the Davis Mountains is semi-arid, as is typical of the northern Chihuahuan Desert, with annual rainfall averaging 48 centimeters (19 in) across the Davis Mountains. The elevation of the site results in relatively mild temperatures, but extremes of more than 35°C (95°F) during the summer are common. Winter temperatures may reach below -6°C (20°F) (NPS 2010a).

To determine departure from baseline climate conditions, seasonal and annual precipitation are compared to the average precipitation received during a historic

or “normal” period (Gray 2008). The most recent 30-year normal computed for the weather station at Fort Davis, Texas spans 1981-2010. Therefore, the monthly precipitation and temperature data from 2007-2011 are presented in the context of that time period (Figure 1-4; NCDC 2012). The average annual precipitation from 2007-2011 was lower than the 1981-2010 precipitation normals (14.9” vs. 17.5”). Although precipitation at the start of the summer monsoon (July) was higher from 2007-2011, the overall monsoon strength was similar to the normals. The 2007-2011 period had slightly less rainy winters and somewhat more rainy monsoons.

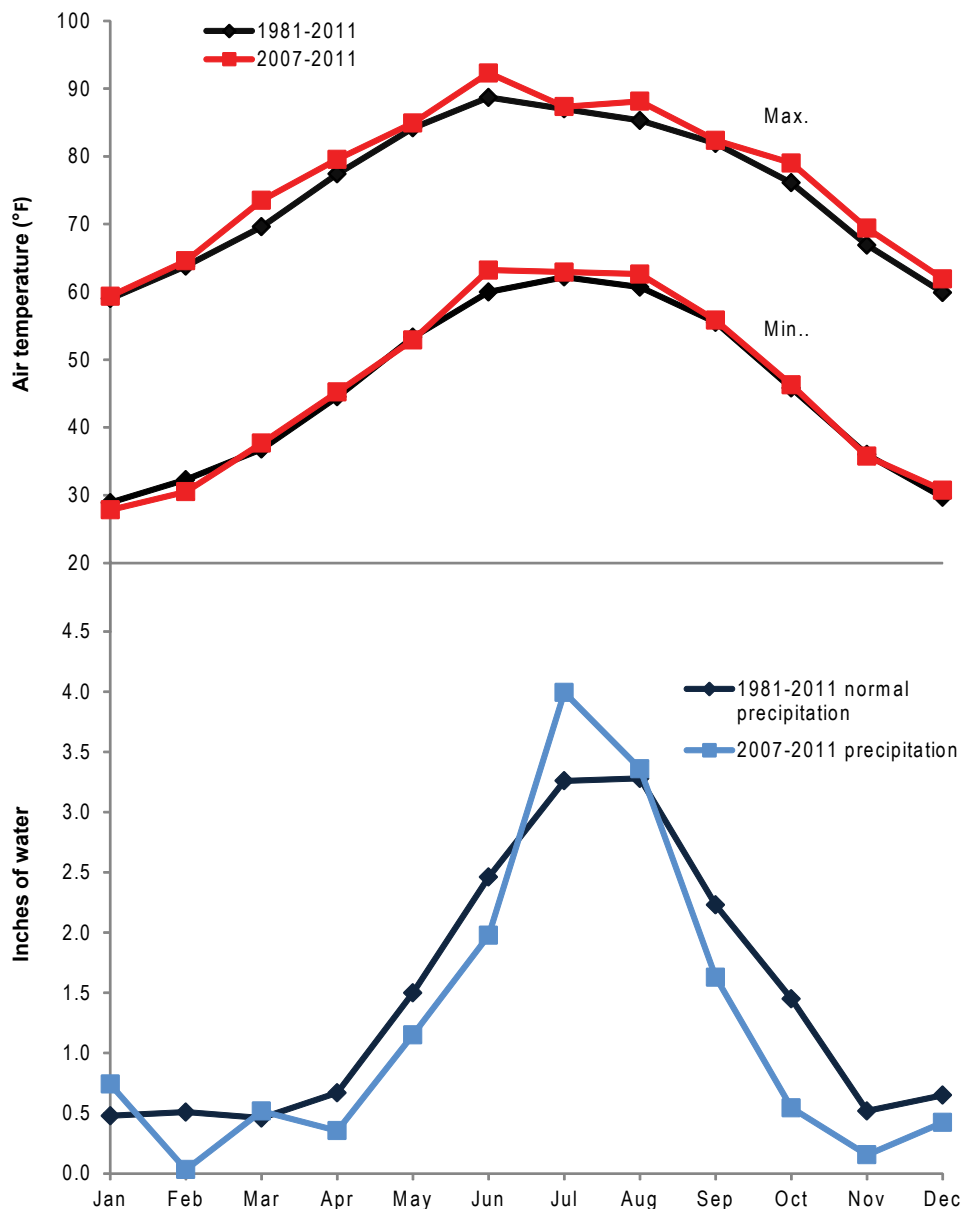


Figure 1-4. Climate data from 2007-2011 in the context of 30-year normals (1981-2010) for Fort Davis, Texas (NCDC 2012).

Monthly average maximum and minimum temperatures from 2001-2007 were similar when compared to the 1981-2010 normals.

1.4.6 Army Occupation of Fort Davis

In October 1854, Brevet Major General Persifor Smith established Fort Davis and named the fort in honor of Secretary of War Jefferson Davis. Initial construction at the fort consisted of tents and jacales, but these structures could not persist through the region's winters. By 1857, the Eighth Infantry completed construction of stone barracks. The Eighth Infantry occupied the fort from 1854-1861 and around 400 enlisted men and officers occupied the fort at its pre-Civil War peak (Welsh 1996). In January 1861, the state of Texas voted to secede from the United States. Brevet Major General David E. Twiggs, commander of the Department of Texas, surrendered Fort Davis and all federal forts in Texas to the Confederate States of America. The Union troops evacuated Fort Davis in April 1861 (Wooster 2006). Shortly thereafter, Confederate troops occupied the fort, but by October 1861 only 62 troops occupied Fort Davis. In the spring of 1862, the Confederate troops abandoned Fort Davis. Union troops regained control of Fort Davis in the fall of 1862, but troops did not occupy the fort until after the conclusion of the Civil War.

In June 1867, Lieutenant Colonel Wesley Merritt arrived at Fort Davis with four troops from the Ninth Cavalry (Wooster 2006). The Ninth Cavalry was composed of black soldiers and over time all four of the black units would serve at Fort Davis. Troop strength averaged around 390 men and officers from 1867 to 1880 (Wooster 2006) and reached over 650 officers and men in 1884 (Welsh 1996). The return of the Army encouraged growth in the Davis Mountains and in the town of Fort Davis (Wooster 2006). The U.S. Army deactivated Fort Davis in 1891 and the last soldiers left the fort in June 1891.

1.4.7 Other Long-term Monitoring and Related Ecological Research at Fort Davis NHS

In addition to terrestrial vegetation and soils monitoring, the Chihuahuan Desert

Network conducts long-term monitoring on birds, climate, early detection of exotic plants, and landscape condition. Details on these efforts are provided in NPS (2010a) and on the Chihuahuan Desert Network website: <http://science.nature.nps.gov/im/units/chdn/>.

The CHDN implemented a monitoring protocol for early detection of invasive non-native plants at Fort Davis NHS in the spring of 2011. Surveys were conducted along seven road and trail sections within the site that will be routinely monitored, and an additional 29 randomly located 50 m transects were surveyed within the area affected by the 2011 Rock House Fire. These "fire" transects may be repeated to continue to monitor for new species or populations responding to fire disturbance or suppression activities. Across the two year period (2011-2012) a total of 22 exotic species were observed (Table 1-1) and most of these were found to be concentrated along three vectors: the entrance road, the Old El Paso-San Antonio Road and the Rock House Fire area (Reiser et al. 2012, CHDN unpublished data).

Fort Davis NHS has been the focus of other ecological research relevant to terrestrial vegetation and soils monitoring. One of the earliest vegetation studies was completed by Nelson (1981), who compared 19 historical photographs and current repeat photographs to determine vegetation changes. Change was described in terms of "departure from climax" as described by the USDA-Soil Conservation Service (now the Natural Resource Conservation Service) range condition guidelines, and the report was intended as the basis for a vegetation management program for the Fort. Nelson noted a moderate departure from climax due to an increase in blue grama (*Bouteloua gracilis*) and several brush species, mostly catclaw mimosa (*Mimosa aculeaticarpa* var. *biuncifera*). In addition, Nelson (1981) indicated that the distribution of vegetation had not changed considerably since the late 1800s with a few notable exceptions: brush increase, the appearance and spread of Mesquite (*Prosopis* spp.) and a slight decrease (~7%) in grassland extent. These observations are considered again in the discussion of this report.

Table 1-1. Non-native species recorded by CHDN in 2011 and 2012.

Scientific name	Common name	Spring 2011	Fall 2011	Spring 2012	Fall 2012
<i>Cynodon dactylon</i>	Bermudagrass	X	X	X	X
<i>Marrubium vulgare</i>	horehound	X		X	X
<i>Salsola tragus</i>	prickly Russian thistle	X	X		X
<i>Chenopodium album</i>	lambquarters	X	X		X
<i>Sorghum halepense</i>	Johnsongrass	X	X	X	X
<i>Bothriochloa ischaemum</i>	King Ranch bluestem		X	X	X
<i>Eragrostis cilianensis</i>	stinkgrass		X		X
<i>Portulaca oleracea</i>	little hogweed		X*	X	X*
<i>Taraxacum officinale</i>	common dandelion		X	X	
<i>Tribulus terrestris</i>	puncturevine		X*		X*
<i>Alternanthera pungens</i>	khakiweed			X	
<i>Bromus catharticus</i>	rescuegrass			X	
<i>Convolvulus arvensis</i>	field bindweed			X*	
<i>Erodium cicutarium</i>	redstem stork's bill			X	
<i>Setaria pumila</i>	yellow bristlegrass			X	
<i>Amaranthus blitoides</i>	mat amaranth				X
<i>Amaranthus retroflexus</i>	redroot amaranth				X*
<i>Dactylis glomerata</i>	orchard grass				X
<i>Euphorbia davidii</i>	David's spurge				X*
<i>Euphorbia dentata</i>	toothed spurge				X*
<i>Salsola kali</i>	Russian thistle				X
<i>Stellaria media</i>	common chickweed				X

Records marked with an "*" indicate the species was observed along one of the Rock House Fire transects.

Haynie (2000) built on the work of Nelson (1981) and repeated the photographs in 2000 and the analysis of these timeseries of photographs. Haynie used these observations to describe historic and current vegetative conditions at the NHS also making use of comparisons of historical vegetation lists and a current delineation of the vegetative communities at the site. This work provided a baseline vegetation map of communities using an existing vegetation classification (developed by Henrickson and Johnston 1986) and was delineated by tracing visible boundaries on infrared aerial photographs.

Haynie (2000) identified four historical and two contemporary vegetation communities at Fort Davis NHS, with focus on dominant species for each type. Grama grassland, mixed-desert scrub, sotol scrub, and montane chaparral were identified from photographs taken in the mid to late 1800s and sandy arroyo scrub and canyon scrub were the newly recognized communities.

A 2004 study of ferns and fern allies at the NHS (Yarborough 2004) identified and vouchered 23 taxa occurring at the site. Duplicate specimens reside at the A. Michael Powell Herbarium at Sul Ross State University, and others were deposited at the NHS. The author noted the abundance and good vigor of the ferns in 2004 due to the above-average winter rainfall. It is unclear how these populations may have been affected by the 2011 Rock House fire, but it is likely that in burned areas fern aboveground biomass would have been destroyed, and it is not known if these will recover or how long before they recover.

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 Fort Davis NHS (NPS 2009). At time of writing, all of these inventories have been completed (Table 1-2). Coordinated at the national-level, most of these inventories rely on existing

information and deliver products ranging from electronic data sets to short reports.

Two reports from these inventories are particularly relevant to vegetation and soils monitoring: vascular plant species (Worthington 2002) and vegetation characterization (Muldavin et al. 2012) inventories. Worthington (2002) produced an inventory of the flora of the Davis Mountains, compiling the collections of many botanists as well as reviewing an impressive amount of botanical literature. As with many such studies, it was noted at the time of publication that it was incomplete, due to over 1,000 herbarium records awaiting review for addition. Worthington speculated that upon completion of the review, several hundred taxa would be added to the Davis Mountains flora. Muldavin et al. (2012) conducted a vegetation inventory documenting the location and extent of 22 plant communities defined at the association level of the National Vegetation Classification Standard, the finest level of national program classification hierarchy.

1.5 Leading Natural Resource Management Issues at Fort Davis NHS

1.5.1 Invasive Exotic Plants

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

1.5.2 Fire

The Rock House Fire swept through Fort Davis NHS and the Davis Mountains in April 2011. Approximately 100 acres in the western portion of the site were affected with low- to moderate-severity burns (Sirotnak and Bennett 2011). The initial post-fire assessment described the overall effects of the fire as having fully consumed many woody species while leaving perennial bunch grasses relatively intact (un-burned root crowns). Sirotnak and Bennett (2011) expected vigorous regrowth of grasses, sotol (*Nolina* spp.) and forbs, and high mortality of yuccas and cacti. In savanna areas, the scattered Juniper trees suffered scorch heights of approximately 5-8 feet and should recover well with only slight damage sustained to canopies (Sirotnak and Bennett 2011).

With any major change in disturbance, such as fire or flooding, the risk of non-native plant invasion increases and can in turn facilitate more disturbance by way of positive feedback mechanisms (Brooks et al. 2004). Invasion by non-natives can be facilitated by the transport of seed on fire suppression tools or vehicles, or may simply result from the opening of niche space, allowing new or existing (yet suppressed) plant species to take hold or spread. The CHDN has increased the area over which exotic plant surveys are typically conducted to include the area burned. During the 2011 fall sampling period, only two species were recorded along any of the burned area transects: *Portulaca oleracea* and *Tribulus terrestris*. Both species are found commonly throughout the site (Reiser et al. 2012). During the fall 2012 surveys, three additional species were observed on the burned area transects: *Amaranthus blitoides*, *Euphorbia davidii*, and *Euphorbia dentata*. No indication is given that these species were responding positively to the fire (CHDN unpublished data).

1.5.3 Historic Landscape

The primary resource concern of Fort Davis NHS is maintaining the historic landscape, viewshed, and sounds both inside the park and on private and state lands bordering the park. The intent is when visitors enter the

Table 1-2. Status of natural resource inventories at Fort Davis NHS, November 2012.

Inventory	Description	Status (2012)
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 in Middle and West Forks of Gila River. Products: http://www.nature.nps.gov/water/horizon.cfm	Complete
Climate	A basic assessment of nearby climate stations and instrumentation. Products: http://www1.nrintra.nps.gov/NPClimate/	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/	Complete
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: http://science.nature.nps.gov/im/units/chdn/reportpubs.cfm	Complete
Vegetation Characterization	Description, classification, and mapping of vegetation communities, based on fieldwork. Products: https://irma.nps.gov/App/Reference/Profile/2190806	Complete
Water Body Location and Classification	Basic geographic data on hydrologic units.	Complete

park they should be able to look and listen in all directions and feel they are on an active military post in the mid- to late-19th century. Therefore, natural resources generally have been managed with the goal of maintaining the historic late-19th century landscape of the fort. Most of the park's viewshed is protected by natural barriers, however, adjacent private land to the northeast could be developed and impact the viewshed.

1.5.4 Adjacent Land Use

The land management and conservation status metrics are based on version 1.2 of the Protected Areas Database of the United States (PAD-US v.1.2). Based on PAD-US v.1.2 data, over 99% of the land surrounding Fort Davis NHS (within 30 km) is private land (USGS 2011). Fort Davis NHS is the only federal land in the area. State lands in the region consist of Davis Mountain State Park and Indian Lodge State Park, which cover less than 0.25% of area (less than 2,000 acres). In PAD-US v.1.2, stewardship intent and management status are classified using GAP Status codes, which range from 1 to 4. Typically, national parks are classified as GAP status 1 and wilderness areas and wildlife refuges are classified as GAP status 2 (USGS 2010). According to the PAD-US v.1.2, 0.3% of the lands within the area are classified as GAP status 3. The GAP status 3 lands include Davis Mountain and Indian Lodge state parks and most of Fort Davis NHS. The recent expansion lands of Fort Davis NHS are classified as GAP status 4. The remaining lands in the area are private lands and do not have an assigned GAP status (USGS 2011).

In 1900, population of the three counties surrounding Fort Davis NHS (Brewster, Jeff Davis, and Presidio) was under 8,000 (Waisanen and Bliss 2002). The population grew to nearly 20,000 by 1940, declined to under 15,000 by 1980 (Waisanen and Bliss 2002), and then increased to nearly 20,000 in 2010 (USCB 2011). The three-county population is projected to grow at a modest rate in the future and reach 22,000 around 2025 (NPS 2010b).

Housing density estimates come from the Spatially Explicit Regional Growth Model. The model considers over 99% of the land within 30 km of Fort Davis NHS as "developable" (Theobald 2005). The towns of Alpine and Marfa are not within 30 km of the historic site. In 1970, over 7% of the developable land contained development with rural residential development (<6 units/km²), the dominant development pattern. In 2010, the model projected that over 13% of the developable land would be developed. The majority of development between 1970 and 2010 was rural residential development. Future projections forecast that development densities will increase somewhat with more land moving in to the exurban residential category (7-145 units/km²), but that rural residential development will continue to dominate the area around Fort Davis NHS. The model does not predict a substantial increase in the total amount of land developed beyond 2020 (Theobald 2005).

2 Methods

2.1 Response Design

The response design for the terrestrial vegetation and soils monitoring 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 perennial or non-native annual plant species or lifeform not observed on the adjacent transects. See Hubbard and others (2012) for details on plot configuration and data collection.

2.1.1 Vegetation and Soil Cover, Line-point Intercept

Line-point intercept is a common and efficient technique for measuring the vegetation cover of plants. Line-point intercept measures the number of “hits” of a given species out of the total number of points measured (Elzinga et al. 1998,

Bonham 1989). Vegetation was recorded within three height categories along each of the six transects using the line-point intercept method, with points spaced every 0.5 m (240 points total). The three height categories were field (0.025–0.5 m), subcanopy (>0.5–2.0 m), and canopy (>2.0 m) (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 was recorded by substrate class (e.g., bare ground, rock, gravel, litter; see SOP #5 in Hubbard et al. 2012). Bare ground (bare soil <2 mm) cover, both under and without vegetative cover, was calculated from the line-point intercept measurements. The litter category was divided into the standard

Table 2-1. Height categories for vegetation measurement.

Layer	Height
Field	<0.5 m
Subcanopy	0.5–2.0 m
Canopy	>2.0 m

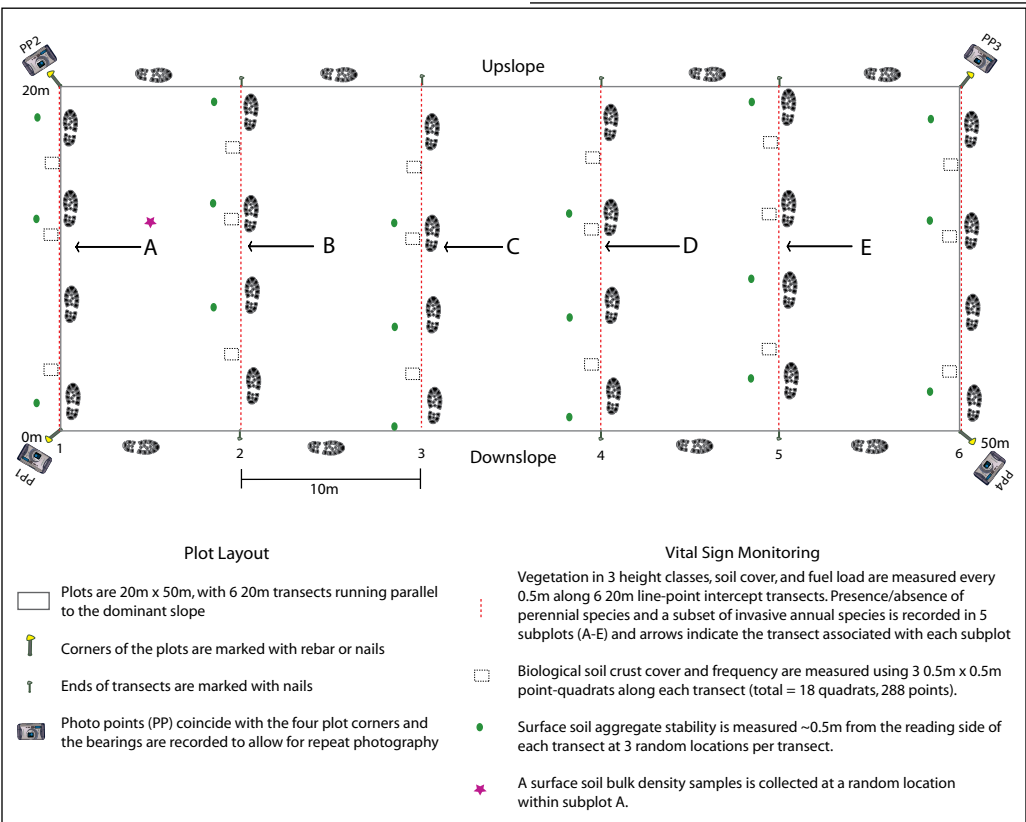


Figure 2-1. Terrestrial vegetation and soils monitoring plot design. See Hubbard et al. (2012) for additional details on design and data collection.

fuel classes as used by the NPS Fire Ecology program (NPS 2003) to obtain additional data about fire potential and for fuel models. The litter categories represent different size classes of fuels, from leaves and needles up through litter over 3" in diameter (1,000-hour fuels). Biological soil crust cover was recorded to morphological group (light cyanobacteria, dark cyanobacteria, lichen, moss).

2.1.2 Vegetation Frequency, Subplots

The area between any two adjacent transects formed the boundary of 10×20-m subplots that were used to estimate within-plot frequency of perennial plant species, annual and perennial exotic plants, and all lifeforms. 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. Figure 2-1 shows the relationship between each subplot and its corresponding adjacent transect.

2.1.3 Soil Aggregate Stability

Surface soil aggregate stability was measured using a modified wet aggregate stability method (Herrick et al. 2005a). Within each plot, samples were attempted at 18 pre-determined points on the reading side of the six line-point intercept transects. The dominant vegetation canopy cover and substrate cover at each point were determined. Uniformly sized (2-3 mm thick and 6-8 mm on each side) samples were collected. Each sample was placed on a screen and soaked in water for five minutes. After five minutes, the samples were slowly dipped up and down in the water, with the remaining amount of soil recorded as an index of the wet aggregate stability of the sample. Samples were scored from 1 to 6, with 6 being the most stable.

2.1.4 Biological Soil Crust Cover and Frequency, Point Quadrats

In addition to line-point intercept measurements, biological soil crust cover was measured using 0.25 m² quadrats. Three quadrats were measured per transect using the point-quadrat method (similar in concept to line-point intercept), with 16 intercept measurements per quadrat, resulting in 18

quadrats and 288 measurements per plot. At each intercept, biological soil crusts were recorded as light cyanobacteria, dark cyanobacteria, bryophytes (moss and liverworts), and lichens by growth form (crustose, gelatinous, foliose, fruticose, and squamulose). The observer then visually surveyed the quadrat for any species or morphological group that was present. Soil crust frequency by lichen species and morphological group was determined by the number of quadrats occupied relative to the total number of quadrats (i.e., 18). The CHDN terrestrial vegetation and soils monitoring protocol (Hubbard et al. 2012, SOP #6) provides a detailed description of the point-quadrat methodology.

2.1.5 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 topographic variables were collected through site diagrams, repeat photo points, and collection of soil cores. Landform, slope position, and parent material were recorded at each plot. Slope measurements (%) and descriptions (type and position) were used to depict surface-flow patterns of the hillslope within each plot. Erosion features were described by estimating broad areal percentage classes of areas affected by tunneling, sheeting, rilling, gullying, pedestals, terraces, and burrowing. Permanent photo points were established at each plot corner to characterize general site physiognomy and as an aid to interpreting quantitative trend data in successive sampling periods. In addition, general site descriptions (including observed disturbances such as fire) were collected for each plot.

2.2 Sampling Design

2.2.1 Overview

All plots are sampled in the fall of the same year, and then revisited at five-year intervals. If a major disturbance (e.g., an extended drought, extreme frost, significant soil erosion event, major fire) occurs in the intervening years, we may collect additional

plot data to characterize and account for the potential effects of these important stochastic events.

Stratification (see Section 3.2.3, Hubbard et al. 2012) was employed to reduce spatial variability and increase sampling efficiency. Consequently, inference from the plots at Fort Davis NHS is to all terrestrial areas of the park, except for the areas discussed in Section 2.2.3, Sampling Frame. Terrestrial vegetation and soils plots were proportionally allocated to two strata based on elevation and soil rock-fragment classes. Five permanent monitoring plots were allocated to each stratum within Fort Davis NHS and sampled in 2011 (Table 2-2, Figure 2-2). Sample sizes were based on *a priori* expectations of required sample size to meet our criteria for statistical power and detectability.

The first three numbers, or prefix, of the plot name signify the stratum in which the plot is located. The first number indicates the elevation band in which the plot is located. Fort Davis NHS falls entirely within the 4,501–6,000' elevation band so all plots begin with 40x. The 1, 2, or 3 in the “ones place” of the strata is associated with the soil rock-fragment content in the surface horizon derived from the county-level soil survey (Turner and Jaco 1969, NRCS 2012). A “1” indicates that the rock fragment content is less than 35% (based on the soil survey), a “2” indicates that the rock fragment content is between 35% and 90%, and a “3” indicates that the rock fragment content is greater than 90% or the area is bedrock or rock outcrops.

Soils in the Mainstay-Brewster association, hilly map unit were assigned to the 401

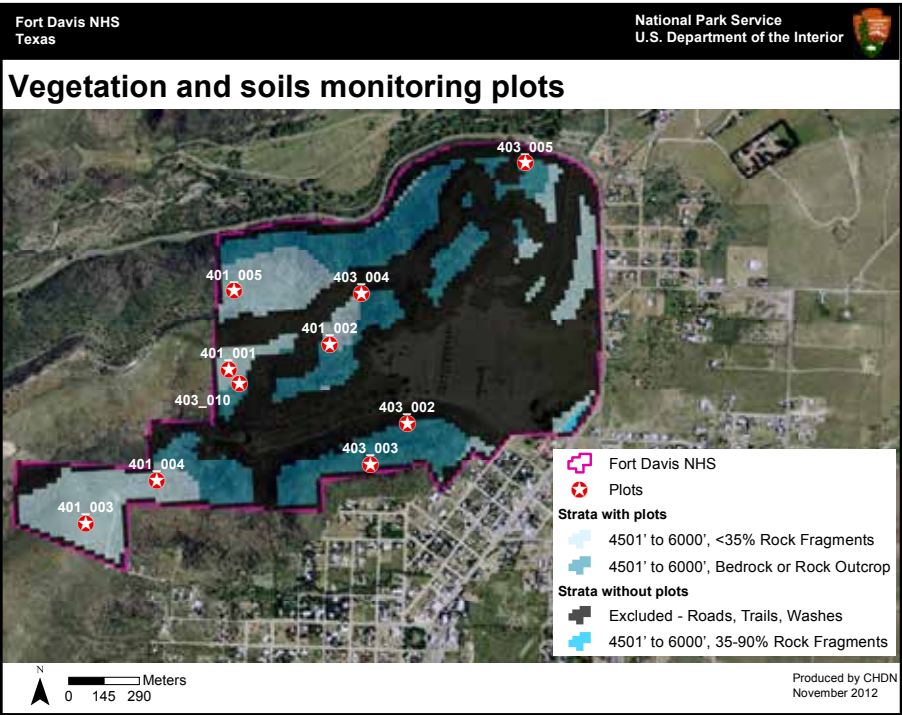


Figure 2-2. Allocation of monitoring plots for terrestrial vegetation and soils monitoring at Fort Davis National Historic Site.

Table 2-2. Allocation of permanent terrestrial vegetation and soils monitoring plots by strata, Fort Davis NHS. Strata with <5% of frame area are excluded.

Stratum	Elevation	Rock-fragment Percentage	Total Area (acres)	Percentage of Total		Plots per Stratum	
				Park Area	Frame Area	Number	Number Every 5 Years
Excluded	---	---	315	61%	0%	0	0
401	4,501-6,000'	<35%	93	18%	46%	5	5
402	4,501-6,000'	35-90%	1	0%	0%	0	0
403	4,501-6,000'	>90% or bedrock or rock outcrop	109	21%	54%	5	5

stratum (non-rocky). According to the NRCS Soil Survey Geographic (SSURGO) database (NRCS 2012), the Mainstay-Brewster association, hilly map unit consists of unnamed minor components (45% of map unit; unknown surface texture), Mainstay (30% of map unit; stony silt loam surface texture), and Brewster soils (25% of map unit, very gravelly loam surface texture). Since the texture of the dominant component of the Mainstay-Brewster association, hilly map unit is unknown, the map unit was assigned to the 401 stratum (<35% rock fragments) based on the surface texture of the two known components using the all component aggregation method (NRCS 2012).

2.2.2 Spatial Balance

The spatial sampling design for this protocol employs permanent, 20×50 m sampling plots, allocated through a Reversed Randomized Quadrant-Recursive Raster (RRQRR) spatially balanced design (Theobald et al. 2007), using the spatially balanced sample (SBS) tool with the RRQRR algorithm (ArcGIS 9.0). 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 they 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 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 Fort Davis NHS includes all terrestrial areas within park boundaries, except for the following (Figure 2-2):

- Slopes $\geq 45^\circ$ (for crew safety)
- Roads and buildings (including 100 m buffer)
- Trails, washes, and streams (including 50 m buffer)
- Selected cultural features (the fort)
- Park boundary (including 20 m buffer)
- Elevation x soil strata types that constituted <5% of the area of the park

The total area excluded under these criteria was 315 acres (~127ha), or 61% of the park area.

2.2.4 Management Assessment Points as the Link Between Science and Management

To achieve the NPS's core mission of resource protection, resource management and monitoring must be explicitly linked (Bingham et al. 2007). We suggest the use of management assessment points as a bridge between science and management. Management assessment points, which 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. 2007:59), aid interpretation of ecological information within a management context. They do not define strict management or ecological thresholds, inevitably result in management actions, or reflect any legal or regulatory standard; they are only intended to serve as a potential early warning system allowing scientists and managers to pause, review the available information in detail, and consider options. Bennetts and others (2007) have

Table 2-3. Proposed management assessment points for terrestrial vegetation and soils parameters monitored at Fort Davis National Historic Site.

Issue	Management Assessment Point	Information Source
Site Stability and Erosion Hazard	Exposed bare ground cover is >30%	La Cienegas National Conservation Area Management Plan (2003, as cited in Gori and Schussman 2005)
	Average stability of surface soil aggregates <3	Value is based on professional judgment of authors; issue is described in Herrick et al. 2005
	Foliar cover of perennial grasses in field layer is <25%	Value is based on professional judgment of authors; issue is described in Herrick et al. 2005
	Proportion of foliar grass cover (%) composed of annuals in field layer is >33%	Value is based on professional judgment of authors; issue described in Laycock 1991, Corbin and D'Antonio 2004
Shrub Encroachment	Shrub foliar cover in field layer is >35% Shrub foliar cover in subcanopy layer is >35%	
Mesquite Invasion	Mesquite (<i>Prosopis</i> spp.) foliar cover in the field layer is >15% Mesquite (<i>Prosopis</i> spp.) foliar cover in subcanopy and canopy layers combined is >20%	McAulliffe 1995, McPherson 1997, Shaver et al. 2000
Exotic Plant Dispersal	Extent (plot frequency) of invasive exotic plants is >20%	Professional judgment of authors; see SODN Monitoring Plan (NPS 2005) for an overview of the issue
Exotic Plant Invasion	Proportion of foliar plant cover (%) contributed from exotic plants is >10%	Professional judgment of authors; see SODN Monitoring Plan (NPS 2005) for an overview of the issue

provided a detailed explanation of this concept and its application to monitoring and management of protected areas.

Although no management assessment points have been formally established for Fort Davis NHS, we propose some assessment points here, based on the ecological literature and our knowledge of these ecosystems and park management goals. We intend for these assessment points to (1) initiate a discussion of potential indicators and assessment points and (2) provide a useful framework for evaluating terrestrial vegetation and soils data in a broader ecological and managerial context. Proposed assessment points are summarized in Table 2-3 and discussed further in this report.

2.2.5 Statistical Power to Distinguish Status from Management Assessment Points

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

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

Where:

S= Standard deviation of the sample

Z_{α} = Z-coefficient for false-change (Type I) error (we set at 90%)

Z_{β} = Z-coefficient for missed-change (Type II) error (we set at 10%)

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

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

2.2.6 Statistical Power to Detect Trends

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

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

Where:

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

Z_{α} = Z-coefficient for false-change (Type I) error (we set at 90%)

Z_{β} = Z-coefficient for missed-change (Type II) error (we set at 10%)

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

In this case, we only have one year of data, so we estimate “ S_{diff} ” using the following equation:

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

Where:

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

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

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

2.2.7 Evaluation of Strata

The terrestrial vegetation monitoring design apportions long-term monitoring sites to strata to improve the efficiency of park-wide 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 management and monitoring timescales (Bonham 1989).

To evaluate the efficiency and pertinence of our preselected strata, we contrasted the similarity of the vegetation communities on each stratum using analysis of similarity (ANOSIM), non-metric multi-dimensional scaling (MDS), and similarities of percentages (SIMPER). These non-parametric multivariate community analysis techniques make few assumptions about the data, yielding a simple yet powerful analysis tool (Clarke and Warwick 2001).

3 Results

3.1 Evaluation of Strata, Fire Effects, and Species Detectability

3.1.1 Were the Strata Effective?

Analysis of similarity (ANOSIM) results suggested that field (<0.5 m height), subcanopy (0.5-2.0 m), and canopy (>2.0 m) vegetation did not significantly differ between sites in mid-elevation non-rocky sites ("401," 4,501-6,000' with less than 35% surface rock fragment) and mid-elevation bedrock and rock outcrop sites ("403," 4,501-6,000' with greater than 90% surface rock cover) ($P \geq 54\%$, $R = -0.02$). Based on this result, we further evaluated the adequacy of the soil survey data that were used in developing the two original strata. We had concern that the broad scale (county level) of the soil map used (Turner and Jaco 1969, NRCS 2012) and the lack of soil texture data for one of the soil map units, may have led to the identification of soil strata that were not accurate for this relatively small park. To investigate this potential uncertainty, we used our soil cover data collected from each of the ten sites to post-stratify the plots. Using the line-point intercept soil cover data we calculated the proportion of intercepts (out of 240 at each site) that had rock, gravel, or bedrock as the ground cover. Using these percentages, we assigned a rock-fragment class to each site, following the same criteria as described above (Sampling Design). These data classified nine of the ten sites as being in the 402 stratum, having 35-90% rock-fragment cover. Site 403_002 was the only site classified in the 401 stratum, with less than 35% rock fragments. ANOSIM was repeated and results showed no significant differences between strata assigned based on soil cover data ($P \geq 53\%$, $R = 0.53$).

Although the post-stratification method does not exactly duplicate the rock-fragment content of the surface horizon from the soil survey, these results reinforce and perhaps explain the lack of any differences based upon the soil rock-fragment stratification.

Based on the lack of significant differences between the two strata, we combined data from plots in the two elevation-soil strata and conducted analyses as if we had a single stratum.

3.1.2 Evaluation of Potential Fire Effects

Because fire can have dramatic influences on vegetation structure and composition, the plots were evaluated for fire effects using the ANOSIM routine in Primer (Clarke and Warwick 2001). From the Burned Area Reflectance Classification (BARC) assessment report completed in April 2011, we determined five of the ten plots fell within the estimated Rock House Fire boundary (Sirotnak and Bennett 2011) on the western edge of the historic site. ANOSIM was run on the data summed across height layers and on each height layer individually. Results indicate no fire effects were discernible on vegetation similarity between burned and unburned sites ($P \leq 7\%$, $R = 0.24$).

3.1.3 Plant Species Detectability

Overall, we recorded 68 species on the ten monitoring plots (Figure 3-1). We detected 46 species (32 native perennial species and 14 genera) on the line-point intercept transects and an additional 22 species (18 native perennial species and 4 genera) in the frequency subplots.

3.2 Vegetation

Because the ten sites were not differentiated based on our initial or post stratifications, nor strongly differentiated based on other analyses (Section 3.1), we pooled the data from the ten plots and analyzed the data as if we had a single stratum.

3.2.1 Cover and Frequency of Exotic Species

No non-native plant species were recorded at Fort Davis NHS during this sampling effort.

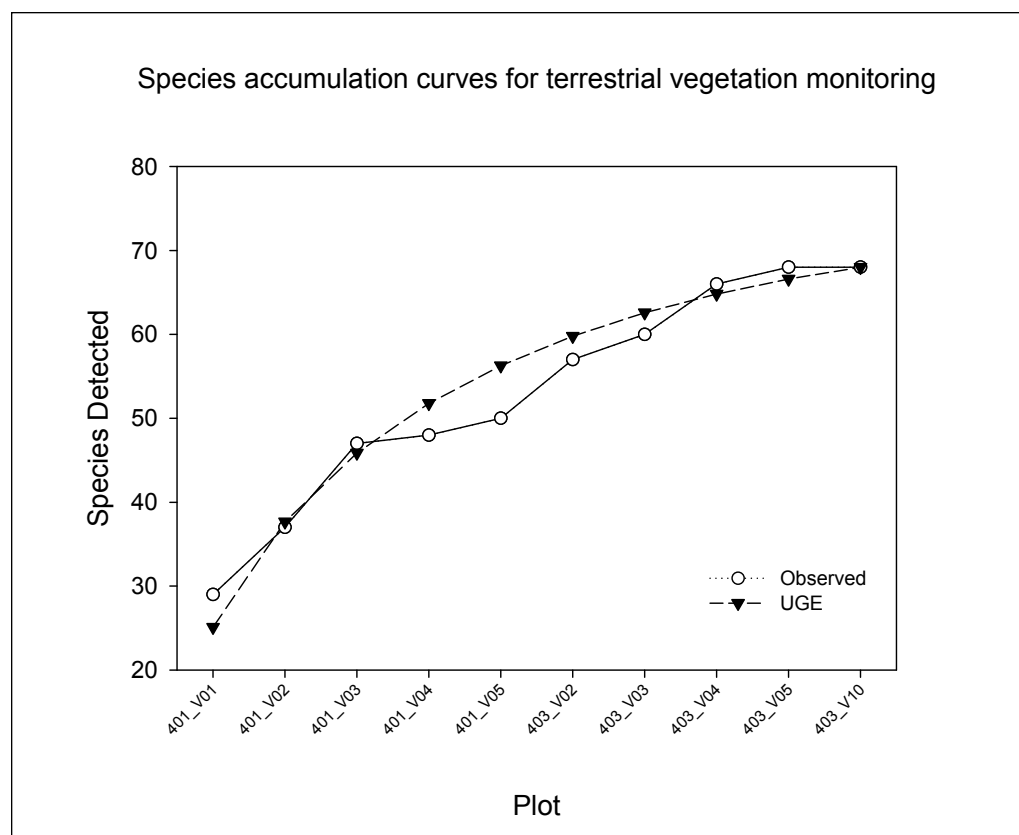


Figure 3-1. Species area curve for cover and frequency data collected on terrestrial vegetation and soils plots at Fort Davis NHS in 2011. Curves show cumulative numbers of species detected as plots are added. UGE=mean species accumulation curve with samples entered in random order (Ugland et al. 2003).

Table 3-1. Parkwide averages (%) for species measured in the “field” (<0.5 m stature), “subcanopy” (0.5-2 m stature), and “canopy” (>2 m stature) layers on line-point intercept transects at Fort Davis NHS, 2011. No species or lifeforms failed to meet our statistical power criteria. No non-native species were recorded.

Species	Primary Growth Habit	Field (0-0.5 m) Parkwide Averages				Subcanopy (0.5-2 m) Parkwide Averages				Canopy (>2 m) Parkwide Averages			
		AVG	SE	MDC	n	AVG	SE	MDC	n	AVG	SE	MDC	n
<i>Asclepias latifolia</i>	Forb/Herb	0.0%	0.0%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Boerhavia</i> sp.	Forb/Herb	0.5%	0.3%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Commelina</i> sp.	Forb/Herb	0.1%	0.1%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Croton pottsii</i>	Forb/Herb	0.3%	0.2%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Croton</i> sp.	Forb/Herb	0.1%	0.1%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Dalea</i> sp.	Forb/Herb	0.1%	0.1%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Euphorbia</i> sp.	Forb/Herb	0.7%	0.3%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Evolvulus</i> sp.	Forb/Herb	0.1%	0.1%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Menodora</i> sp.	Forb/Herb	0.0%	0.0%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
Annual Grass	Graminoid	2.2%	1.0%	5%	2	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Aristida</i> sp.	Graminoid	1.5%	0.7%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0

Table 3-1. Parkwide averages (continued).

Species	Primary Growth Habit	Field (0-0.5 m) Parkwide Averages				Subcanopy (0.5-2 m) Parkwide Averages				Canopy (>2 m) Parkwide Averages			
		AVG	SE	MDC	n	AVG	SE	MDC	n	AVG	SE	MDC	n
<i>Bothriochloa barbinodis</i>	Graminoid	0.1%	0.1%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Bouteloua curtipendula</i>	Graminoid	9.3%	2.3%	5%	10	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Bouteloua gracilis</i>	Graminoid	2.6%	2.0%	5%	7	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Bouteloua hirsuta</i>	Graminoid	0.0%	0.0%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Bouteloua</i> sp.	Graminoid	1.5%	0.9%	5%	2	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Digitaria californica</i>	Graminoid	0.1%	0.1%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Muhlenbergia tenuifolia</i>	Graminoid	0.3%	0.3%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Schizachyrium scoparium</i>	Graminoid	6.7%	1.5%	5%	4	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Scleropogon brevifolius</i>	Graminoid	0.3%	0.2%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Sporobolus cryptandrus</i>	Graminoid	0.7%	0.5%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Carphochaete bigelovii</i>	Subshrub	0.0%	0.0%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Nolina texana</i>	Subshrub	1.3%	0.5%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Senecio flaccidus</i>	Subshrub	0.0%	0.0%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Solanum elaeagnifolium</i>	Subshrub	0.2%	0.2%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Zinnia grandiflora</i>	Subshrub	0.0%	0.0%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Adolphia infesta</i>	Shrub	1.0%	0.8%	5%	1	0.4%	0.3%	5%	1	0.0%	0.0%	5%	0
<i>Aloysia gratissima</i>	Shrub	0.0%	0.0%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Baccharis pteronioides</i>	Shrub	0.4%	0.2%	5%	1	0.2%	0.2%	5%	1	0.0%	0.0%	5%	0
<i>Cylindropuntia imbricata</i>	Shrub	0.0%	0.0%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Dasyliion leiophyllum</i>	Shrub	1.9%	0.9%	5%	2	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Mahonia trifoliolata</i>	Shrub	0.0%	0.0%	5%	1	0.2%	0.2%	5%	1	0.0%	0.0%	5%	0
<i>Mimosa aculeaticarpa</i> var. <i>biuncifera</i>	Shrub	3.8%	1.3%	5%	3	2.5%	0.9%	5%	2	0.0%	0.0%	5%	0

Table 3-1. Parkwide averages (continued).

Species	Primary Growth Habit	Field (0-0.5 m) Parkwide Averages				Subcanopy (0.5-2 m) Parkwide Averages				Canopy (>2 m) Parkwide Averages			
		AVG	SE	MDC	n	AVG	SE	MDC	n	AVG	SE	MDC	n
<i>Parthenium incanum</i>	Shrub	0.4%	0.4%	5%	1	0.1%	0.1%	5%	1	0.0%	0.0%	5%	0
<i>Rhus microphylla</i>	Shrub	0.8%	0.6%	5%	1	1.2%	1.1%	5%	2	0.9%	0.9%	5%	2
<i>Rhus trilobata</i>	Shrub	0.3%	0.3%	5%	1	0.3%	0.3%	5%	1	0.0%	0.0%	5%	0
<i>Yucca</i> sp.	Shrub	0.2%	0.2%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Yucca elata</i>	Shrub	0.2%	0.1%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Echinocereus</i> sp.	Succulent	0.1%	0.1%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Opuntia engelmannii</i>	Succulent	1.3%	0.5%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Opuntia</i> sp.	Succulent	0.8%	0.5%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Acacia constricta</i>	Tree	0.2%	0.1%	5%	1	0.3%	0.2%	5%	1	0.1%	0.1%	5%	1
<i>Juniperus monosperma</i>	Tree	0.2%	0.1%	5%	1	0.5%	0.4%	5%	1	0.5%	0.3%	5%	1
<i>Prosopis glandulosa</i>	Tree	0.2%	0.1%	5%	1	0.3%	0.1%	5%	1	0.0%	0.0%	5%	1
<i>Quercus grisea</i>	Tree	0.2%	0.1%	5%	1	0.2%	0.1%	5%	1	0.3%	0.2%	5%	1
<i>Quercus</i> sp.	Tree	0.3%	0.2%	5%	1	1.1%	0.8%	5%	2	1.1%	0.8%	5%	2
Annual Vine	Vine	0.1%	0.1%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
<i>Ipomoea tenuiloba</i>	Vine	0.3%	0.1%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
	Annual Forb	1.7%	0.5%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
	Annual Grass	2.2%	1.0%	5%	2	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
	Perennial Forb	2.0%	0.8%	5%	2	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
	Perennial Grass	25.5%	4.8%	10%	10	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
	Subshrub	1.6%	0.5%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
	Shrub	9.0%	1.9%	6%	5	4.8%	1.6%	5%	5	0.9%	0.9%	5%	2
	Succulent	2.2%	0.8%	5%	2	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
	Tree	1.0%	0.4%	5%	1	2.3%	1.1%	5%	2	1.9%	0.9%	5%	2
	Snag	3.4%	0.7%	5%	1	1.4%	0.6%	5%	1	1.0%	0.6%	5%	1
	Vine	0.3%	0.1%	5%	1	0.0%	0.0%	5%	0	0.0%	0.0%	5%	0
	Total Cover	49.1%	7.1%	15%	10	8.5%	2.3%	5%	10	3.8%	1.5%	5%	4

AVG=average

SE=standard error

MDC=minimum detectable change

n=number of plots required to meet power criteria

3.2.2 Cover of Plant Lifeforms

Vegetative cover was always greatest in the field layer (<0.5 m height); half of the plots had cover between 22 and 36%, while the other half had a much higher cover of 53-88% (Appendix A, Table A1). Perennial grasses, shrubs, and succulents accounted for the majority of cover across sites, with annual lifeforms and perennial herbs mixed in (Table 3-1). Snags (dead woody species)

were an important component of the field layer contributing up to 8% cover.

Subcanopy vegetation (0.5-2.0 m) was dominated by shrubs and short-statured tree lifeforms (Figure 3-2). Tree species such as mesquite, juniper, and oak were each only encountered on the line intercept transects of two or three plots each, whereas catchlaw mimosa was recorded on eight of the ten plots (Appendix A, Table A2). Canopy (>2.0 m height) cover was low across all sites,

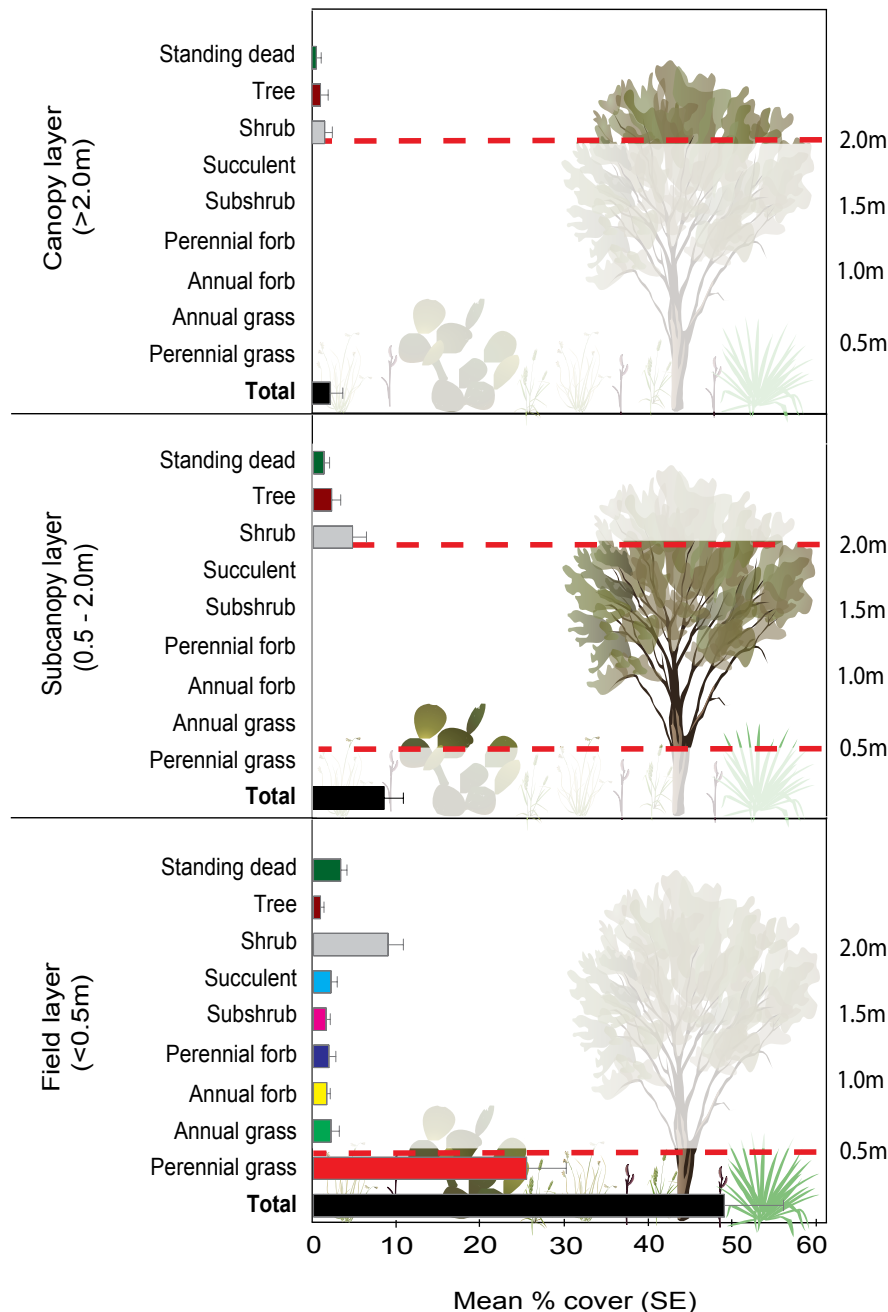


Figure 3-2. Lifeform cover of terrestrial vegetation on line-point intercept transects at Fort Davis NHS, 2011.

Minimum detectable change is the smallest amount of change that we can detect and be confident that it is not due to variation in our measurements.

averaging 3.8% and was composed of only five species (Appendix A, Table A3). Vines were nearly absent on all sites. No species new to the park were detected during sampling.

Changes in lifeform abundance exceeded our desired criteria to detect a 10% absolute change in foliar cover with 90% power and 10% chance of a false change error. All lifeforms found in each height category had a minimum detectable change (MDC) of 5%, except for perennial grasses in the field layer, which had a higher, but still acceptable 10% MDC (Table 3-1).

3.2.3 Cover and Frequency of Perennial Plant Species

The grama grass complex (*Bouteloua* spp.) dominated all plots at the park with *Bouteloua curtipendula* (side-oats grama) occurring on every plot and *Bouteloua gracilis* (blue grama) occurring on six of the ten plots (60% landscape frequency; Table 3-2). *Schizachyrium scoparium* was also widely distributed with 1-15% cover

on nine of the ten sites. Individuals of the genera *Boerhavia* (spiderling) and *Evolvulus* (morning glory) were well represented in the field layer at 70% park-wide frequency. Several field and subcanopy species had relatively low foliar cover but high frequency (presence as measured in the sub-plots) each occurring in at least six of the plots: *Nolina texana* (Texas sacahuista), *Croton pottsii* (leatherweed), *Solanum elaeagnifolium* (silverleaf nightshade), *Cylindropuntia imbricata* (tree cholla), *Dasyllirion leiophyllum* (sotol), and *Rhus microphylla* (littleleaf sumac) (Table 3-2).

Canopy cover was sparse, but dominated by *Juniperus monosperma* (one-seed juniper), mesquite, and *Quercus grisea* (Gray oak). These same species also had a moderate presence in the subcanopy stratum.

Mimosa aculeaticarpa var. *biuncifera* (catclaw mimosa) dominated the subcanopy parkwide (and the field layer to a lesser extent) and served to characterize the majority of the plots as mimosa shrublands and steppe communities. Catclaw mimosa

Table 3-2. Ubiquitous native species (% frequency encountered in plots) observed in monitoring plots at Fort Davis NHS, 2011. Highlighted species were recorded in every plot.

Species	Common Name	Life Form	Landscape Frequency
<i>Boerhavia</i> sp.	spiderling	Forb/Herb	70%
<i>Evolvulus</i> sp.	morning glory	Forb/Herb	70%
<i>Aristida</i> sp.	three-awn	Graminoid	60%
<i>Bouteloua curtipendula</i>	side-oats grama	Graminoid	100%
<i>Bouteloua gracilis</i>	blue grama	Graminoid	60%
<i>Schizachyrium scoparium</i>	little bluestem	Graminoid	90%
<i>Croton pottsii</i>	leatherweed	Subshrub	70%
<i>Nolina texana</i>	Texas sacahuista	Subshrub	80%
<i>Solanum elaeagnifolium</i>	silverleaf nightshade	Subshrub	70%
<i>Cylindropuntia imbricata</i>	tree cholla	Shrub	90%
<i>Dasyllirion leiophyllum</i>	sotol	Shrub	70%
<i>Mimosa aculeaticarpa</i> var. <i>biuncifera</i>	catclaw mimosa	Shrub	100%
<i>Rhus microphylla</i>	littleleaf sumac	Shrub	60%
<i>Opuntia engelmannii</i>	cactus apple	Succulent	100%
<i>Acacia constricta</i>	whitethorn acacia	Tree	50%
<i>Juniperus monosperma</i>	one-seed juniper	Tree	40%
<i>Prosopis glandulosa</i>	honey mesquite	Tree	80%
<i>Quercus grisea</i>	gray oak	Tree	50%

had a mean within-plot frequency of 84% and a park-wide landscape frequency of 100%, evidencing its wide distribution and abundance. The three plots in which mimosa had very low cover were the same sites that had increased mesquite cover and a complex of other shrub species not seen elsewhere. Texas sacahuista and sotol were common across the park and are characteristic shrub species for the Chihuahuan Desert region.

All species observed exceeded our design criteria for change detection in vegetation cover (detect a 10% absolute change in foliar cover with 90% power and 10% chance of a false change error) with an estimated 5% minimum detectable change. Our design met our sampling objectives for detecting trends in frequency of for about one-third of the perennial species observed (detect at least a 10% change in within-plot frequency with 90% power and 10% chance of false change error). For the 22 species found only in the frequency subplots, however, our design met or exceeded our sampling objectives for nearly 60% of the species (Appendix A, Table A8). For species detected on both the transects and subplots, the line-point intercept transects provide better statistical power than do the frequency subplots (Appendix A, Tables A1-A3).

3.2.4 Patterns of Vegetation Similarity

Although the strata were not effective at partitioning the variance among the plots based on elevation and soil rock fragment content, we ran cluster analysis and non-metric multidimensional scaling (MDS) on the vegetation cover data to explore the similarities and differences in species composition between the plots. The ten sites significantly differed and separated into three groups ($P \leq 3\%$, $R=0.85$), each having at least 40% within-group similarity, when all height classes of vegetation were considered together (Figure 3-3). We used similarity of percentage contributions analysis (SIMPER) to determine which species contributed the most to differentiating plots into the three groups. In general, different abundances of shared species rather than different species compositions drove the separation of the plots into three groups, with some exceptions notes below. Canopy data for all sites had no significant differences and

was typically sparse, with an average of 3.8% cover. *Juniper monosperma* (one-seed juniper) and *Quercus* spp. (oaks) dominated the cover in the canopy height category (see Appendix A, Table A3 and Appendix C).

The first group, “Mimosa shrubland and steppe,” contains 7 plots (Figure 3-3) and is characterized by the consistent presence and abundance of *Mimosa aculeaticarpa* var. *biuncifera* (catclaw mimosa), *Schizachyrium scoparium* (little bluestem), *Bouteloua curtipendula* (side-oats grama), and *Dasylirion leiophyllum* (sotol) in the height categories less than 2 m (see Appendix A, Tables A1 and A2 and Appendix C). Perennial grass cover in these plots was lower overall (between 8-32%) than the “semi-desert grassland” group and the shrub *Adolphia infesta* (junco) is absent.

The second group, “Semi-desert grassland,” contained only two plots, 403_002 and 403_005, and had shrub species that were not recorded on the line-intercept transects on the other plots. In particular, the presence of *Adolphia infesta* (junco) drove much of the differentiation. Additionally, *Rhus microphylla* (littleleaf sumac), *Rhus trilobata* (three-leaf sumac), *Acacia constricta* (whitethorn acacia), *Baccharis pteronoides* (yerba de pasmo), *Juniper monosperma*, and *Quercus* spp. (oaks) together strongly characterize these plots. Perennial grass cover in the field layer (<0.5 m) was 46% for plot 403_002 and 55% for plot 403_005, the highest of all plots sampled. Grama grasses, such as *Bouteloua gracilis* (blue grama), *B. curtipendula* (sideoats grama), and *Bouteloua* spp. dominated the perennial grasses community on these plots. Total cover for the field layer (<0.5 m) was also highest in this group, with a predominance of shrubs, sub-shrubs and succulents (*Opuntia* spp.) in addition to the bunch grasses. Snags (dead woody material) were not recorded in the subcanopy (0.5-2 m) of these plots.

Plot 401_003 formed its own group, “Mesquite–herbaceous type.” This plot was different from the other nine because it had more mesquite in the field and subcanopy layers than all other plots, and it lacked several of the dominant species found in the other groups, such as sotol, little bluestem, blue grama, and junco. It had the lowest

Fort Davis NHS All Height Categories Summed

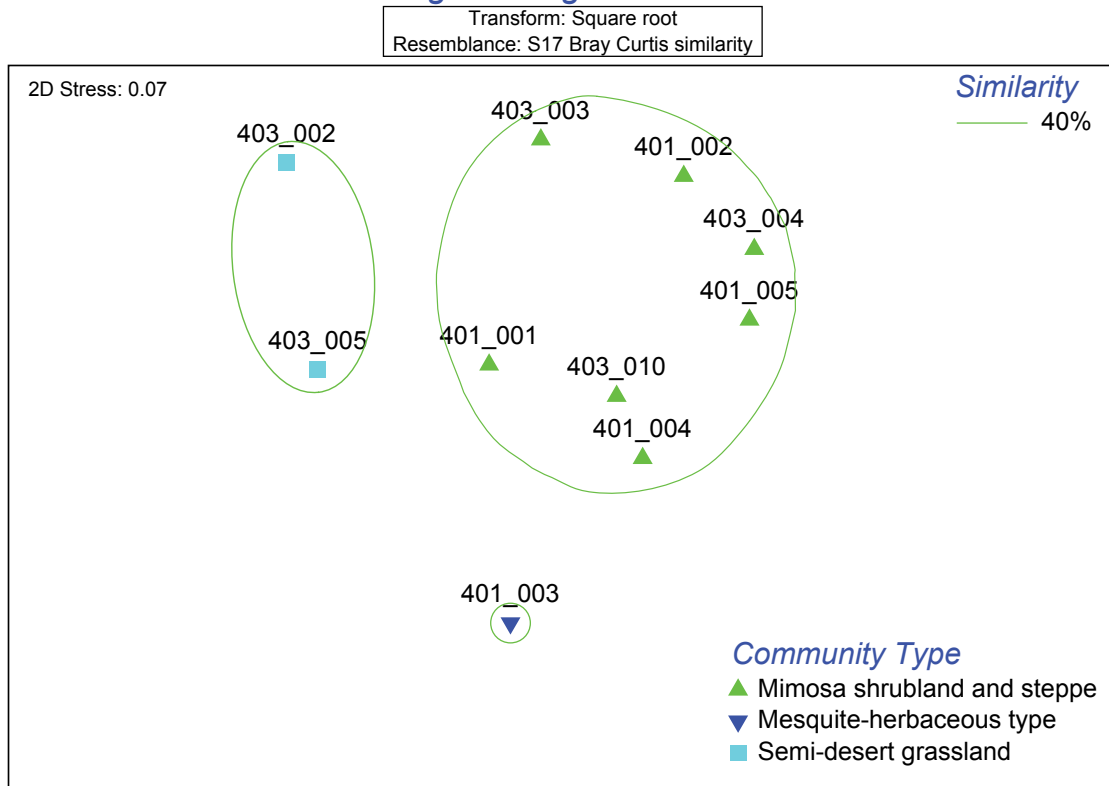


Figure 3-3. Results of the non-metric multi-dimensional scaling (MDS) for ten plots at Fort Davis NHS. Complementary cluster analysis shown as green lines. The three groups derived from the summed data were differentiated at ~40% within-group similarity.

Table 3-3. Groupings of plots by community type based on the results of cluster and similarity of percentage contribution analyses. Species listed in the field (<0.5 m), subcanopy (0.5-2 m), and canopy (>2 m) height categories are those that best differentiate and characterize the groups.

Plot	Community Type	Height Category	Species
401_003	Mesquite-herbaceous type	Field	<i>Bouteloua curtipendula</i> , <i>Muhlenbergia tenuifolia</i>
		Subcanopy	<i>Prosopis glandulosa</i>
		Canopy	None
403_002 403_005	Semi-desert grassland	Field	<i>Bouteloua curtipendula</i> , <i>Adolphia infesta</i> , <i>Schizachyrium scoparium</i> , <i>Bouteloua gracilis</i>
		Subcanopy	<i>Adolphia infesta</i> , <i>Rhus microphylla</i> , <i>Yucca elata</i> , <i>Prosopis glandulosa</i>
		Canopy	Sparse <i>Prosopis glandulosa</i> in 403_002
401_001 401_002 401_004 401_005 403_003 403_004 403_010	Mimosa shrubland and steppe	Field	<i>Mimosa aculeaticarpa</i> var. <i>biuncifera</i> , <i>Schizachyrium scoparium</i> , <i>Bouteloua curtipendula</i>
		Subcanopy	<i>Dasyliroia leiophyllum</i> , <i>Mimosa aculeaticarpa</i> var. <i>biuncifera</i>
		Canopy	Sparse <i>Juniper monosperma</i> and <i>Quercus</i> spp.

amount of cover in the subcanopy height category (0.5-2 m) cover of any plot, with less than 1% contributed from a single species, mesquite. In contrast, plot 401_003 had moderate cover in the field layer (<0.5 m), totaling 31%, that was dominated by the perennial grasses side-oats grama (*Bouteloua curtipendula*) and slender muhly (*Muhlenbergia tenuifolia*), and smaller amounts of Texas sacahuista (*Nolina texana*), mesquite and annual forbs and grasses.

3.3 Soils

3.3.1 Soil Stability

All sites had an average surface soil stability rating of at least “3” (“somewhat stable,” Table 3-4) except for plots 401_001, 40_004, and 403_005, which were just under “3.” Stability samples were not collected at plot 403_004, because of a very high cover of exposed bedrock. On average, samples collected under vegetation tended to have higher stability values than those collected in open spaces (Table 3-4), although this was not seen on all plots. Plot-specific information is given in Appendix A, Table A6.

Our design exceeded our sampling objectives for all surface soil aggregate stability class parameters (detect at least a change of one stability class, with 90% power and 10% chance of false change error) at the proposed sampling intensity (Table 3-4). Average soil stability estimates always exceeded our criteria regardless of vegetative cover (Table 3-4). Plot-level data are given in Appendix A, Table A6.

3.3.2 Soil Cover

Soil cover was dominated by gravel, rock, and bedrock. At least 50% of soil surface was covered by gravel, rock, or bedrock on all plots except plot 403_002. On average, approximately 9% of the soil surface was bare soil without vegetative cover, and an additional 9% was bare soil under vegetation (Table 3-5). Litter, woody debris, and duff covered 6-25% of the soil surface. Plant bases averaged approximately 11% cover of the soil surface and plant base cover ranged from 1% to 35% on individual plots. Plot-specific information is given in Appendix A, Table A7.

Our design met or exceeded our sampling objectives for nearly all soil cover categories (detect at least a 10% change, with 90% power and 10% chance of false change error) at the proposed sampling intensity (Table 3-5). The exceptions to meeting our sampling objectives for substrate cover were gravel cover and bedrock cover. We estimate that we can detect a 12% change in gravel cover and a 14% change in bedrock cover with 90% power and 10% change of false change error (Table 3-5). Plot-level data are given in Appendix A, Table A7.

3.3.3 Biological Soil Crust Cover and Frequency

Biological soil crust cover was measured using two techniques—as part of the soil cover measurements on the line-point intercept transects and in point-quadrats placed adjacent to the transects. Along the line-point intercept transects, biological soil crusts (light cyanobacteria, dark

Table 3-4. Parkwide averages of soil surface aggregate stability class, Fort Davis NHS, 2011.

Surface Soil Stability	AVG	SE	MDC	n
All Samples	3.53	0.30	0.60	10
Samples under vegetation	3.60	0.30	0.60	10
Samples not under vegetation	3.37	0.30	0.60	10

AVG=average

SE=standard error

MDC=minimum detectable change (expressed in stability class rating)

n=number of plots required to meet power criteria

Table 3-5. Soil cover (% by class), on line-point intercept transects, Fort Davis NHS, 2011. Highlighted group failed to meet our 10% change criteria.

Substrate	AVG	SE	MDC	n
Bare soil (<2 mm) - no overhead cover	9%	3%	7%	9
Bare soil (<2 mm) - under vegetation	9%	2%	5%	5
Total bare soil	18.3%	5%	10%	9
Light Cyanobacteria - no overhead cover	0%	0%	5%	0
Light Cyanobacteria - under vegetation	0%	0%	5%	0
Total light cyanobacteria	0%	0%	5%	0
Dark Cyanobacteria	0%	0%	5%	1
Litter and Woody Debris	13%	2%	5%	7
Gravel (2-75 mm)	25%	6%	12%	10
Duff	0%	0%	5%	0
Lichen	0%	0%	5%	1
Moss	2%	2%	5%	7
Rock (76-600 mm)	12%	2%	5%	6
Plant base	11%	4%	10%	6
Bedrock	18%	6%	14%	10
Fuels				
1-hr fuel (<0.062 cm)	1%	0%	5%	1
10-hr fuel (0.62-2.5 cm)	0%	0%	5%	1
100-hr fuel (2.51-7.62 cm)	0%	0%	5%	1
Total fine woody debris (FWD)	1%	1%	5%	1
1,000-hr fuel (>7.62 cm)	0%	0%	5%	1
Total coarse woody debris (CWD)	0%	0%	5%	1
Average CWD diameter (cm)	---	---	---	---

AVG=average

SE=standard error

MDC=minimum detectable change

n=number of plots required to meet power criteria

cyanobacteria, lichen, and moss) accounted for approximately 3% of the soil substrate cover (Table 3-5); however, biological soil crusts were only recorded on the intercept transects on two plots (401_002 and 403_004). Mosses (bryophytes) were the only crust morphological group encountered on the transects. Plot-specific information for biological soil crust cover along the line-point intercept transects is given in Appendix A, Table A7.

Within the point-quadrats, bryophytes (mosses) and selaginella dominated the biological soil crust community, covering approximately 2.5% of the soil surface within the quadrats (Table 3-6). All morphological groups were encountered in the point-quadrats, but lichen and cyanobacteria cover was sparse. Plot-specific information

for biological soil crust cover recorded in the point-quadrats is given in Appendix A, Table A8.

Although bryophytes accounted for the most cover within the point-quadrats, they were only found in three plots. In contrast, gelatinous lichens were ubiquitous in the point-quadrats, but their distribution within a plot was highly variable (Table 3-6). Plot-specific information for biological soil crust frequency in the quadrats is given in Appendix A, Table A9.

Soil cover of biological soil crusts by morphological group and lichen growth form consistently outperformed our statistical power criteria; we estimate that we will be able to detect at least a 5% change in all morphological groups and lichen

Table 3-6. Biological soil crust cover, within-plot frequency, and landscape frequency by lichen growth form and morphological group, in point-quadrats, Fort Davis NHS, 2011. Highlighted groups failed to meet our 10% change criteria.

Morphological Group or Growth Form	Cover				Frequency				
	AVG (%)	SE (%)	MDC	n	Within-Plot Freq		Landscape Freq. (%)	MDC	n
Light cyanobacteria soil crust	0.4%	0.3%	5%	1	6%	4%	30%	8%	10
Dark cyanobacteria soil crust	0.03%	0.03%	5%	1	1%	1%	10%	5%	1
Crustose lichen	0.03%	0.03%	5%	1	1%	1%	10%	5%	3
Gelatinous lichen	0.0%	0.0%	5%	0	25%	5%	90%	11%	10
Squamulose lichen	0.1%	0.1%	5%	1	1%	1%	10%	5%	3
Foliose lichen	0.0%	0.0%	5%	0	0%	0%	0%	5%	0
Fruticose lichen	0.0%	0.0%	5%	0	0%	0%	0%	5%	0
Moss	0.04%	0.04%	5%	1	2%	2%	10%	5%	9
Selaginella	2.4%	1.5%	5%	5	11%	7%	30%	15%	10
Totals by Morphological Group									
Cyanobacteria-dominated soil crust	0.5%	0.3%	5%	1	7%	4%	40%	8%	10
Lichen-dominated soil crust	0.2%	0.2%	5%	1	2%	2%	10%	5%	5
Moss-dominated soil crust	2.5%	1.6%	5%	5	11%	7%	30%	15%	10
Dark cyanobacteria + Lichen + Moss	2.6%	1.5%	5%	4	12%	7%	40%	15%	10

AVG=average

SE=standard error

MDC=minimum detectable change

n=number of plots required to meet power criteria

growth forms (Table 3-6). Plot-specific data are given in Appendix A, Table A8. As is the case for vegetation data, crust frequency was not as efficient as cover, as we failed to meet our power objectives for detecting changes in the frequencies of gelatinous lichens and selaginella (Table 3-6). Plot-specific data are given in Appendix A, Table A9.

3.3.4 Soil and Site Characterization

Surface soil samples consisted of sandy loams or loams with at least 10% rock fragments (fraction of soil sample >2 mm in diameter by volume). Soil samples were not collected at two plots (403_003 and 403_004) because the plots were dominated by bedrock. Our results do not track with the county-level soil survey and suggest that the stratification based on rock fragment

was not accurate (as described in Section 3.1.1). The plots tended to have relatively low organic contents (<3% total organic carbon), but plot 403_002 had 5% organic content. Bulk density ranged from 0.8 to 1.5 grams/cm³. Plot-specific information for the soil characterization is given in Appendix A, Table A10.

Six of eight plots for which landscape characteristics were described showed signs of erosion. Rills were observed on four sites and gullies were observed on two plots (403_003 and 403_004). Small amounts of burrowing were observed on one plot. Signs of tunneling were rare, occurring on a single site. Only one plot showed modest amounts (1-5%) of sheet erosion. Plots 401_001 and 403_010 had the most evidence of erosion among the eight plots

described. Plot-specific information for the site characterization is given in Appendix A, Table A10.

3.4 Management Assessment Points

Averaged across the park, no management assessment points were reached and most indicators did not approach the management assessment points. However, individual plots did reach some of the management assessment points. Six plots had percent cover of perennial grass values (< 25%) that suggested some potential site-specific issues (Appendix A, Table A11). These sites also had relatively lower shrub cover than those that exceed the 25% perennial grass cover, indicating that these plots have an overall more open, sparse vegetation pattern, and are likely within their normal range for these lifeforms. In addition, three plots had average

soil aggregate stability values of less than 3 indicating that these plots may be susceptible to erosion. See Appendix A, Table A11 for plot-specific data in the context of proposed management assessment points. Our design permitted us to detect a 10% difference from the management assessment point for all parameters (minimum detectable change (MDC) ≤ 10%), and a 0.6 difference in surface soil aggregate stability (index ranging from 1-6, MDC=0.6), with 90% power and a 10% chance of a false change error (Table 3-7). With the exception of foliar cover of perennial grass cover in the field layer (10%), all other native vegetation-related management assessment points would allow for a minimum detectable change of 7% or better. Management assessment points for exotic plant extent and proportion of exotic plant cover could not be assessed as no exotic plants were detected within any of the ten plots.

Table 3-7. Terrestrial vegetation and soils monitoring data in the context of proposed management assessment points, Fort Davis NHS.

Issue	Management Assessment Point	Parkwide AVG	SE	MDC	n	Point Met?	Recommendation:
Site Stability and Erosion Hazard	Exposed bare ground cover is >30%	9%	3%	7%	9	No	Continue monitoring
	Average stability of surface soil aggregates <3	3.53	0.30	0.60	10	No	Continue monitoring
	Foliar cover of perennial grasses in field layer is <25%	25.5%	4.8%	10%	10	No	Highly variable among plots—meet and consider
	Proportion of total foliar grass cover (%) composed of annuals in field layer is >33%	8.9%	3.0%	7%	8	No	Continue monitoring
Shrub Encroachment	Shrub foliar cover in field is >35%	9.0%	1.9%	6%	5	No	Continue monitoring
	Shrub foliar cover in sub-canopy layer(s) is >35%	4.8%	1.6%	5%	5	No	Continue monitoring
Mesquite Invasion	Mesquite (<i>Prosopis</i> spp.) foliar cover in the field layer is >15%	0.2%	0.1%	5%	1	No	Continue monitoring
	Mesquite (<i>Prosopis</i> spp.) foliar cover in sub-canopy and canopy layers combined is >20%	0.29%	0.2%	5%	1	No	Continue monitoring
Exotic Plant Dispersal	Extent (plot frequency) of invasive exotic plants is >20%	n/a	n/a	n/a	n/a	No	Continue monitoring
Exotic Plant Invasion	Proportion of foliar plant cover (%) contributed from exotic plants is >10%	n/a	n/a	n/a	n/a	No	Continue monitoring

AVG=average

SE=standard error

MDC=minimum detectable change

n=number of plots required to meet power criteria

4 Discussion

4.1 Vegetation Communities

Despite a relatively small size, Fort Davis NHS supports 22 different associations of plants (Muldavin et al. 2012). These plant associations are typical of the broadly defined desert grassland/shrub-steppe borderlands of New Mexico, Texas, and northern Mexico (Apacherian-Chihuahuan region) and the desert scrub groups of the Chihuahuan Desert (NatureServe 2012 via usnvc.org). Many of the plots exhibit characteristics of both regions, having rich and diverse perennial grass, shrub, and succulent cover. Topographic and edaphic variation drive the majority of these differences across these species' ranges with the colluvial slopes, ridges, and upper bajadas supporting scrub communities, and lower slopes and flatlands containing the semi-desert grasslands and steppe communities.

Although the ten CHDN monitoring plots have species compositions and abundances that resemble many of the associations described by Muldavin and others (2012), they do not directly link to particular vegetation mapping classes, perhaps due to both thematic and spatial scale differences between vegetation mapping and monitoring. Rather, the monitoring plots collectively exemplify local vegetation and provide insights into landscape variability and condition within the park.

Plot 401_003 is located in the western flatlands and is distinguished by its lower overall cover composed of a mix of forbs and grasses, and low cover of shrubs, representing an herbaceous-dominated vegetation type. Total perennial grass cover of 46% for plot 403_002 and 55% for plot 403_005, combined with approximately 15% cover of shrub and subshrubs indicate a composition typical of shrub steppe communities or the ecotone between shrubland and semi-desert grasslands. A diverse mix of shrubs (littleleaf sumac, three-leaf sumac, whitethorn acacia, yerba de pasmo, juniper, and oak) also characterizes plots 403_002 and 403_005 and sets these two sites apart as shrubland-grassland interfaces (Figure 4-1). These

three plots are strongly differentiated by the higher abundance of honey mesquite and low cover of catclaw mimosa.

The other plots appear more representative of desert shrublands or “sotol grasslands,” having a greater diversity of shrub lifeforms intermixed with moderate to high grass cover. These plots are dominated by *Mimosa aculeaticarpa* var. *buincifera* (catclaw mimosa) with commonly occurring *Dasyllirion leiophyllum* (sotol) and are representative of the Chihuahuan Creosotebush Mixed Desert Scrub Group of associations identified during the vegetation mapping inventory (Muldavin et al. 2012). Of these, plot 403_003 has considerably more catclaw mimosa and other shrub cover (~37%) and overall tree cover (15%) than any other site. This plot lies atop the ridge of the Sleeping Lion Mountain and represents the foothill desert microphyllus shrubland type (Muldavin et al. 2012) found here and on the southern face of the North Ridge (Figure 4-2).



Figure 4-1. Photograph taken at plot 403_005 looking into the site from the southeast corner. Note the diverse mix of shrub species intermixed with perennial bunch grasses.



Figure 4-2. Photograph of plot 403_003 looking north along the first transect. *Mimosa aculeaticarpa* var. *buincifera* dominates throughout.

4.2 Shrub Encroachment and Brush Density

The data indicate that the vegetation of Fort Davis NHS currently represents a transition between desert scrub and semiarid grassland and steppe biomes. Previous studies aimed at evaluating vegetative change at the historic site (Nelson 1981, Haynie 2000) expressed specific concerns about shrub encroachment into grasslands and associated loss of semi-desert grassland. Nelson (1981) estimated an increase of approximately 40% in brush cover from light to medium density between 1880 and the 1980s, but did not indicate substantial boundary expansions for these existing shrubland areas. This increase was predominantly seen along the hills and ridges of North Mountain. Nelson also noted a departure from historical grass composition in the grassland to the east, specifically an increase in *Bouteloua gracilis* (blue grama) dominance. Haynie (2000) suggested that the mixed-desert scrub and chaparral communities had expanded. Muldavin and others (2012) also remarked on the vulnerability of semi-desert grasslands to invasions and point out that Fort Davis, while small, is part of a limited network of southwestern reserves that support semi-desert grasslands.

Our data suggest that vegetation at Fort Davis NHS is currently fairly stable, consisting of semi-desert grasslands and shrub savannas, but that brush encroachment could become an issue in future. All plots had the greatest

overall cover in the field layer, and with the exception of three “true” shrubland sites, all others have twice to three times as much native perennial grass and forb cover as they do shrub and succulent cover. Still, mesquite is present in all but two plots and has an average within-plot frequency of 36%. Although the within-plot frequency is low, the park-wide extent of mesquite is high and indicates this species is well distributed.

Mesquite tends to have a long life span and low post-establishment mortality rates (Brown and Archer 1999). Therefore, we set our management assessment point for cover in the field layer at 15%. Additional management assessment points can be established based on within-plot and landscape-level frequency for this species should park staff decide mesquite is a priority for management action.

The other shrub noted by Nelson (1981) as having “increased from light to heavy concentrations” is catclaw mimosa. Our data support his observations of broad distribution of this species. Based on our sampling effort, catclaw mimosa was found in every plot and had high within-plot frequency (average within-plot frequency $84\% \pm 8\%$). While far from singularly dominant, catclaw mimosa is a well-established common associate in terrestrial vegetation at Fort Davis NHS.

4.3 Invasive Exotic Plants

Exotic plant encroachment typically occurs in two phases (1) colonization, the process by which a problematic species gradually disperses into suitable habitats, recruits into the system, and competes for resources with other members of the plant community; and (2) via asymmetrical competition (often mediated through disturbance), in which the new species becomes 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), but can also occur after many years of a species being in

a relatively stable non-invasive status. Which phase—“colonization” or “domination”—has occurred can have great implications for successful management strategies and effective monitoring designs.

Based on the results of the CHDN exotic plant early detection work conducted in 2011 and 2012, it is possible that non-native species occur on some of the upland monitoring sites, but went undetected during the 2011 sampling period. This speculation is based on the proximity of some plots to three exotics early-detection transects: the Old El Paso-San Antonio Road, Tall Grass Trail (both sections), and the North Ridge Trail, all of which had several non-native species observed (Reiser et al. 2012). However, our data indicate that even though several exotic species occur at Fort Davis NHS, none have as of yet completed colonization of the interior upland areas of the site. Unlike many other southwestern grassland systems that have been invaded by African grasses such as *Eragrostis lehmanniana* (Lehmann’s lovegrass) or *Bromus* spp. (e.g., cheatgrass or red brome), Fort Davis NHS currently has a distinct lack of non-native grass species, indicating a stable and presumably resilient system. Continued protection from disturbance and continued vigilance and monitoring for new exotic species occurrences are encouraged to help prevent future infestations.

4.4 Site and Soil Stability

Our data on the dynamic factors of water erosion (soil cover and soil aggregate stability) indicate that the sites are fairly stable. In general, the sites did not show substantial evidence of disturbance. Five plots (401_001, 401_005, 403_003, 403_004, and 403_010), however, contained rills or gullies—signs of water erosion. Overall, the soil aggregate stability of the sites is moderate, but three plots had an average stability value of less than three. This indicates that the sites generally can resist raindrop and surface flow erosion. Total cover of the sites is very high with little exposed bare soil (bare soil without vegetative cover averaged less than 10%). Litter and woody debris cover ranges from 6% to 25%. Gravel, rocks, and bedrock dominate and protect the soil surface.

4.5 Issues with Stratification

Stratification for this protocol is aimed at partitioning the inherent variation of vegetation based on ecological processes derived from elevation constraints and soil properties. Soil rock fragment content in the surface layer is used as a proxy for soil development and correlates to the potential for nutrient delivery and water-holding capacity. The county-level soil survey we used to develop the strata was not completed at an adequate scale for our stratification—being too coarse to apply effectively at the small extent (516 acres) of the historic site. Additionally, the soil survey did not have soil texture data for the dominant component of the Mainstay-Brewster association, which covers a substantial portion of our upland sampling frame. However, the county-level survey was the best information available and was used to stratify the site (Hubbard et al. 2012).

Our soil cover monitoring data from the ten plots do not suggest large differences between plots in terms of soil surface cover of rock-fragment cover (gravel, rock, and bedrock combined). This lack of differentiation in soils (a proxy for soil water-holding capacity) was also reflected in the vegetation similarity data, as we would expect. We combined the ten plots into a single stratum because the variation in park soils and elevation was relatively low. This ultimately serves to increase our power to detect change at Fort Davis NHS. In the future, we may be able reduce our sampling intensity and still meet our monitoring objectives. Although we do not have any major concerns that soil strata need further evaluation, we will continue to collect data for all ten plots sampled in 2011 and will reanalyze the strata in our next report.

4.6 Potential Problems with Plant Identification and Taxonomic Resolution

Based on review of other vegetation studies (Haynie 2000, Yarborough 2004, Muldavin et al. 2012, Worthington 2002), it is clear that this current effort did not capture some of the more common species that occur throughout the NHS. For example, no ferns were recorded during the 2011 sampling

season, and while it is possible that none occurred on these sites by chance, it is also possible that some were consumed by fire or missed due to desiccation because of the drought (difficult to detect) or simply missed due to observer error. Many fern species are found growing under rocky outcrops and are small and therefore easily missed. It is expected that future sampling will capture these species, especially if rebounding from fire disturbance or after a particularly wet season.

Other common species that were not recorded were *Bouteloua eriopoda* (black grama) and *Eragrostis intermedia* (plains lovegrass), both reported as occurring throughout the more herbaceous dominated areas of the NHS (Muldavin et al. 2012). Field crews did record *Bouteloua* sp. and *Aristida* sp. on six of the plots; genera were reported due to the inability to discern these individuals to the species level. These and other taxonomic identification problems (several shrub species were also only resolved to the genus level) will be rectified during the next sampling period in 2016.

In addition to difficulties of field identification, which was in part due to crew inexperience in this area, several “unknown” plant species collections were unable to be rectified due to the lack of flowers or other diagnostic features, or poor specimen preservation. These records were resolved to the finest taxonomic level possible which in a few cases was too coarse to include in this data analysis (e.g., “grass”). For this reason, we recognize that this initial sampling at Fort Davis likely underrepresented the floristic diversity of these plots (the work of Haynie completed in 2000, identified 227 species within 57 different families). Coupled with the (assumed) temporary loss of some species to the Rock House Fire, we anticipate a substantial “increase” in plant species diversity in future sampling that will be due to improved sampling rather than colonization by species new to the park.

4.7 Implications for Terrestrial Vegetation and Soils Monitoring

Because this effort entailed some of the first terrestrial vegetation and soils monitoring

in the Chihuahuan Desert Network, much of our focus was on evaluating the efficacy of the sampling and response designs to support improvement of the protocol. We found the plot sampling design to be efficient. Most plots were sampled within two to four hours, including tasks that will not need to be repeated in successive visits (i.e., initial plot layout, permanent marking and mapping, and collection of *in situ* soil and landscape parameters). Hiking access within the park is good and probably the greatest overall cost is in travel time for crews to reach the site from Las Cruces, New Mexico.

In this report, we combined the ten plots into a single stratum because the variation in park soils and elevation was relatively low. Although, in the future we may be able reduce our sampling intensity and still meet our monitoring objectives, we will continue to collect data for all ten plots sampled in 2011 until we are confident that the lack of differentiation between strata is not due to sampling issues.

As described in Section 4.6, we had problems with taxonomic identification of several grasses and shrubs and with “unknown” plant identification. We have improved our training of uplands monitoring crews and these issues will be rectified during the next sampling period in 2016.

4.8 Are Terrestrial Vegetation and Soils Within the Range of Natural Variability?

Within the context of the network’s vital signs for species composition, community structure, and dynamic soil function, we conclude that terrestrial vegetation and soils at Fort Davis NHS are within the range of natural variability. The grassland systems appear to be in good condition with high overall vegetative cover, a high ratio of perennial to annual species, and a near lack of non-native grasses. Soil and site stability is relatively high, suggesting the park is fairly resistant to erosion or altered water and nutrient cycles.

Mesquite distribution in the northeastern grasslands does represent a deviation from the historical landscape of the 1800s, but does

not seem to have substantially increased in the three decades since Nelson's 1981 study. It is hard to definitively comment on the possible increase in cover, as former studies were conducted in different areas and using different methods.

Type conversion from grassland to mesquite shrubland/woodland has been reported extensively elsewhere in the southwest (Van Auken 2000, Brown and Archer 1999)

due to factors such as livestock grazing, fire suppression, and periodic drought. As grazing has been retired from Fort Davis NHS and drought remains a pervasive and frequent stressor, the primary management answer would appear to be effective fire use and management. We will continue to monitor terrestrial vegetation and soils at Fort Davis NHS, and encourage managers to remain vigilant to potential increases in mesquite and other brush species.

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Appendix A Supplementary Data Tables

Table A1. Within-plot cover (%) for species measured in the “field” (<0.5 m stature) layer on line-point intercept transects, Fort Davis NHS, 2011. No non-native species were detected.

Species	Primary Growth Habit	Parkwide (10 plots)									
		401_V01	401_V02	401_V03	401_V04	401_V05	403_V02	403_V03	403_V04	403_V05	403_V10
Annual Forb	Forb/Herb	2.5%	2.1%	0.8%	0.8%	0.4%	0.0%	0.4%	3.8%	2.1%	4.2%
<i>Asclepias latifolia</i>	Forb/Herb	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
<i>Boerhavia</i> sp.	Forb/Herb	0.4%	0.0%	0.4%	0.4%	0.0%	0.0%	0.0%	0.0%	3.3%	0.8%
<i>Commelina</i> sp.	Forb/Herb	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%
<i>Croton</i> sp.	Forb/Herb	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.8%
<i>Dalea</i> sp.	Forb/Herb	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
<i>Euphorbia</i> sp.	Forb/Herb	0.8%	0.0%	2.1%	0.8%	0.0%	0.4%	0.0%	0.0%	2.9%	0.0%
<i>Evolvulus</i> sp.	Forb/Herb	0.0%	0.0%	0.4%	0.4%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%
Annual Grass	Graminoid	10.4%	0.0%	2.1%	1.3%	3.8%	0.0%	0.0%	2.1%	0.0%	2.5%
<i>Aristida</i> sp.	Graminoid	0.8%	5.8%	0.0%	0.0%	0.4%	2.1%	0.0%	4.6%	0.8%	0.0%
<i>Bothriochloa barbinodis</i>	Graminoid	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.4%	0.0%	0.0%	0.0%
<i>Bouteloua curtipendula</i>	Graminoid	19.2%	3.8%	5.4%	5.4%	4.6%	17.9%	7.1%	1.7%	22.1%	6.3%
<i>Bouteloua gracilis</i>	Graminoid	2.1%	0.8%	0.0%	0.0%	0.0%	2.5%	0.0%	0.0%	20.4%	0.0%
<i>Bouteloua hirsuta</i>	Graminoid	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%
<i>Bouteloua</i> sp.	Graminoid	0.8%	0.4%	0.0%	0.0%	0.0%	9.2%	2.9%	0.0%	2.1%	0.0%
<i>Digitaria californica</i>	Graminoid	0.0%	0.0%	0.4%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%
<i>Muhlenbergia tenuifolia</i>	Graminoid	0.0%	0.0%	2.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%
<i>Schizachyrium scoparium</i>	Graminoid	5.0%	14.6%	0.0%	0.8%	9.2%	4.2%	4.2%	12.9%	6.7%	9.2%
<i>Scleropogon brevifolius</i>	Graminoid	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%
<i>Sporobolus cryptandrus</i>	Graminoid	0.0%	5.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.1%	0.0%	0.0%
<i>Carphochaete bigelovii</i>	Subshrub	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%
<i>Croton pottsii</i>	Subshrub	0.4%	0.0%	0.4%	0.0%	0.0%	0.4%	0.0%	0.0%	1.7%	0.0%
<i>Menodora longiflora</i>	Subshrub	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%
<i>Nolina texana</i>	Subshrub	0.0%	1.7%	4.6%	2.9%	0.0%	0.4%	3.3%	0.0%	0.0%	0.4%
<i>Senecio flaccidus</i>	Subshrub	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%

Table A1. Within-plot cover (%) for species measured in the “field” (<0.5 m stature) on line-point intercept transects, Fort Davis NHS, 2011 (continued).

Species	Primary Growth Habit	Parkwide (10 plots)									
		401_V01	401_V02	401_V03	401_V04	401_V05	403_V02	403_V03	403_V04	403_V05	403_V10
<i>Solanum elaeagnifolium</i>	Subshrub	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%
<i>Zinnia grandiflora</i>	Subshrub	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%
<i>Adolphia infesta</i>	Shrub	0.0%	0.0%	0.0%	0.0%	0.0%	2.1%	0.0%	0.0%	7.5%	0.0%
<i>Aloysia gratissima</i>	Shrub	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%
<i>Baccharis pteronioides</i>	Shrub	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	2.1%	0.4%
<i>Cylindropuntia imbricata</i>	Shrub	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%
<i>Dasyllirion leiophyllum</i>	Shrub	2.1%	1.7%	0.0%	3.3%	1.7%	0.0%	9.2%	0.4%	0.0%	0.4%
<i>Mahonia trifoliolata</i>	Shrub	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%
<i>Mimosa aculeaticarpa</i> var. <i>biuncifera</i>	Shrub	1.7%	11.3%	0.0%	2.9%	3.8%	0.8%	10.8%	4.2%	0.4%	2.5%
<i>Parthenium incanum</i>	Shrub	4.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
<i>Rhus microphylla</i>	Shrub	1.3%	0.0%	0.4%	0.0%	0.0%	5.8%	0.0%	0.0%	0.4%	0.0%
<i>Rhus trilobata</i>	Shrub	0.0%	0.0%	0.0%	0.0%	0.0%	2.5%	0.0%	0.0%	0.0%	0.0%
<i>Echinocereus</i> sp.	Succulent	0.0%	0.4%	0.0%	0.0%	0.0%	0.4%	0.4%	0.0%	0.0%	0.0%
<i>Opuntia engelmannii</i>	Succulent	1.3%	0.0%	0.0%	0.4%	0.0%	4.6%	3.3%	0.0%	0.4%	2.5%
<i>Opuntia</i> sp.	Succulent	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.8%	0.0%	4.2%	0.0%
<i>Acacia constricta</i>	Tree	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%	0.4%	0.4%
<i>Juniperus monosperma</i>	Tree	0.0%	0.0%	0.0%	0.0%	0.4%	1.3%	0.0%	0.0%	0.0%	0.0%
<i>Prosopis glandulosa</i>	Tree	0.0%	0.0%	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%
<i>Quercus grisea</i>	Tree	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%	0.0%
<i>Quercus</i> sp.	Tree	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	2.5%	0.0%	0.0%	0.0%
<i>Yucca elata</i>	Tree	0.0%	2.1%	0.0%	0.0%	0.0%	0.8%	0.0%	0.0%	0.8%	0.0%
Annual Vine	Vine	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	0.0%	0.0%	0.0%
<i>Ipomoea tenuiloba</i>	Vine	0.0%	1.3%	0.4%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.4%

Table A1. Within-plot cover (%) for species measured in the “field” (<0.5 m stature) on line-point intercept transects, Fort Davis NHS, 2011 (continued).

Species	Primary Growth Habit	Parkwide (10 plots)									
		401_V01	401_V02	401_V03	401_V04	401_V05	403_V02	403_V03	403_V04	403_V05	403_V10
Summaries by lifeform	Annual Forb	2.5%	2.1%	0.8%	0.8%	0.4%	0.0%	0.4%	3.8%	2.1%	4.2%
	Annual Grass	10.4%	0.0%	2.1%	1.3%	3.8%	0.0%	0.0%	2.1%	0.0%	2.5%
	Perennial Forb	2.5%	0.4%	2.9%	1.7%	0.0%	0.8%	0.0%	0.4%	6.7%	1.7%
	Perennial Grass	29.6%	32.1%	16.3%	8.3%	14.6%	46.3%	14.6%	22.1%	55.0%	16.7%
	Subshrub	0.4%	1.7%	5.0%	2.9%	0.0%	2.9%	3.3%	0.4%	2.5%	0.4%
	Shrub	9.17%	12.92%	0.42%	6.25%	5.83%	13.75%	20.00%	4.58%	10.83%	3.33%
	Succulent	1.25%	0.42%	0.00%	0.42%	0.00%	5.00%	7.50%	0.00%	4.58%	2.50%
	Tree	0.42%	2.08%	1.25%	0.00%	0.42%	3.75%	3.75%	0.00%	1.67%	0.42%
	Snag	1.7%	7.9%	2.1%	1.3%	2.1%	6.7%	2.9%	2.1%	5.0%	2.5%
	Vine	0.00%	1.25%	0.42%	0.00%	0.00%	0.00%	0.83%	0.42%	0.00%	0.42%
Total Cover		57.92%	60.83%	31.25%	22.92%	27.08%	79.17%	53.33%	35.83%	88.33%	34.58%

Table A2. Within-plot cover (%) for species measured in the "subcanopy" (0.5-2.0 m stature) layer on line-point intercept transects, Fort Davis NHS, 2011. No non-native species were detected.

Parkwide (10 plots)											
Species	Primary Growth Habit	401_V01	401_V02	401_V03	401_V04	401_V05	403_V02	403_V03	403_V04	403_V05	403_V10
<i>Adolphia infesta</i>	Shrub	0.00%	0.00%	0.00%	0.00%	0.00%	0.83%	0.00%	0.00%	3.33%	0.00%
<i>Baccharis pteronioides</i>	Shrub	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.67%	0.00%
<i>Mahonia trifoliolata</i>	Shrub	0.00%	0.00%	0.00%	0.00%	0.00%	2.08%	0.00%	0.00%	0.00%	0.00%
<i>Mimosa aculeaticarpa</i> var. <i>biuncifera</i>	Shrub	0.83%	7.08%	0.00%	0.42%	4.58%	0.00%	7.08%	2.92%	0.83%	0.83%
<i>Parthenium incanum</i>	Shrub	0.83%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
<i>Rhus microphylla</i>	Shrub	0.83%	0.00%	0.00%	0.00%	0.00%	10.83%	0.00%	0.00%	0.00%	0.00%
<i>Rhus trilobata</i>	Succulent	0.00%	0.00%	0.00%	0.00%	0.00%	2.92%	0.00%	0.00%	0.00%	0.00%
<i>Acacia constricta</i>	Tree	0.00%	0.00%	0.00%	0.00%	0.00%	2.50%	0.00%	0.00%	0.00%	0.42%
<i>Juniperus monosperma</i>	Tree	0.00%	0.00%	0.00%	0.00%	1.67%	3.33%	0.00%	0.00%	0.00%	0.00%
<i>Prosopis glandulosa</i>	Tree	0.00%	0.00%	0.83%	0.00%	0.00%	0.42%	0.00%	0.00%	1.25%	0.00%
<i>Quercus grisea</i>	Tree	0.00%	1.25%	0.00%	0.00%	0.00%	0.00%	0.42%	0.00%	0.00%	0.00%
<i>Quercus</i> sp.	Tree	0.00%	0.42%	0.00%	0.00%	0.00%	2.08%	8.33%	0.00%	0.00%	0.00%
Summaries by lifeform	Annual Forb	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Annual Grass	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Perennial Forb	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Perennial Grass	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Subshrub	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Shrub	2.50%	7.08%	0.00%	0.42%	4.58%	10.83%	7.08%	2.92%	0.83%	0.83%
	Succulent	0.00%	0.00%	0.00%	0.00%	0.00%	2.92%	0.00%	0.00%	0.00%	0.00%
	Tree	0.00%	1.67%	0.83%	0.00%	1.67%	8.33%	8.75%	0.00%	1.25%	0.42%
	Snag	5.83%	1.67%	0.00%	1.67%	0.42%	0.00%	0.42%	2.08%	0.00%	2.08%
	Vine	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total Cover		8.33%	10.42%	0.83%	2.08%	6.67%	22.08%	16.25%	5.00%	2.08%	3.33%

Table A3. Within-plot cover values (%) for species measured in the "canopy" (>2.0 m stature) layer on line-point intercept transects, Fort Davis NHS, 2011.

Parkwide (10 plots)											
Species	Primary Growth Habit	401_V01	401_V02	401_V03	401_V04	401_V05	403_V02	403_V03	403_V04	403_V05	403_V10
<i>Rhus microphylla</i>	Shrub	0%	0%	0%	0%	0%	9%	0%	0%	0%	0%
<i>Acacia constricta</i>	Tree	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%
<i>Juniperus monosperma</i>	Tree	0%	0%	0%	0%	2%	3%	0%	0%	0%	0%
<i>Prosopis glandulosa</i>	Tree	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
<i>Quercus</i> sp.	Tree	0%	0%	0%	0%	0%	3%	8%	0%	0%	0%
<i>Quercus grisea</i>	Tree	0%	1%	0%	0%	0%	0%	0%	1%	0%	0%
Summaries by lifeform	Annual Forb	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Annual Grass	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Perennial Forb	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Perennial Grass	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Subshrub	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Shrub	0%	0%	0%	0%	0%	9%	0%	0%	0%	0%
	Succulent	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Tree	0%	1%	0%	0%	2%	7%	8%	1%	0%	0%
	Snag	3%	0%	0%	6%	0%	0%	0%	1%	0%	0%
	Vine	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total		2.50%	1.25%	0.00%	6.25%	2.08%	16%	8%	2%	0%	0%

Table A4. Average within-plot frequency and landscape frequency (%) by stratum and parkwide for all plots and species sampled on monitoring plots in Fort Davis NHS, 2011. Species that are highlighted fail to meet our statistical power criteria. No non-native plants were detected.

Scientific Name	Primary Growth Habit	Parkwide (10 Plots)				
		AVG Within-Plot Freq. (%)	SE Within-Plot Freq. (%)	Landscape Frequency	MDC	n
<i>Acourtia wrightii</i>	Forb/Herb	12%	9%	20%	18%	10
<i>Asclepias latifolia</i>	Forb/Herb	22%	11%	40%	23%	10
<i>Asclepias</i> sp.	Forb/Herb	2%	2%	10%	5%	7
<i>Berlandiera lyrata</i>	Forb/Herb	14%	8%	30%	18%	10
<i>Boerhavia</i> sp.	Forb/Herb	34%	11%	70%	24%	10
<i>Commelina</i> sp.	Forb/Herb	16%	9%	30%	19%	10
<i>Croton</i> sp.	Forb/Herb	10%	4%	40%	10%	9
<i>Dalea</i> sp.	Forb/Herb	4%	4%	10%	9%	9
<i>Dalea wrightii</i>	Forb/Herb	4%	4%	10%	9%	9
<i>Eriogonum</i> sp.	Forb/Herb	12%	10%	20%	21%	10
<i>Euphorbia</i> sp.	Forb/Herb	18%	9%	40%	19%	10
<i>Evolvulus</i> sp.	Forb/Herb	40%	12%	70%	25%	10
<i>Macrosiphonia lanuginosa</i> var. <i>macrosiphon</i>	Forb/herb	16%	11%	20%	24%	10
<i>Senna roemeriana</i>	Forb/Herb	22%	11%	40%	22%	10
<i>Tragia</i> sp.	Forb/Herb	24%	11%	40%	23%	10
<i>Aristida</i> sp.	Graminoid	30%	12%	60%	26%	10
<i>Bothriochloa barbinodis</i>	Graminoid	10%	6%	30%	13%	10
<i>Bouteloua curtipendula</i>	Graminoid	94%	3%	100%	7%	9
<i>Bouteloua gracilis</i>	Graminoid	26%	10%	60%	21%	10
<i>Bouteloua hirsuta</i>	Graminoid	2%	2%	10%	5%	7
<i>Bouteloua</i> sp.	Graminoid	16%	6%	60%	13%	9
<i>Digitaria californica</i>	Graminoid	6%	4%	20%	9%	10
<i>Muhlenbergia tenuifolia</i>	Graminoid	14%	8%	30%	18%	9
<i>Schizachyrium scoparium</i>	Graminoid	76%	11%	90%	23%	10
<i>Scleropogon brevifolius</i>	Graminoid	10%	7%	20%	15%	9
<i>Sporobolus cryptandrus</i>	Graminoid	28%	14%	30%	30%	10
<i>Bouvardia ternifolia</i>	Subshrub	2%	2%	10%	5%	7
<i>Carphochaete bigelovii</i>	Subshrub	4%	4%	10%	9%	9
<i>Croton pottsii</i>	Subshrub	40%	11%	70%	24%	9
<i>Machaeranthera pinnatifida</i> ssp. <i>pinnatifida</i>	Subshrub	4%	3%	20%	6%	9
<i>Menodora</i> sp.	Subshrub	16%	9%	30%	20%	9
<i>Nolina</i> sp.	Subshrub	6%	4%	20%	9%	10
<i>Nolina texana</i>	Subshrub	54%	12%	80%	26%	10
<i>Quercus</i> sp.	Subshrub	16%	9%	30%	19%	10
<i>Senecio flaccidus</i>	Subshrub	4%	4%	10%	9%	9

Table A4. Average within-plot frequency and landscape frequency (%) by stratum and parkwide for all plots and species sampled on monitoring plots in Fort Davis NHS, 2011. Species that are highlighted fail to meet our statistical power criteria (continued).

Scientific Name	Primary Growth Habit	Parkwide (10 Plots)				
		AVG Within-Plot Freq. (%)	SE Within-Plot Freq. (%)	Landscape Frequency	MDC	n
<i>Solanum elaeagnifolium</i>	Subshrub	34%	11%	70%	23%	10
<i>Tetraclea coulteri</i>	Subshrub	6%	4%	20%	9%	10
<i>Trixis californica</i>	Subshrub	2%	2%	10%	5%	7
<i>Zinnia grandiflora</i>	Subshrub	22%	9%	50%	19%	10
<i>Adolphia infesta</i>	Shrub	12%	8%	20%	17%	10
<i>Aloysia gratissima</i>	Shrub	8%	5%	20%	12%	9
<i>Anisacanthus linearis</i>	Shrub	2%	2%	10%	5%	7
<i>Baccharis pteronioides</i>	Shrub	30%	10%	50%	22%	10
<i>Mahonia trifoliolata</i>	Shrub	22%	11%	40%	23%	10
<i>Brongniartia minutifolia</i>	Shrub	2%	2%	10%	5%	7
<i>Croton fruticosus</i>	Shrub	4%	4%	10%	9%	9
<i>Cylindropuntia imbricata</i>	Shrub	42%	10%	90%	20%	10
<i>Dasyllirion leiophyllum</i>	Shrub	66%	15%	70%	31%	10
<i>Mimosa aculeaticarpa</i> var. <i>biuncifera</i>	Shrub	84%	8%	100%	18%	10
<i>Parthenium incanum</i>	Shrub	6%	4%	20%	9%	10
<i>Rhus microphylla</i>	Shrub	26%	9%	60%	19%	10
<i>Rhus trilobata</i>	Shrub	10%	8%	20%	17%	10
<i>Yucca baccata</i>	Shrub	2%	2%	10%	5%	7
<i>Yucca elata</i>	Shrub	22%	11%	30%	24%	10
<i>Yucca faxoniana</i>	Shrub	6%	4%	20%	9%	10
<i>Yucca</i> sp.	Shrub	14%	10%	20%	22%	10
<i>Ziziphus obtusifolia</i>	Shrub	2%	2%	10%	5%	7
<i>Echinocactus</i> sp.	Succulent	8%	5%	20%	12%	9
<i>Echinocereus</i> sp.	Succulent	16%	7%	50%	14%	10
<i>Echinocereus stramineus</i>	Succulent	18%	9%	40%	18%	10
<i>Opuntia engelmannii</i>	Succulent	86%	7%	100%	16%	9
<i>Opuntia macrocentra</i> var. <i>macrocentra</i>	Succulent	12%	8%	20%	17%	10
<i>Opuntia</i> sp.	Succulent	18%	12%	20%	25%	10
<i>Acacia constricta</i>	Tree	24%	11%	50%	24%	10
<i>Juniperus deppeana</i>	Tree	2%	2%	10%	5%	7
<i>Juniperus monosperma</i>	Tree	14%	7%	40%	14%	10
<i>Prosopis glandulosa</i>	Tree	36%	10%	80%	21%	10
<i>Quercus grisea</i>	Tree	28%	10%	50%	21%	10
<i>Ungnadia speciosa</i>	Tree	2%	2%	10%	5%	7
<i>Ipomoea tenuiloba</i>	Vine	24%	13%	30%	28%	10

AVG=average

SE=standard error

MDC=minimum detectable change

n=number of plots required to meet power criteria

Table A5. Within-plot frequency (0-5) for all plots and species sampled in monitoring plots in Fort Davis NHS, 2011. No non-native species were detected.

Scientific Name	Primary Growth Habit	Within-Plot Frequency (0-5)									
		Parkwide (10 plots)									
		401_V01	401_V02	401_V03	401_V04	401_V05	403_V02	403_V03	403_V04	403_V05	403_V10
<i>Acourtia wrightii</i>	Forb/Herb	0	0	2	0	0	4	0	0	0	0
<i>Asclepias latifolia</i>	Forb/Herb	3	0	0	5	0	0	0	0	2	1
<i>Asclepias</i> sp.	Forb/Herb	0	0	0	0	0	0	0	1	0	0
<i>Berlandiera lyrata</i>	Forb/Herb	0	0	1	0	0	0	0	0	4	2
<i>Boerhavia</i> sp.	Forb/Herb	1	1	2	4	0	0	0	1	5	3
<i>Commelina</i> sp.	Forb/Herb	0	4	0	0	0	0	0	2	0	2
<i>Croton</i> sp.	Forb/Herb	0	0	1	1	0	0	0	0	1	2
<i>Dalea</i> sp.	Forb/Herb	2	0	0	0	0	0	0	0	0	0
<i>Dalea wrightii</i>	Forb/Herb	0	0	0	0	0	0	0	2	0	0
<i>Eriogonum</i> sp.	Forb/Herb	0	0	0	0	0	0	0	5	0	1
<i>Euphorbia</i> sp.	Forb/Herb	1	0	3	1	0	0	0	0	4	0
<i>Evolvulus</i> sp.	Forb/Herb	1	2	5	5	0	2	0	0	2	3
<i>Macrosiphonia lanuginosa</i> var. <i>macrosiphon</i>	Forb/herb	3	0	0	0	0	0	0	0	0	5
<i>Senna roemeriana</i>	Forb/Herb	2	0	5	0	0	0	0	0	2	2
<i>Tragia</i> sp.	Forb/Herb	0	2	0	4	0	2	0	0	0	4
<i>Aristida</i> sp.	Graminoid	2	5	0	0	1	1	0	5	1	0
<i>Bothriochloa barbinodis</i>	Graminoid	0	0	0	0	1	0	3	1	0	0
<i>Bouteloua curtipendula</i>	Graminoid	5	5	5	4	5	5	4	4	5	5
<i>Bouteloua gracilis</i>	Graminoid	1	2	0	1	0	2	0	2	5	0
<i>Bouteloua hirsuta</i>	Graminoid	0	0	0	0	0	0	0	0	1	0
<i>Bouteloua</i> sp.	Graminoid	1	1	0	0	0	3	1	1	1	0
<i>Digitaria californica</i>	Graminoid	0	0	1	2	0	0	0	0	0	0
<i>Muhlenbergia tenuifolia</i>	Graminoid	0	0	3	0	0	0	0	0	3	1
<i>Schizachyrium scoparium</i>	Graminoid	5	5	0	3	5	2	3	5	5	5
<i>Scleropogon brevifolius</i>	Graminoid	0	0	0	2	0	0	0	0	0	3
<i>Sporobolus cryptandrus</i>	Graminoid	0	5	0	0	0	0	4	5	0	0

Table A5. Within-plot frequency (0-5) for all plots and species sampled in monitoring plots in Fort Davis NHS, 2011 (continued).

Scientific Name	Primary Growth Habit	Within-Plot Frequency (0-5)									
		Parkwide (10 plots)									
		401_V01	401_V02	401_V03	401_V04	401_V05	403_V02	403_V03	403_V04	403_V05	403_V10
<i>Bouvardia ternifolia</i>	Subshrub	0	0	0	0	0	0	0	1	0	0
<i>Carphochaete bigelovii</i>	Subshrub	0	0	0	0	0	0	0	2	0	0
<i>Croton pottsii</i>	Subshrub	4	1	4	4	0	2	0	0	3	2
<i>Machaeranthera pinnatifida</i> ssp. <i>pinnatifida</i>	Subshrub	0	0	1	0	0	0	0	0	0	1
<i>Menodora</i> sp.	Subshrub	2	0	0	0	0	0	0	0	4	2
<i>Nolina</i> sp.	Subshrub	0	0	2	1	0	0	0	0	0	0
<i>Nolina texana</i>	Subshrub	2	0	4	5	5	4	4	0	1	2
<i>Quercus</i> sp.	Subshrub	0	4	0	0	0	2	2	0	0	0
<i>Senecio flaccidus</i>	Subshrub	0	0	0	0	0	0	0	0	2	0
<i>Solanum elaeagnifolium</i>	Subshrub	3	0	3	1	0	5	0	1	1	3
<i>Tetradlea coulteri</i>	Subshrub	0	0	0	0	0	1	0	0	2	0
<i>Trixis californica</i>	Subshrub	0	0	0	0	0	0	1	0	0	0
<i>Zinnia grandiflora</i>	Subshrub	4	0	0	2	0	1	0	0	3	1
<i>Adolphia infesta</i>	Shrub	0	0	0	0	0	3	0	0	3	0
<i>Aloysia gratissima</i>	Shrub	0	0	0	0	0	2	0	0	2	0
<i>Anisacanthus linearis</i>	Shrub	0	0	0	0	0	0	1	0	0	0
<i>Baccharis pteronioides</i>	Shrub	0	0	3	3	0	4	0	0	2	3
<i>Mahonia trifoliolata</i>	Shrub	3	0	0	1	0	5	0	0	0	2
<i>Brongniartia minutifolia</i>	Shrub	1	0	0	0	0	0	0	0	0	0
<i>Croton fruticulosus</i>	Shrub	0	0	0	0	0	0	0	2	0	0
<i>Cylindropuntia imbricata</i>	Shrub	1	2	5	1	4	3	2	0	1	2
<i>Dasyllirion leiophyllum</i>	Shrub	5	4	0	5	5	0	5	4	0	5
<i>Mimosa aculeaticarpa</i> var. <i>biuncifera</i>	Shrub	5	5	4	5	4	1	5	5	3	5

Table A5. Within-plot frequency (0-5) for all plots and species sampled in monitoring plots in Fort Davis NHS, 2011 (continued).

Scientific Name	Primary Growth Habit	Within-Plot Frequency (0-5)									
		Parkwide (10 plots)									
		401_V01	401_V02	401_V03	401_V04	401_V05	403_V02	403_V03	403_V04	403_V05	403_V10
<i>Parthenium incanum</i>	Shrub	2	0	0	0	0	0	1	0	0	0
<i>Rhus microphylla</i>	Shrub	3	2	1	0	0	4	0	0	2	1
<i>Rhus trilobata</i>	Shrub	0	0	0	0	0	4	1	0	0	0
<i>Yucca baccata</i>	Shrub	0	0	0	0	0	1	0	0	0	0
<i>Yucca elata</i>	Shrub	0	0	4	0	0	3	0	0	4	0
<i>Yucca faxoniana</i>	Shrub	0	0	2	0	0	0	1	0	0	0
<i>Yucca</i> sp.	Shrub	2	5	0	0	0	0	0	0	0	0
<i>Ziziphus obtusifolia</i>	Shrub	0	0	0	0	0	1	0	0	0	0
<i>Echinocactus</i> sp.	Succulent	2	0	0	0	0	0	0	0	0	2
<i>Echinocereus</i> sp.	Succulent	0	3	0	0	1	1	2	1	0	0
<i>Echinocereus stramineus</i>	Succulent	0	2	0	0	0	4	2	0	0	1
<i>Opuntia engelmannii</i>	Succulent	5	3	5	5	3	5	5	5	2	5
<i>Opuntia macrocentra</i> var. <i>macrocentra</i>	Succulent	3	0	0	0	0	0	0	0	0	3
<i>Opuntia</i> sp.	Succulent	0	0	0	0	0	0	5	0	4	0
<i>Acacia constricta</i>	Tree	1	0	0	0	0	5	0	1	4	1
<i>Juniperus deppeana</i>	Tree	0	0	0	0	0	1	0	0	0	0
<i>Juniperus monosperma</i>	Tree	0	0	0	0	3	2	1	0	0	1
<i>Prosopis glandulosa</i>	Tree	1	0	1	1	3	4	1	0	4	3
<i>Quercus grisea</i>	Tree	0	2	0	3	0	2	4	3	0	0
<i>Ungnadia speciosa</i>	Tree	0	0	0	0	0	0	0	1	0	0
<i>Ipomoea tenuiloba</i>	Vine	0	5	0	0	0	0	0	5	0	2

Table A6. Soil surface aggregate stability class and proportion of samples in "very stable" (=6) category, by monitoring plot, for Fort Davis NHS, 2011.

	Parkwide (10 plots)									
	401_ V01	401_ V02	401_ V03	401_ V04	401_ V05	403_ V02	403_ V03	403_ V04	403_ V05	403_ V10
Surface Soil Aggregate Stability All Samples										
Average Soil Stability	2.75	5.70	3.60	2.97	3.23	4.00	3.26	---	2.98	3.25
SD	2.22	0.70	2.30	1.79	1.45	1.73	0.90	---	1.69	1.66
SE	0.44	0.16	0.52	0.45	0.40	0.26	0.17	---	0.25	0.28
% samples "very stable"	27%	90%	40%	6%	0%	30%	0%	---	11%	8%
n	48	27	47	31	39	43	27	---	44	36
Surface Soil Aggregate Stability Under Vegetation										
Average Soil Stability	3.15	5.80	3.60	3.00	3.38	4.06	3.33	---	2.95	3.16
SD	2.22	0.70	2.30	1.79	1.45	1.81	0.92	---	1.61	1.80
SE	0.44	0.16	0.52	0.45	0.40	0.32	0.19	---	0.27	0.41
% samples "very stable"	27%	90%	40%	6%	0%	34%	0%	---	8%	11%
n	26	20	20	16	13	32	24	---	37	19
Surface Soil Aggregate Stability No Vegetation Cover										
Average Soil Stability	2.27	5.43	3.59	2.93	3.15	3.82	2.67	---	3.14	3.35
SD	1.70	0.79	1.87	2.02	1.35	1.54	0.58	---	2.19	1.54
SE	0.36	0.30	0.36	0.52	0.26	0.46	0.33	---	0.83	0.37
% samples "very stable"	5%	57%	19%	20%	0%	18%	0%	---	29%	6%
n	22	7	27	15	26	11	3	---	7	17

SD=standard deviation

SE=standard error

n=number of plots required to meet power criteria

Table A7. Soil substrate cover (% by class) on line-point intercept transects by monitoring plot, Fort Davis NHS, 2011.

Substrate	Parkwide (10 plots)									
	401_V01	401_V02	401_V03	401_V04	401_V05	403_V02	403_V03	403_V04	403_V05	403_V10
Bare soil (<2 mm) no overhead cover	4%	0%	20%	24%	21%	2%	3%	0%	0%	17%
Bare soil (<2 mm) under vegetation	11%	3%	10%	11%	16%	10%	6%	3%	5%	17%
Total bare soil	15%	3%	31%	35%	37%	12%	8%	3%	5%	34%
Light Cyanobacteria no overhead cover	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Light Cyanobacteria under vegetation	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total light cyanobacteria	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dark Cyanobacteria	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%
Litter and Woody Debris	6%	16%	9%	14%	10%	25%	21%	9%	10%	8%
Gravel (2-75 mm)	55%	2%	38%	16%	39%	13%	8%	6%	41%	33%
Duff	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Lichen	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Moss	0%	5%	0%	0%	0%	0%	0%	19%	0%	0%
Rock (76-600 mm)	15%	6%	7%	23%	8%	7%	12%	6%	15%	18%
Plant base	7%	15%	5%	1%	1%	35%	13%	7%	29%	2%
Bedrock	2%	53%	9%	11%	5%	9%	39%	50%	0%	6%
(litter, woody debris and duff) - for MAP	6%	16%	9%	14%	10%	25%	21%	9%	10%	8%
Fuels										
1-hr fuel (<0.062 cm)	1%	3%	0%	0%	0%	2%	1%	0%	0%	0%
10-hr fuel (0.62-2.5 cm)	0%	3%	0%	0%	0%	0%	1%	0%	0%	0%
100-hr fuel (2.51-7.62cm)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total fine woody debris (FWD)	1%	7%	0%	0%	0%	3%	2%	0%	0%	0%
1,000-hr fuel (>7.62 cm)	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%
Total coarse woody debris (CWD)	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%
Average CWD diameter (cm)	---	---	---	---	---	---	---	---	---	---
Litter (twigs, leaves, etc.)	5%	9%	9%	13%	9%	22%	18%	8%	10%	8%
Duff	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total litter and duff	5%	9%	9%	13%	9%	22%	18%	8%	10%	8%
Average litter/duff depth (cm)	10%	30%	10%	11%	12%	25%	23%	79%	23%	32%

Table A8. Absolute biological soil crust cover (% by class), in point-quadrats by monitoring plot, Fort Davis NHS, 2011.

Morphological Group or Growth Form	Parkwide (10 plots)									
	401_ V01	401_ V02	401_ V03	401_ V04	401_ V05	403_ V02	403_ V03	403_ V04	403_ V05	403_ V10
Light cyanobacteria soil crust	2.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.4%
Dark cyanobacteria soil crust	0.0%	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Crustose lichen	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Gelatinous lichen	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Squamulose lichen	0.0%	0.0%	1.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Folise lichen	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Fruticose lichen	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Moss	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Selaginella	0.0%	8.3%	0.0%	0.0%	0.0%	1.9%	0.0%	14.1%	0.0%	0.0%
Totals by Morphological Group										
Cyanobacteria- dominated soil crust	2.8%	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	1.4%
Lichen-dominated soil crust	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Moss-dominated soil crust	0.0%	8.7%	0.0%	0.0%	0.0%	1.9%	0.0%	14.1%	0.0%	0.0%
Dark cyanobacteria + Lichen + Moss	0.0%	8.3%	1.7%	0.3%	0.0%	1.9%	0.0%	14.1%	0.0%	0.0%

Table A9. Within-plot and landscape frequency (%) for all plots and biological soil crust morphological groups and growth forms in point-quadrats by monitoring plot, Fort Davis NHS, 2011.

Morphological Group or Growth Form	Within-Plot Frequency (0-18)									
	Parkwide (10 plots)									
	401_V01	401_V02	401_V03	401_V04	401_V05	403_V02	403_V03	403_V04	403_V05	403_V10
Light cyanobacteria soil crust	6	0	0	0	0	1	0	0	0	4
Dark cyanobacteria soil crust	0	0	0	1	0	0	0	0	0	0
Crustose lichen	0	0	2	0	0	0	0	0	0	0
Gelatinous lichen	0	1	2	3	4	5	6	7	8	9
Squamulose lichen	0	0	2	0	0	0	0	0	0	0
Foliose lichen	0	0	0	0	0	0	0	0	0	0
Fruticose lichen	0	0	0	0	0	0	0	0	0	0
Moss	0	4	0	0	0	0	0	0	0	0
Selaginella	0	12	0	0	0	1	0	6	0	0
Totals by Morphological Group										
Cyanobacteria-dominated soil crust	6	0	0	1	0	1	0	0	0	4
Lichen-dominated soil crust	0	0	3	0	0	0	0	0	0	0
Moss-dominated soil crust	0	12	0	0	0	1	0	6	0	0
Dark cyanobacteria + Lichen + Moss	0	12	3	0	0	1	0	6	0	0

Table A10. Soil and site characterization of terrestrial vegetation and soils plots at Fort Davis NHS, 2011.

		Parkwide (10 plots)									
		401_V01	401_V02	401_V03	401_V04	401_V05	403_V02	403_V03	403_V04	403_V05	403_V10
Slope	Average plot slope (%)	23	---	---	---	26.5	15.5	---	15.5	13.5	23.5
	Slope position	Backslope	---	Summit	Shoulder	Backslope	Backslope	Summit	Summit	Footslope	Backslope
Aspect	Description	South	Southeast	Northwest	Northwest	South	North	---	Southeast	East	South
Soil Lab Results	Soil Texture	Sandy loam	Sandy loam	Loam	Sandy loam	Sandy loam	Sandy loam	---	---	Sandy loam	Sandy loam
	Rock Fragments (%) ¹	53.0%	10.4%	26.2%	23.4%	34.7%	42.2%	---	---	30.1%	36.2%
	Oven Dry Soil Bulk Density ²	1.54	1.32	0.77	1.46	0.99	0.85	---	---	0.93	0.97
	Total Organic Content (%)	2.55%	1.21%	2.36%	1.49%	2.42%	5.37%	---	---	1.33%	1.58%
	Electrical Conductivity	0.44	0.12	0.31	0.43	0.45	0.69	---	---	0.15	0.27
	pH 1:1	6.02	6.23	5.88	5.64	7.39	5.71	---	---	6.16	6.34
	Reserve Acidity	0.56	0.81	0.88	0.83	0.43	0.91	---	---	0.63	0.66
Erosion Features	Tunneling	1-5%	---	---	none	none	none	none	none	none	none
	Sheet	1-5%	---	---	none	none	none	none	none	none	none
	Rill	6-25%	---	---	none	1-5%	none	1-5%	none	none	6-25%
	Gully	none	---	---	none	none	none	1-5%	1-5%	none	none
	Pedestals	none	---	---	none	none	none	none	none	none	1-5%
	Terracettes	none	---	---	none	none	none	none	none	none	none
	Burrowing	none	---	---	1-5%	none	none	none	none	none	none
Landform	Description	Hill	---	Alluvial Terrace	Hill	Hill	Hill	Mountain	Hill	Hill	Hill

¹Rock Fragments (%) = Volume of rocks /Total volume of sample. Assumes rock density of 2.65 g/cm³ (1cm³ = 1mL)

²Oven Dry Soil Bulk Density excludes the weight and volume of rock fragments in sample. Rock fragment density assumed to be 2.65 g/cm³

Table A11. Terrestrial vegetation and soils monitoring data by plot in the context of proposed management assessment points, Fort Davis NHS. Plots not meeting the assessment point are in red.

Issue	Management Assessment Point	Parkwide (10 plots)									
		401_V01	401_V02	401_V03	401_V04	401_V05	403_V02	403_V03	403_V04	403_V05	403_V10
Site Stability and Erosion Hazard	Bare ground cover is >30%	4%	0%	20%	24%	21%	2%	3%	0%	0%	17%
	Average stability of surface soil aggregates <3	2.75	5.70	3.60	2.97	3.23	4.00	3.26	---	2.98	3.25
	Foliar cover of perennial grasses in field layer is <25%	29.6%	32.1%	16.3%	8.3%	14.6%	46.3%	14.6%	22.1%	55.0%	16.7%
	Proportion of foliar grass cover (%) composed of annuals in field layer is >33%	26.0%	0%	11%	14%	21%	0%	0%	4%	0%	13%
Shrub Encroachment	Shrub foliar cover in field layer is >35%	9.2%	15.0%	0.4%	6.3%	5.8%	14.2%	20.0%	4.6%	11.7%	3.3%
	Shrub foliar cover in subcanopy layer is >35%	2.5%	7.1%	0.0%	0.4%	4.6%	16.7%	7.1%	2.9%	5.8%	0.8%
Mesquite Invasion	Mesquite (<i>Prosopis</i> spp.) foliar cover in the field layer is >15%	0.0%	0.0%	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%
	Mesquite (<i>Prosopis</i> spp.) foliar cover in subcanopy and canopy layers combined is >20%	0.0%	0.0%	0.8%	0.0%	0.0%	0.8%	0.0%	0.0%	1.3%	0.0%
Exotic Plant Dispersal	Extent (plot frequency) of invasive exotic plants is >20%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Exotic Plant Invasion	Proportion of foliar plant cover (%) contributed from exotic plants is >10%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Appendix B Permanent Plot Locations and Photos

Fort Davis NHS
Texas

National Park Service
U.S. Department of the Interior

2011 Photographs of Uplands Plot 401_01



Photo Point 2 (0m,20m corner): 141 degrees



Photo Point 3 (50m,20m corner): 247 degrees

Plot Location



★ Uplands Plot
□ Fort Davis NHS

0 500 1,000
Meters



Photo Point 1 (0m,0m corner): 91 degrees



Photo Point 4 (50m,0m corner): 311 degrees

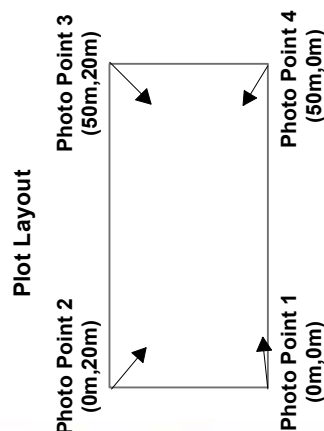


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m,20m) represent the spatial location of the plot corner. Bearings, in degrees, reflect the direction of the photo into the plot. Exact photo locations and higher resolution photos are available from CHDN.

Produced by CHDN
November 2012



2011 Photographs of Uplands Plot 401_02



Photo Point 2 (0m,20m corner): 45 degrees



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



Photo Point 1 (0m,0m corner): 36 degrees



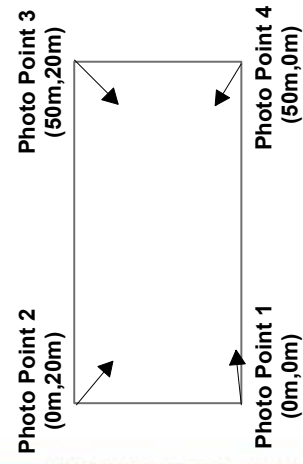
Photo Point 4 (50m,0m corner): 247 degrees

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 CHDN.

Plot Location



Plot Layout





2011 Photographs of Uplands Plot 401_03



Photo Point 2 (0m,20m corner): 344 degrees



Photo Point 3 (50m,20m corner): 71 degrees



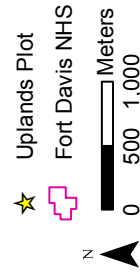
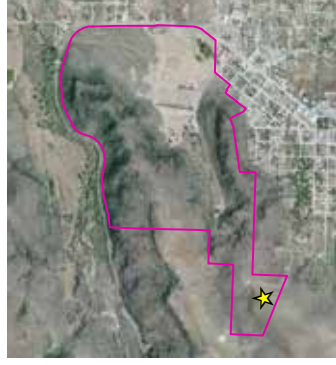
Photo Point 1 (0m,0m corner): 293 degrees



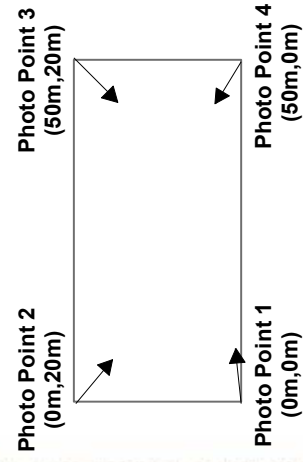
Photo Point 4 (50m,0m corner): 134 degrees

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 CHDN.

Plot Location



Plot Layout





2011 Photographs of Uplands Plot 401_04



Photo Point 2 (0m,20m corner): 204 degrees



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



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



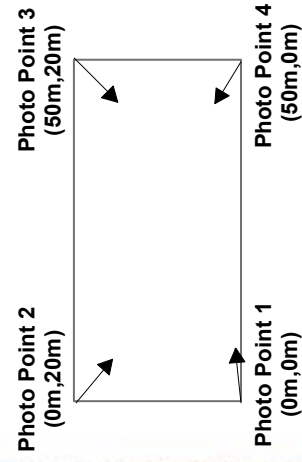
Photo Point 4 (50m,0m corner): 22 degrees

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 CHDN.

Plot Location



Plot Layout





2011 Photographs of Uplands Plot 401_05



Photo Point 2 (0m,20m corner): 89 degrees



Photo Point 3 (50m,20m corner): 212 degrees



Photo Point 1 (0m,0m corner): 71 degrees



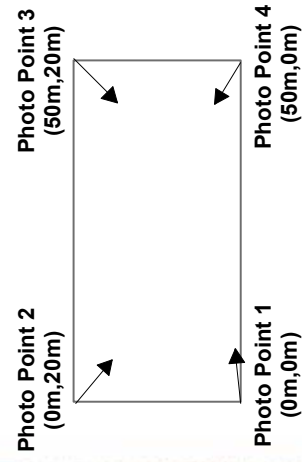
Photo Point 4 (50m,0m corner): 292 degrees

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 CHDN.

Plot Location



Plot Layout





2011 Photographs of Uplands Plot 403_02



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



Photo Point 3 (50m,20m corner): 20 degrees



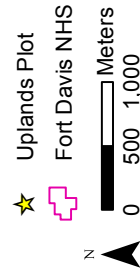
Photo Point 1 (0m,0m corner): 264 degrees



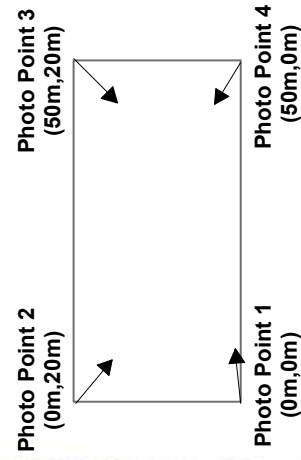
Photo Point 4 (50m,0m corner): 151 degrees

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 CHDN.

Plot Location



Plot Layout





2011 Photographs of Uplands Plot 403_03



Photo Point 2 (0m,20m corner): 101 degrees



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



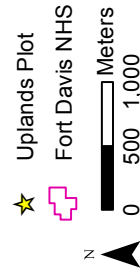
Photo Point 1 (0m,0m corner): 90 degrees



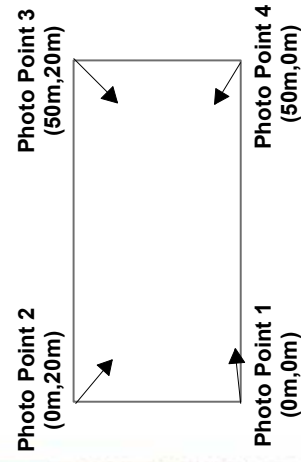
Photo Point 4 (50m,0m corner): 279 degrees

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 CHDN.

Plot Location



Plot Layout





2011 Photographs of Uplands Plot 403_04



Photo Point 2 (0m,20m corner): 291 degrees



Photo Point 3 (50m,20m corner): 37 degrees



Photo Point 1 (0m,0m corner): 225 degrees



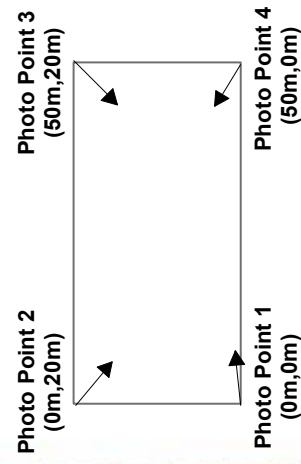
Photo Point 4 (50m,0m corner): 71 degrees

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 CHDN.

Plot Location



Plot Layout





2011 Photographs of Uplands Plot 403_05



Photo Point 2 (0m,20m corner): 256 degrees



Photo Point 3 (50m,20m corner): 319 degrees

Plot Location



Photo Point 1 (0m,0m corner): 191 degrees



Photo Point 4 (50m,0m corner): 51 degrees

Plot Layout

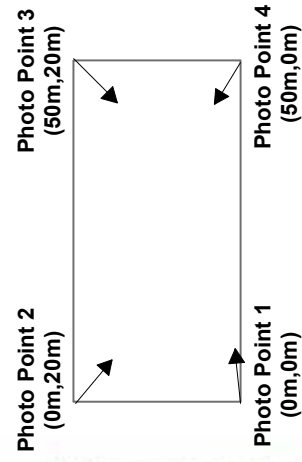


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m,20m) represent the spatial location of the plot corner. Bearings, in degrees, reflect the direction of the photo into the plot. Exact photo locations and higher resolution photos are available from CHDN.

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November 2012



2011 Photographs of Uplands Plot 403_10



Photo Point 2 (0m,20m corner): 119 degrees



Photo Point 3 (50m,20m corner): 216 degrees



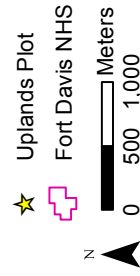
Photo Point 1 (0m,0m corner): 86 degrees



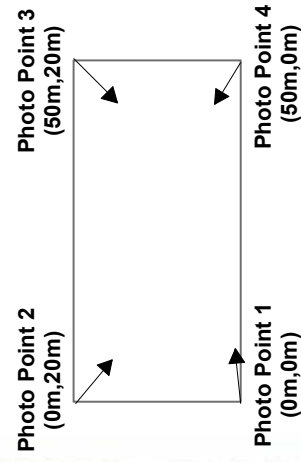
Photo Point 4 (50m,0m corner): 306 degrees

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 CHDN.

Plot Location



Plot Layout



Appendix C Similarity Percentage (SIMPER) Results

Values are square-root transformed. Sim/SD is the average abundance divided by the standard deviation for each species; a high value here indicates a species that contributes relatively consistently to the similarity across all pairs of plots within that group, that is, it typifies that group. Similarly, a high value in the Diss/SD column for the tables showing dissimilarity between pairs of groups indicates a good discriminating species. When a group has only two samples and only one within-group similarity, Sim/SD is undefined, as represented by “#####,” because the standard deviation of the within-group similarity cannot be defined. The Cum% column shows the cumulative percent contribution each species has to the overall within or between-group similarity.

SIMPER

Similarity Percentages - species contributions

One-Way Analysis

Data worksheet

Name: SQ Sum

Data type: Abundance

Sample selection: All

Variable selection: 1-37,39-49,53-55

Parameters

Resemblance: S17 Bray Curtis similarity

Cut off for low contributions: 90.00%

Factor Groups

Sample	Sum SQ No unks
401_001	c (“Mimosa shrubland and steppe”)
401_002	c (“Mimosa shrubland and steppe”)
401_004	c (“Mimosa shrubland and steppe”)
401_005	c (“Mimosa shrubland and steppe”)
403_003	c (“Mimosa shrubland and steppe”)
403_004	c (“Mimosa shrubland and steppe”)
403_010	c (“Mimosa shrubland and steppe”)
401_003	b (“Mesquite-herbaceous type”)
403_002	a (“Semi-desert grassland”)
403_005	a (“Semi-desert grassland”)

Group c (“Mimosa shrubland and steppe”)

Average similarity: 53.15

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Mimosa aculeaticarpa var. biuncifera	4.27	8.96	3.3	16.85	16.85
Schizachyrium scoparium	4.13	8.8	2.2	16.56	33.41
SNAG	3.78	8.75	4.26	16.47	49.88
Bouteloua curtipendula	3.81	8.28	3.85	15.59	65.47
Dasyllirion leiophyllum	2.25	4.21	2.59	7.93	73.4
Annual Forb	2.04	4.1	2.29	7.72	81.11
Annual Grass	2.06	3.12	0.91	5.86	86.98
Nolina texana	1.21	1.22	0.56	2.29	89.27
Aristida sp.	1.35	1.15	0.53	2.16	91.43

Group b (“Mesquite-herbaceous type”)

Less than 2 samples in group

Group a (“Semi-desert grassland”)

Average similarity: 50.40

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
<i>Bouteloua curtipendula</i>	6.92	9.96	#####	19.77	19.77
SNAG	3.73	5.26	#####	10.44	30.21
<i>Schizachyrium scoparium</i>	3.58	4.8	#####	9.53	39.74
<i>Adolphia infesta</i>	3.87	4.02	#####	7.98	47.72
<i>Bouteloua gracilis</i>	4.72	3.72	#####	7.38	55.1
<i>Bouteloua</i> sp.	3.46	3.4	#####	6.74	61.84
<i>Baccharis pteronioides</i>	2.5	3.04	#####	6.03	67.87
<i>Aristida</i> sp.	1.83	2.15	#####	4.26	72.14
<i>Mimosa aculeaticarpa</i> var. <i>biuncifera</i>	1.57	2.15	#####	4.26	76.4
<i>Prosopis glandulosa</i>	1.71	2.15	#####	4.26	80.66
<i>Yucca elata</i>	1.41	2.15	#####	4.26	84.93
<i>Acacia constricta</i>	2.16	1.52	#####	3.01	87.94
<i>Croton pottsii</i>	1.5	1.52	#####	3.01	90.96

Groups c & b (“Mimosa shrubland and steppe” & “Mesquite-herbaceous type”)

Average dissimilarity = 63.52

Species	Group c Av.Abund	Group b Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
<i>Mimosa aculeaticarpa</i> var. <i>biuncifera</i>	4.27	0	6.79	2.93	10.69	10.69
<i>Schizachyrium scoparium</i>	4.13	0	6.66	2.49	10.48	21.17
<i>Muhlenbergia tenuifolia</i>	0	2.65	4.3	7.07	6.77	27.94
<i>Prosopis glandulosa</i>	0	2.24	3.63	7.07	5.72	33.66
<i>Dasyllirion leiophyllum</i>	2.25	0	3.56	1.97	5.61	39.27
<i>Nolina texana</i>	1.21	3.32	3.47	1.56	5.47	44.74
<i>Euphorbia</i> sp.	0.4	2.24	2.98	2.49	4.68	49.42
SNAG	3.78	2.24	2.44	1.56	3.84	53.26
<i>Aristida</i> sp.	1.35	0	2.12	0.86	3.33	56.59
Annual Grass	2.06	2.24	1.83	1.21	2.88	59.47
<i>Opuntia engelmannii</i>	1.14	0	1.77	0.96	2.78	62.26
<i>Rhus microphylla</i>	0.32	1	1.67	8.22	2.63	64.89
<i>Digitaria californica</i>	0	1	1.62	7.07	2.56	67.45
<i>Quercus</i> sp.	1.11	0	1.55	0.44	2.44	69.89
<i>Quercus grisea</i>	1.03	0	1.51	0.98	2.38	72.27
<i>Croton pottsii</i>	0.14	1	1.43	2.16	2.25	74.52
<i>Bouteloua curtipendula</i>	3.81	3.61	1.39	0.88	2.19	76.71
Annual Forb	2.04	1.41	1.38	1.24	2.17	78.88
<i>Evolvulus</i> sp.	0.14	1	1.36	2.15	2.14	81.02
<i>Sporobolus cryptandrus</i>	0.81	0	1.25	0.58	1.96	82.98
<i>Ipomoea tenuiloba</i>	0.53	1	1.08	1.36	1.7	84.68
<i>Boerhavia</i> sp.	0.49	1	1.02	1.29	1.6	86.28
<i>Bouteloua</i> sp.	0.72	0	1	0.7	1.58	87.86
<i>Scleropogon brevifolius</i>	0.49	0	0.89	0.58	1.4	89.26
<i>Juniperus monosperma</i>	0.45	0	0.85	0.38	1.34	90.6

Groups c & a (“Mimosa shrubland and steppe” & “Semi-desert grassland”)

Average dissimilarity = 64.01

Species	Group c Av.Abund	Group a Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Bouteloua gracilis	0.52	4.72	4.3	1.54	6.72	6.72
Rhus microphylla	0.32	4.44	4.07	1.27	6.36	13.08
Adolphia infesta	0	3.87	3.88	2.58	6.05	19.14
Bouteloua curtipendula	3.81	6.92	3.16	2.08	4.93	24.07
Bouteloua sp.	0.72	3.46	2.75	1.87	4.3	28.37
Mimosa aculeaticarpa						
var. biuncifera	4.27	1.57	2.59	1.75	4.05	32.41
Baccharis pteronioides	0.14	2.5	2.34	3.12	3.66	36.07
Dasyllirion leiophyllum	2.25	0	2.18	1.98	3.4	39.48
Quercus sp.	1.11	1.73	2.07	1.05	3.23	42.71
Annual Grass	2.06	0	2.05	1.31	3.2	45.91
Juniperus monosperma	0.45	2.06	1.95	1.02	3.05	48.96
Acacia constricta	0.2	2.16	1.92	1.77	3	51.96
Prosopis glandulosa	0	1.71	1.7	4.06	2.65	54.61
Rhus trilobata	0	1.8	1.68	0.96	2.63	57.24
Opuntia sp.	0.43	1.58	1.62	0.96	2.53	59.77
Euphorbia sp.	0.4	1.82	1.55	1.6	2.42	62.19
Opuntia engelmannii	1.14	2.16	1.54	1.47	2.4	64.59
Boerhavia sp.	0.49	1.41	1.44	1.22	2.25	66.84
Aristida sp.	1.35	1.83	1.42	2.05	2.21	69.05
Yucca elata	0	1.41	1.39	9.97	2.18	71.23
Croton pottsii	0.14	1.5	1.38	1.93	2.15	73.37
Schizachyrium scoparium	4.13	3.58	1.36	1.56	2.12	75.5
Annual Forb	2.04	1.12	1.34	1.51	2.1	77.6
Mahonia trifoliata	0	1.22	1.14	0.96	1.78	79.38
Nolina texana	1.21	0.5	1.11	1.15	1.74	81.12
Solanum elaeagnifolium	0	1	0.93	0.96	1.46	82.57
Quercus grisea	1.03	0.5	0.91	1.22	1.43	84
SNAG	3.78	3.73	0.84	1.81	1.32	85.32
Sporobolus cryptandrus	0.81	0	0.77	0.6	1.21	86.53
Croton sp.	0.2	0.5	0.57	1.04	0.89	87.42
Scleropogon brevifolius	0.49	0	0.52	0.61	0.81	88.23
Aloysia gratissima	0	0.5	0.52	0.96	0.81	89.04
Bouteloua hirsuta	0	0.5	0.52	0.96	0.81	89.85
Menodora sp.	0	0.5	0.52	0.96	0.81	90.66

Groups b & a (“Mimosa shrubland and steppe” & “Semi-desert grassland”)
Average dissimilarity = 68.42

Species	Group b Av.Abund	Group a Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum. %
Bouteloua gracilis	0	4.72	5.31	1.35	7.76	7.76
Adolphia infesta	0	3.87	4.31	1.92	6.3	14.07
Schizachyrium scoparium	0	3.58	3.94	4.07	5.76	19.83
Bouteloua sp.	0	3.46	3.71	2.34	5.42	25.25
Bouteloua curtipendula	3.61	6.92	3.65	4.26	5.33	30.58
Rhus microphylla	1	4.44	3.54	0.71	5.18	35.75
Nolina texana	3.32	0.5	3.11	3.03	4.55	40.3
Baccharis pteronioides	0	2.5	2.77	2.77	4.04	44.34
Annual Grass	2.24	0	2.45	12.22	3.57	47.92
Muhlenbergia tenuifolia	2.65	0.5	2.31	3.98	3.38	51.3
Acacia constricta	0	2.16	2.29	1.43	3.34	54.64
Opuntia engelmannii	0	2.16	2.29	1.43	3.34	57.99
Juniperus monosperma	0	2.06	2.12	0.71	3.1	61.09
Aristida sp.	0	1.83	1.97	4.17	2.88	63.97
Rhus trilobata	0	1.8	1.86	0.71	2.71	66.69
Opuntia sp.	0	1.58	1.83	0.71	2.67	69.36
Quercus sp.	0	1.73	1.78	0.71	2.61	71.97
Mimosa aculeaticarpa						
var. biuncifera	0	1.57	1.73	4.48	2.53	74.5
SNAG	2.24	3.73	1.62	5.77	2.37	76.86
Boerhavia sp.	1	1.41	1.57	2.05	2.3	79.16
Yucca elata	0	1.41	1.55	12.22	2.26	81.42
Mahonia trifoliata	0	1.22	1.26	0.71	1.84	83.27
Annual Forb	1.41	1.12	1.2	3.36	1.76	85.03
Ipomoea tenuiloba	1	0	1.09	12.22	1.6	86.62
Solanum elaeagnifolium	0	1	1.03	0.71	1.51	88.13
Euphorbia sp.	2.24	1.82	0.87	1.55	1.28	89.41
Aloysia gratissima	0	0.5	0.58	0.71	0.85	90.25

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