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Terrestrial Vegetation and Soils Monitoring at Fort Bowie National Historic Site

2008 Status Report

Natural Resource Technical Report NPS/SODN/NRTR—2010/368

ON THE COVER

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Acronyms

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

Executive Summary

This report summarizes results of the Sonoran Desert Network's first season of terrestrial vegetation and soils monitoring in upland areas of Fort Bowie National Historic Site (NHS), in southeastern Arizona. Ten permanent field-monitoring sites were established and sampled in 2008. Our objectives were to determine the status of and detect trends, over five-year intervals, in vegetation cover, frequency, soil cover, and surface soil stability.

Our results revealed the presence of diverse, complex semi-desert grassland and savanna communities, in which all major vegetation lifeforms were well represented. Two exotic species, Lehmann lovegrass (*Eragrostis lehmanniana*) and stinkgrass (*Eragrostis cilianensis*), were found on 100% and 69% of the sites, respectively, but at relatively low cover (<3.3%). Both species are common in the park, but are not currently outcompeting (nor dominating) native flora, as is so common in other semi-desert grasslands in the American Southwest. Frequency subplots also detected Russian thistle (*Salsola kali*) and redstem storksbill (*Erodium cicutarium*), both non-native and potentially invasive species, at one monitoring site.

Preventing mesquite invasion and subsequent conversion of grassland to shrubland has been a focus of park managers for the last few decades. We found mesquite (*Prosopis* sp.) and other shrubs to be common (found at 85% and 100% of our sites, respectively) but not dominant (<2% and 4% cover, respectively). Mesquite seedlings were nearly twice as abundant (3%) as adults, but were still well below any management assessment points or thresholds (e.g., 20% cover) that we have encountered. Repeat photography indicates that mesquite cover in adjacent riparian systems has clearly increased over the past century (an effect we expect to document in the network's Washes Monitoring protocol).

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 evidence of rill development from overland flow. Less than 1% of the soil surface was unprotected, due to high cover of vegetation and leaf litter and the abundance of surface rocks and gravels. However, loss of leaf litter and vegetative cover—particularly annuals (>20% cover)—following fire or prolonged drought could result in a dramatic decrease in the "armored" soil surface. As soil erosion has important consequences for natural and cultural resources at Fort Bowie NHS, this is an important consideration.

We conclude that the terrestrial vegetation and soils in uplands of Fort Bowie NHS are well within the historic range of natural variability. Recognizing the limitations of historic data, the current park conditions compare very favorably with most semi-desert grasslands and savannas in the ecoregion, of which 85% are estimated to be degraded. We recommend continued vigilance toward potential invasions of exotic plants and mesquite, as well as erosion potential. We also emphasize the critical importance of restoring natural fire regimes through wildland fire use or prescribed fire, as advocated by current and former park staff.

Acknowledgements

We thank Fort Bowie National Historic Site staff members Danielle Foster, Larry Ludwig, and Superintendent Brian Carey for their on-site support of the field effort and the overall Sonoran Desert Network (SODN) Inventory and Monitoring Program. Beth Fallon, Laura Crumbacher, Aaron Curtis, Veronica Pistoia, Kate Connor, Scot Pipkin, Betsy Vance, Michael Molloy, Steve Buckley, and Sam Drake conducted the field data collection, often under arduous (but always scenic) conditions. Betsy Vance and Scot Pipkin also carefully processed all of the soil samples. Expert data processing and management were completed in record time by Acting SODN Data Manager Kristen Beaupré, and Lindsay Fitzgerald-DeHoog updated the master plant lists. Alice Wondrak Biel worked her usual magic on the draft manuscript. Finally, we thank Rob Bennetts and Tomye Folts-Zettner, of the Southern Plains Inventory and Monitoring Network, who graciously provided data from Fort Union National Monument for the comparison of semi-desert grassland and shortgrass prairie.

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. In the national parks, land-management actions often manipulate vegetation to achieve park objectives, with defined conditions based on community structure or lifeform composition.

In the Sonoran Desert and Apache Highlands ecoregions (Bailey 1998), vegetation composition, distribution, and production are highly influenced by edaphic factors, such as soil texture, mineralogy depth, and landform type (McAuliffe 1999). Especially as they relate to water, these influences are magnified at local scales, as described by pioneering desert ecologist Forrest Shreve (1951):

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

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

The Sonoran Desert Network (SODN), as part of the National Park Service's Inventory and Monitoring Program, has identified terrestrial vegetation and dynamic soil functional attributes as important ecosystem monitoring parameters, or "vital signs" (NPS 2005) that provide key insights into the integrity of terrestrial ecosystems at Fort Bowie National Historic Site (NHS; Figure 1.1). Indicators of terrestrial-vegetation integrity include vegetation community structure, lifeform abundance, status and trends of established exotic plants, and early detection of previously undetected exotic plants. Indicators of soil dynamic function and erosion resistance include mineral soil cover and the stability of surface soil aggregates.

NPS/S. STUDD

Figure 1.1. Fort Bowie National Historic Site.

1.2 Goals and objectives

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

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

1. Terrestrial *vegetation cover* for common (≥10% absolute canopy cover) perennial species, including non-native plants, and all plant lifeforms.
2. Terrestrial *vegetation frequency* of uncommon (<10% absolute canopy cover) perennial species, including non-native plants.
3. Terrestrial *soil cover* by substrate classes (bare soil, litter, vegetation, biological soil crust, rock fragments of several size classes) that influence resistance to erosion.
4. Terrestrial *soil stability* of surface aggregates by stability class (1–6).

1.1 Scope of this report

This document reports and interprets the results of the first round of terrestrial vegetation and soils monitoring at Fort Bowie NHS. Our focus is necessarily on current status, with trend evaluations to commence after the next sampling period in 2013. We do, however, compare these current results with those from previous studies and interpret the information in the context of management objectives and ecological considerations. The thematic scope is limited to terrestrial ecosystems, as well; aquatic resources, including riparian and xeroriparian vegetation, are addressed in the SODN Washes protocol.

1.2 Fort Bowie NHS overview

1.2.1 Park establishment and purpose

Authorized in 1964 and established in 1972, Fort Bowie NHS protects and interprets the remains of a key territorial military fort and the Butterfield trans-regional stage route, and commemorates the "tragic clash of cultures that characterized America's western expansion" (NPS 1975): in this case, expansion into the heartland of the Chiricahua Apache. This 405-hectare (1,000-acre) unit preserves the stabilized (but unrestored) remains of two successive forts, Butterfield Stage and U.S. Indian Agent stations, early mining works, and a military graveyard containing the remains of combatants from both sides of the (at times) violent conflict (Figure 1.2.1).

As with other cultural sites in the American Southwest, the location of these important historic resources is directly related to scarce and important natural resources: a strategically important pass through the rugged mountains of the Arizona–Sonora borderlands, and reliable perennial springs.

1.2.2 Biogeographic and physiographic context

Though it is part of the Sonoran Desert Network, Fort Bowie NHS lies east of the Sonoran Desert, in a region called the "Apache Highlands," or "Apacheria" (Gori and Enquist 2003). This 30 million-acre area comprises the western section of the Chihuahuan Desert and northern limits of the Madrean ecoregions (Bailey 1998; Figure 1.2.2). This continental position—a transition point between the Sonoran and (particularly) Chihuahuan deserts on the east and west, and the Rocky Mountains and Sierra Madre to the north and south—is reflected in the composition and biodiversity of the flora and fauna at Fort Bowie NHS (Powell et al. 2005).

Fort Bowie NHS is located in Apache Pass, which divides the Chiricahua and Dos Cabezas Mountains. These rugged mountain ranges are typical of the basin and range topography of the intermountain west (Scarborough 2000), with the north–south-aligned ranges separating the San Simon and Sulphur Springs valleys. Lying between 1,400 and 1,600 m (4,575–5,200') elevation,

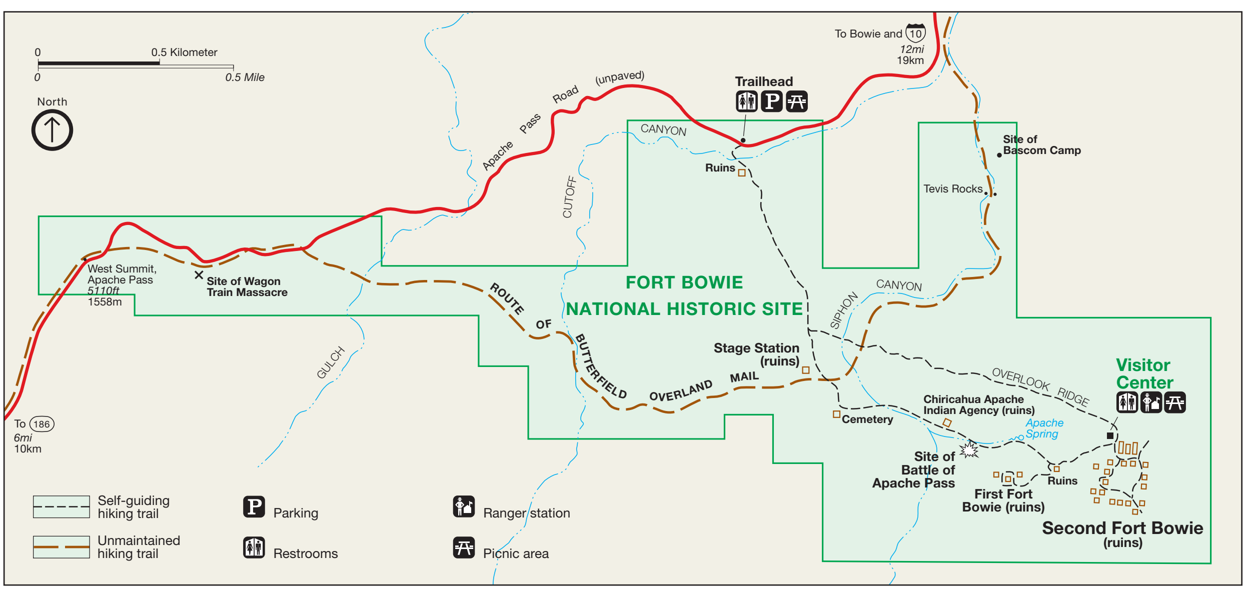

Figure 1.2.1. General map of Fort Bowie NHS.

Fort Bowie NHS contains three steep-gradient ephemeral riparian systems (Siphon Canyon, Cutoff Canyon, Willow Gulch) in a matrix of rolling hills and an alluvial terrace, the Triangular Valley (Figure 1.2.2). Though riparian systems are not considered in this protocol, we did explore geomorphologic and landscape relationships with vegetation and dynamic soil monitoring parameters.

1.2.3 Local geology and soils

Fort Bowie NHS is centered on the Apache Pass fault, an overthrust block of Permian and Cretaceous limestone atop Precambrian granite. As a result, there is great geologic variation within this relatively small park, with exposed granite outcroppings in the western area, as distinguished from the Horquilla limestone and other highly calcareous rock in highly stratified and folded layers in the eastern portions of the unit (Denney and Peacock 2000). This sharply contrasting local geology has important implications for soils within the park. In addition to the diverse effects of pedogenic processes, the variance in parent material contributes to eight major soil types (Figure 1.2.3; Denney and Peacock 2000), a surprising number for such a small area. Soil properties have important consequences for vegetation composition, persistence, and productivity (McAullife 1999). Therefore, we explored relationships between in-situ soil characteristics and vegetation monitoring parameters in a complementary effort (SODN unpublished data).

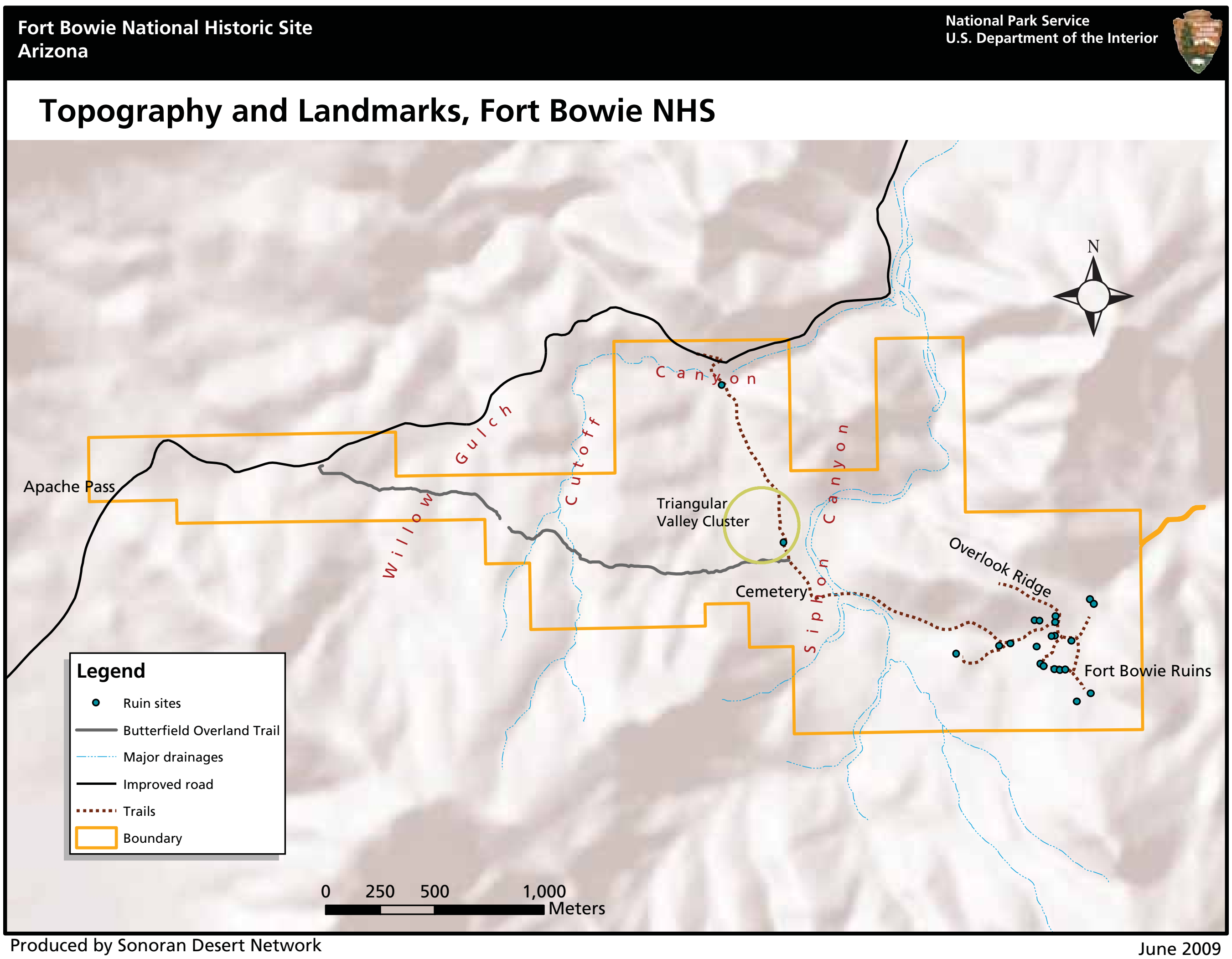

Figure 1.2.2. Topography of Fort Bowie National Historic Site.

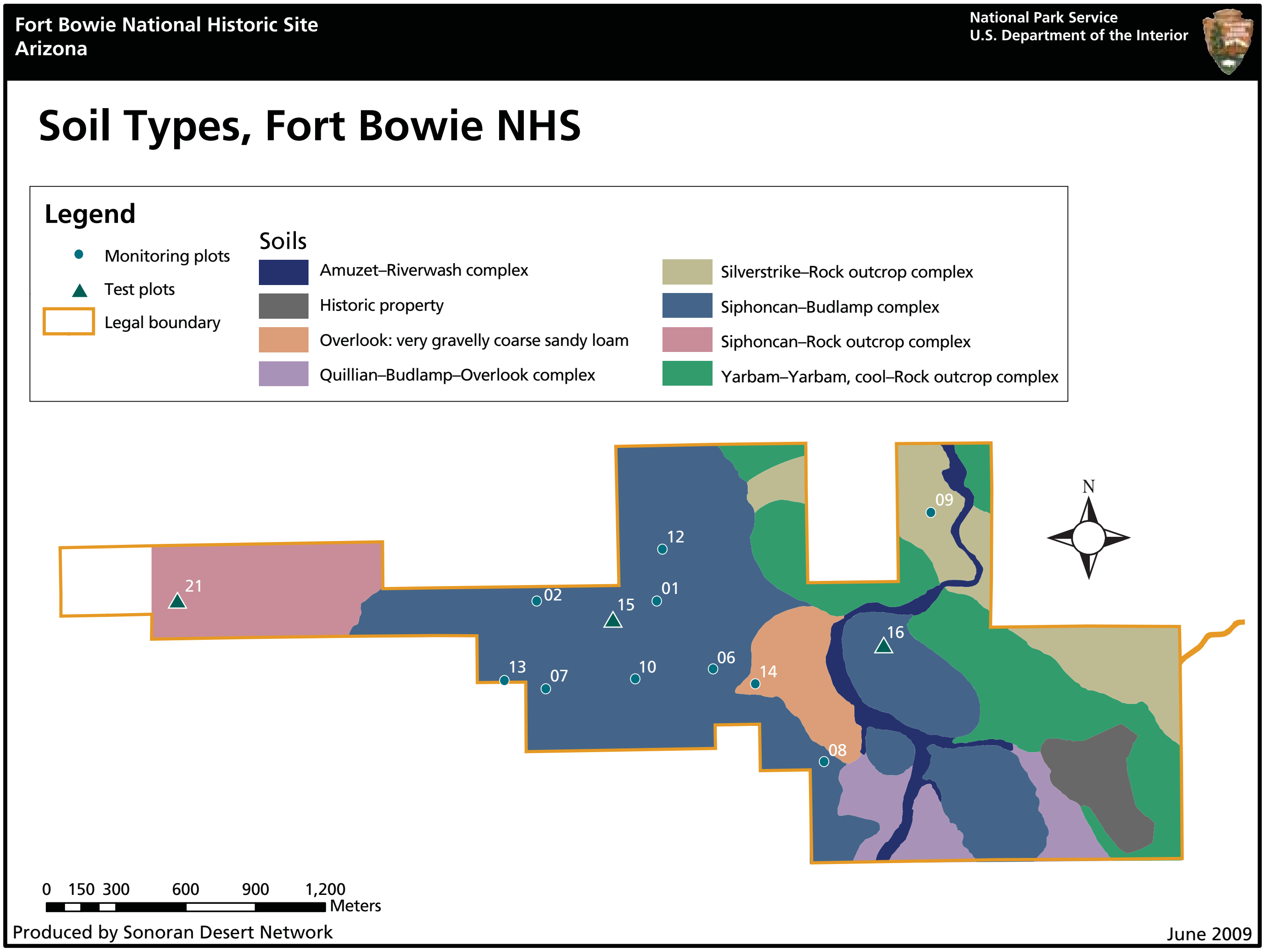

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Figure 1.2.3. Major soil types at Fort Bowie National Historic Site. From Denney and Peacock (2000).

1.2.4 Climate and hydrology

The climate at Fort Bowie NHS is typical of the Apache Highlands ecoregion: highly variable, bimodal precipitation with a considerable range in daily and seasonal air temperature, and relatively high potential evapotranspiration rates (Gori and Enquist 2003). Approximately half of the annual precipitation falls during summer thunderstorms, where maximum air temperatures can exceed 40°C and lead to violent (and often localized) rainstorms. The bulk of the remaining annual precipitation falls in relatively gentle events of broad extent, occasionally as snow. Precipitation data (from the nearest weather station with reliable climate information) appear in Figure 1.2.4-1.

Apache Spring and the two Mine Tunnel springs are groundwater emanating to the surface due to the Apache Pass fault. Other surface-hydrology characteristics are largely the product of local climate patterns and the configuration of the on-site and surrounding watersheds. The rolling terrain, dissected by steep drainages, tends to funnel runoff through Siphon and Cutoff canyons and Willow Gulch, with relatively little on-site water storage within the soil. Locally intense storms can therefore result in tremendous runoff and even mass soil movement events, as occurred in Siphon Canyon in 2007 (Figure 1.2.4-2).

1.2.5 Human habitation

Prehistoric human use of the Fort Bowie NHS area appears to have begun around 200 B.C., based on preliminary evidence of the remains of a village that appears to be associated with the Mogollon culture (Pinto et al. 2000).

Protohistoric use, by cultures including the Suma, Jocome, Janos, Opata, and Sobaipuri, is evident in

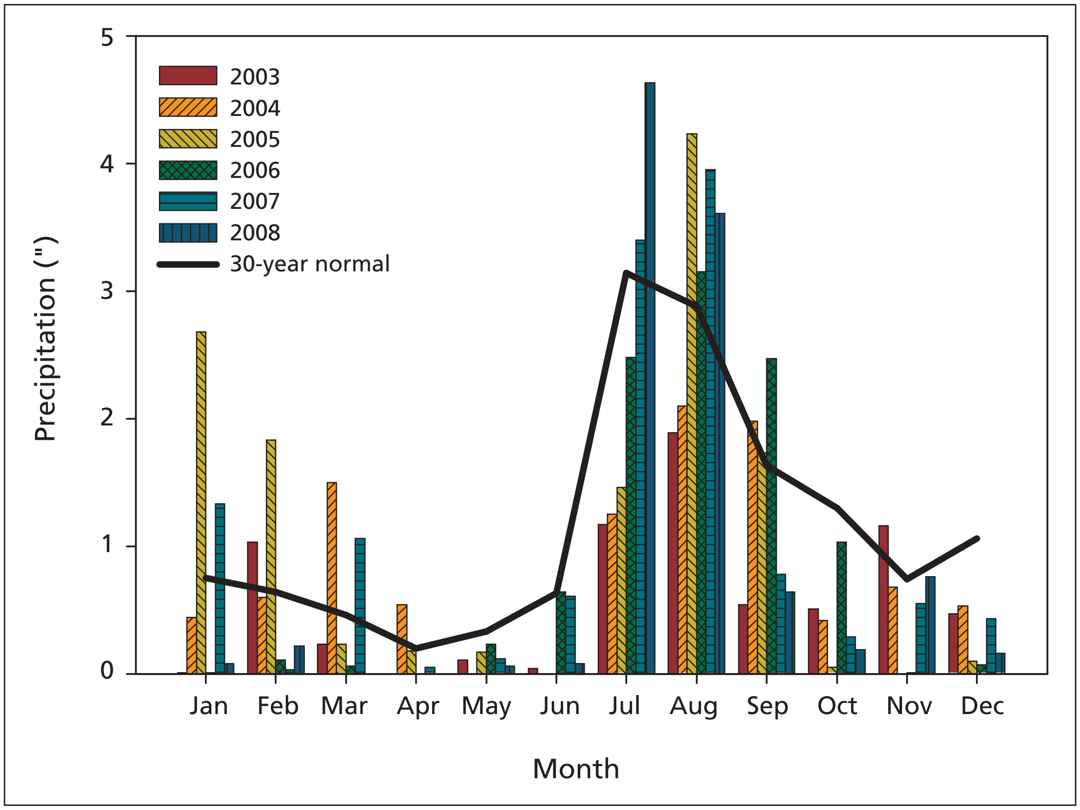

Figure 1.2.4-1. Monthly precipitation, Douglas Bisbee International Airport (~50 miles from Fort Bowie NHS), 2003–2008.

NPS/C.L. FILIPPONE

Figure 1.2.4-2. Channel cutting resulting from intensive runoff event in Siphon Canyon, 2007.

the region, but it was the Chiricahua Apache who dominated this site during the 17th–19th centuries A.D. (Bronitsky and Merritt 1986, as cited in Pinto et al. 2000). Though little physical evidence remains of land-use activities during this time period, historical accounts and ethnographic research indicate that these semi-nomadic people placed great significance on Apache Pass and extensively utilized the local resources (Kinniard 1958, as cited in Pinto et al. 2000). The Apache Pass area was the focus of cultural and spiritual activities, as well, with such famous Apache leaders as Cochise, Naiche, and Geronimo spending significant periods encamped in the area with their family-based bands. The latter exemplified the spiritual importance of the landscape by scaling nearby Bowie Mountain to pray for the safe recovery of his ailing sister (Pinto et al. 2000). Apache Pass was also the scene of the infamous "Bascom Affair" that ignited the 11-year conflict between the Chiricahua Apache (led by Cochise) and the U.S. Army, leading to the Battle of Apache Pass and the establishment of Fort Bowie (Pinto et al. 2000).

The military garrison rapidly outgrew the initial fort that was established in 1862 near Apache Spring, resulting in the 1869 construction of the much-larger, second fort on the plateau above the first (see Figure 1.2.1). The forts served as the foundation for military operations in the region, the headquarters of the Chiricahua Indian Agency during part of the short-lived Chiricahua Reservation (1872–1876), and as a key hub of regional communications and transportation. At the height of operations in 1886, the fort supported more than 300 soldiers and civilians. With the forced removal of the Chiricahua Apache to reservations in Florida and the extension of the Southern Pacific Railroad across the northern reach of the Dos Cabezas Mountains, the need for the fort diminished, and the site was decommissioned in 1894 (NPS 1998).

The abandoned site was sold in 1911, with many of the unsold parcels passing into public lands entrusted to the Bureau of Land Management. Whether private or public, land use shifted to livestock grazing and, to a lesser extent, recreation and limited hard-rock mining. Interest in developing the site as a national park began in 1939, with legislation authorizing the acquisition being passed in 1964. Establishment of park infrastructure began in the 1970s, resulting in the current site composition (NPS 1998).

1.2.6 Livestock grazing

Increasing contact with the Spanish and their native allies (often through raiding) resulted in the acquisition of livestock, primarily horses, by the Chiricahua Apache. It is reasonable to assume that increasing livestock use by native peoples likely resulted in episodic periods of intensive grazing of the Fort Bowie landscape from the late 17th through the mid-19th centuries. Livestock would intensively utilize forage while Chiricahua Apache were temporarily encamped in the area, with periods of vegetation recovery between successive visits. This same pattern would be expected to result from land use by settlers, explorers, mail carriers, stagecoach operations, military patrols, and other transient Anglo-American parties.

In their Cultural Landscapes Inventory of Fort Bowie NHS, Pinto and others (2000) concluded that the site has been continuously grazed by livestock since around 1850, based on early accounts of Anglo-American settlement in the region. Livestock grazing in the American Southwest peaked in the early 1890s, when approximately 50,000 head of cattle grazed the semi-desert grasslands of the nearby Sulphur Springs Valley (Bailey 1994). Overgrazing, combined with drought, contributed to widespread range deterioration, and stocking rates in the region have never again approached the optimist levels of the late 19th century (Bailey 1994).

Operation of the military installation required forage for horses, mules, cattle, and other livestock. However, the active existence of the post into the 1890s may have mitigated, at a local scale, some of the regional extremes in overgrazing. Livestock grazing was ended in the park in the early 21st century (NPS 1999), although trespass livestock are not uncommon.

1.2.7 Woodcutting and other land uses

Fuelwood cutting, once extensive in southeastern Arizona, likely peaked in the 1870s–1880s, as large volumes of cordwood were harvested to feed a growing mine industry that required wood to fuel stamp mills and for building material (Turner et al. 2003). Preferred species included mesquite (*Prosopis* spp.), evergreen oaks (*Quercus* spp.), junipers (*Juniperus* spp.) and, to a lesser extent, pine (*Pinus* spp.). Given the difficulties of transporting downed trees, it is reasonable to assume that well-wooded sites nearest to habitation were

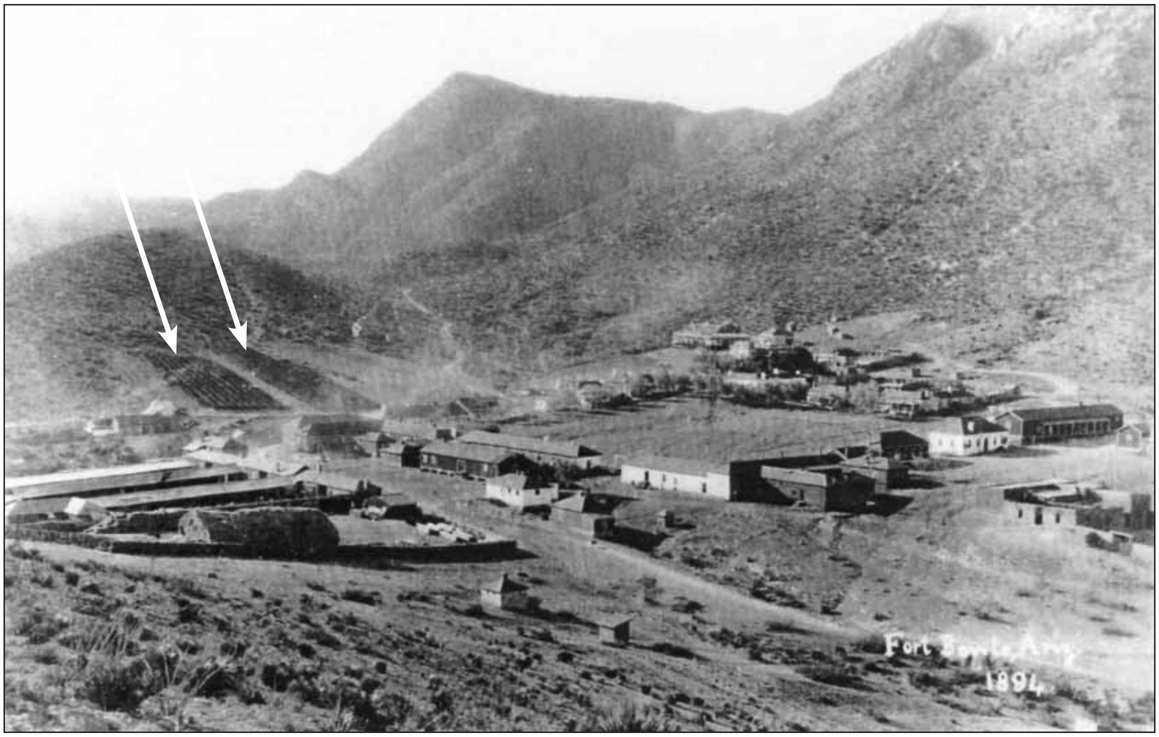

Figure 1.2.7. Fort Bowie in 1894. Arrows indicate rows of cordwood.

likely denuded first and most intensively. Local use by the fort was well documented by Pinto and others (2000), and is evident in the enormous cordwood rows in the background of an 1894 photo of the second Fort Bowie (Figure 1.2.7).

Resource use by the Chiricahua Apache included hunting wild game and harvesting more than 100 species of plants, including yucca, beargrass, mesquite, and agave for food, clothing, tools, medicine, and weapons (Castetter and Opler 1934, as cited in Pinto et al. 2000). Human-caused fire appears to have been an important tool for managing many of these critical natural resources, with fire return intervals of between five and 10 years for any particular location (McPherson 1995).

1.2.8 Natural resource inventories and monitoring

1.2.8.1 Inventories

Twelve basic natural-resource inventories have been authorized and funded through the National Park Service for all 270 park units deemed to have "significant" natural resources (NPS 2009). At time of writing, seven of these inventories had been completed for Fort Bowie NHS. Two others were nearly complete, one was being updated, and the last was scheduled for completion at some future date (Table 1.2.8.1). Coordinated at the national level, most of these inventories rely on existing information and deliver products ranging from electronic data sets to short reports. However, three inventories (species lists, species occurrence and distribution, and vegetation characterization) involved extensive fieldwork culminating in detailed reports. See National Park Service (2009) for additional information on the National Park Service Natural Resource Inventory Program.

1.2.8.2 Long-term monitoring and related ecological research

In addition to terrestrial vegetation and soils monitoring, the Sonoran Desert Network conducts long-term monitoring on air quality, birds, climate, exotic plants (early detection), springs (Apache and Mine Tunnel), and washes (Siphon Canyon) at Fort Bowie NHS. Details on these efforts are provided in NPS (2005) and on the SODN website, http://science.nature.nps.gov/im/units/sodn/.

Fort Bowie NHS has been the focus of other ecological research relevant to terrestrial vegetation and soils monitoring, as well. Warren and others (1992) described vegetation and flora of the site collected from 1972 to 1977, from 36 plots of

Table 1.2.8.1. Status of natural resource inventories at Fort Bowie NHS, October 2009.

Inventory	Description	Status (2009)
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/	In Update
Base Cartographic Data	A compilation of basic electronic cartographic materials. Products: http://science.nature.nps.gov/nrdata/	Complete
Baseline Water Quality	Assessment of water chemistry at Apache and Mine Tunnel Springs. Products: http://www.nature.nps.gov/water/horizon.cfm	Complete
Climate	A basic assessment of nearby climate stations and instrumentation. Products: http://www1.nrintra.nps.gov/NPClime/	Complete
Geologic Resources	A synthesis of existing geologic data, resulting in a report and electronic map.	In progress (complete 2009)
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	Documentation of the occurrence and distributions of >90% of the vertebrates & vascular plant species, based on prior research and fieldwork. Products: Powell et al. 2007	Complete
Species Occurrence and Distribution		
Vegetation Characterization	Description, classification, and mapping of vegetation communities, based on fieldwork.	In progress (complete 2010)
Water Body Location and Classification	Basic geographic data on hydrologic units.	In progress (no completion date given)

0.4 ha, using a modified Braun-Blanquet method (Kent and Coker 1992) to rank species based on ocular estimates. The resulting data were used to produce a vascular-plant checklist (Bennett et al. 1996), and to describe (through subjective classification) and map 11 plant associations using the Brown and others (1979) classification system. Unfortunately, neither descriptive summary data nor actual plot data were presented, precluding any additional analysis or interpretation of these potentially valuable legacy data.

Vegetation characteristics also were addressed qualitatively in faunal research projects. Cockrum and others (1976) completed a survey of all park vertebrates, while Johnson and Lowe (1978) and Lukose (2002) focused on particular reptile species—the latter in the context of Lehmann lovegrass (*Eragrostis lehmanniana*). Powell and others (2007) provided a more comprehensive review of natural-resource research at Fort Bowie NHS.

At time of writing, the Arizona-Sonora Desert Museum, Sonoran Institute, and park staff were conducting a natural resource condition assessment for Fort Bowie NHS. This detailed assessment should identify additional information on resources and resource conditions relevant to terrestrial vegetation and soils of the park. See http://www.nature.nps.gov/water/ for additional information on this servicewide program.

1.3 Natural resource management issues

1.3.1 Cultural landscape considerations

Pinto and others (2000) provided a detailed description and assessment of the cultural history and landscape of Fort Bowie NHS and related off-park resources. In that document, they also specifically evaluated the current condition of the Fort Bowie landscape and highlighted the central role that natural resources (a strategic pass, perennial water, and productive semi-desert grassland) played in the historical activities that the park commemorates and protects. Given this tight linkage between natural and cultural resources at Fort Bowie NHS, managing park vegetation as a cultural landscape (as described by Pinto et al. 2000) is a primary management objective, as emphasized in the park's General Management Plan (NPS 1975) and by its managers (Brian Carey, personal communication).

1.3.2 Mesquite encroachment and shrubland conversion

Woody-plant encroachment into temperate and tropical desert grassland and savanna community types has been widely reported (Brown and Archer 1999). Invasive shrubs and trees are typically native species that have increased in abundance due to shifting biotic or abiotic conditions, such as intensive and often asymmetrical herbivory by livestock or wildlife, altered fire regimes, or shifting climate regimes (Van Auken 2000). Intensive grazing by livestock, such as occurred in and around Fort Bowie NHS in the 1890s (Bailey 1994), has been a primary culprit in woody-plant encroachment. Livestock are effective vectors for seed dispersal, supply a favorable microclimate for germination and recruitment, and reduce interspecific competition and fire occurrence through selective grazing of palatable grasses (Harris 1966; Van Auken 2000; Kupfer and Miller 2005).

In the American Southwest, mesquite plays a pivotal role in shrub encroachment into grasslands and savannas, often converting these systems into dense shrublands and thorn woodlands, with important and potentially irreversible consequences for key structural and functional attributes of these ecosystems (Brown and Archer 1999). As a result, mesquite control has become a major management focus in the region for economic and ecological reasons.

At Fort Bowie NHS, mesquite (*Prosopis velutina* and *P. glandulosa*) is common in both riparian and upland areas. Since the mid-1970s, park staff have sporadically treated mature mesquite trees through cutting and herbicide application, with focus on the Triangle Valley area (Larry Ludwig, personal communication). Future management of the park's grasslands will likely include the reintroduction of fire (D. Foster, personal communication), which, combined with shrub-removal efforts, may mitigate potential mesquite encroachment and support persistence of semi-desert grassland.

1.3.3 Exotic invasive plants

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

Reduced species richness and biological soil cover are indicative of communities degraded by grazing, and have also been linked to invasion by non-native grasses in place of native species not as well-adapted to such pressures (Shinneman and Baker 2009). In general, southwestern semi-desert grasslands, savannas, and riparian community types are at greatest risk of invasion due to modified disturbance regimes involving herbivory and fire.

As part of the U.S. Geological Survey's Weeds in the West project (Halvorson and Guertin 2003), the presence and abundance of 50 pre-selected, introduced plants were assessed and mapped. During this survey effort (1999–2001), 26 non-native, introduced plant species were recorded at Fort Bowie, 12 of which were grasses. Most of the other species were annual forbs, along with notable perennials horehound (*Marrubium vulgare*), tamarisk (*Tamarix* spp., one individual, current status unknown), Boer's lovegrass (*Eragrostis curvula*), Lehmann lovegrass, and Bermuda grass (*Cynodon dactylon*). In 2002–2003, the NPS (Powell et al. 2007) conducted a vascular-plant inventory, adding one more species to the non-native list, wand mullein (*Verbascum virgatum*). Several of these non-native species were introduced to the park as a direct result of human activities, such as past settlement, grazing, farming, excavation, and construction activities.

Figure 1.3.4. Vegetative response a few days after a prescribed fire in mixed-grass prairie. Note the profusion of new, green shoots and leaves amongst the blackened litter.

1.3.4. Fire

Fires consume live and dead plant material, typically in a patchy, mosaic pattern across landscapes, rather than as a contiguous, blanket treatment. Plants are most susceptible to damage or mortality during their active growth period (Wright and Bailey 1982), whereas survivors or post-fire colonizers (Figure 1.3.4) can benefit from increased solar radiation, available nitrogen, and potentially increased surface soil temperature and moisture, and space (Collins 1987).

Fire imposes strong selective pressures on grassland species to develop life-history traits that avoid or mitigate the direct impacts of fire so as to persist and profit from the post-fire environment. Avoidance, either through leaf senescence and protection of growth points (meristems) or persistence as seeds, is the primary adaptation mechanism of semi-desert grassland species. Most perennial grasses and mature woody plants exhibit the former, replacing lost photosynthetic tissue from buds protected within the soil surface or thick bark. Annual grasses are good examples of prolific seed producers, enduring the exposure to fire between successive generations by investing in the seed bank. Some perennial plants also exhibit this strategy.

The timing of grassland fires is critical to determining the vegetative outcome. Wildfires typically occur in conjunction with summer thunderstorms, whereas many prescribed fires are implemented just prior to the spring growing season to stimulate warm-season (C4) grass production, reduce recruitment of woody-plant seedlings and saplings, and decrease fine-fuel loads (Scifries and Hamilton 1993). As these two fire regimes occur under dissimilar climatic conditions and on opposite ends of the growth cycle of most semi-desert grassland plants, the consequences for vegetation dynamics are often quite different.

1.3.5 Changing regional land use and illegal migration

Historically, ranching on private and leased public lands has been the dominant land use in southeastern Arizona. While ranching continues to be an important driver of human activity in the region, there has been a recent increase in demand for exurban housing and services for retirees and telecommuters attracted to the region's scenic landscapes and mild climate (U.S. Census Bureau 2009). This trend is expected to continue, as Cochise County, Arizona (which encompasses Fort Bowie NHS), is expected to well outpace the national annual growth rate of 0.91% from 2009 to 2014 (ESRI 2009). To the east of Fort Bowie NHS, the San Simon Valley and town of Portal have seen an increase in exurban development (including ranchettes and the Diamond Ranch Buddhist Colony on the park boundary), whereas the Sulphur Springs Valley, to the west, remains largely farm and ranchland (Coronado Planning Partnership 2008).

In northern Mexico, populations are also increasing overall. From 1995 to 2005, annual population growth averaged 0.5%—led by the municipality of Agua Prieta in Sonora, with an annual growth rate of 2.5%. However, some municipalities shrank during this period, losing population to U.S. migration (INEGI 2009).

In recent years, national parks near the U.S./Mexico border have experienced dramatic increases in illegal immigrant traffic and counteracting law-enforcement activities (Drake et al. 2005). Within Fort Bowie NHS, most of the traffic is on foot. Impacts include the accumulation of trash, such as backpacks, water bottles, and clothing. In the region, impacts tend to be more severe, with the establishment of well-used trails and campsites, as well as off-road vehicle travel (Drake et al. 2005).

2 Methods

2.1 Response design

The response design for this protocol employs permanent, 20 × 50-m sampling plots (Figure 2.1). The 50-m edges of a 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 a plot. In the spaces between transects (subplots), within-plot frequency is estimated by noting the occurrence of any plant species or lifeform not observed on the adjacent transects. See Hubbard and others (in review) for details on plot configuration and collection of measures.

2.1.1 Vegetation and soil cover

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). Perennial vegetation was recorded to species, whereas annual vegetation was recorded to lifeform—with the exception of a suite of annual non-native plants recorded to the species level. Soil cover was recorded by substrate class (e.g., rock, gravel, litter; see Hubbard et al. in review, SOP #4), with biological soil crust cover recorded to morphological group (e.g., light cyanobacteria, dark cyanobacteria, lichen, moss; see SOP #7).

2.1.2 Vegetation frequency

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

2.1.3 Soil aggregate stability

Surface soil aggregate stability was measured using a modified wet aggregate stability method (Herrick et al. 2005b). Within each plot, samples were collected at pre-determined points on either side of the six line-point intercept transects (see Figure 2.1). A total of 48, uniformly sized (2–3-mm thick and 6–8 mm on each side) samples were tested per plot, in groups of 16. Each sample was placed on a screen and soaked in water for five minutes. After five minutes, the samples were slowly dipped up and down in the water, with the remaining amount of soil recorded as an index of the wet aggregate stability of the sample. Samples were scored from 1 to 6, with 6 being the most stable.

2.1.4 Soil and site characterization

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

2.2 Sampling design

2.2.1 Overview

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

Terrestrial vegetation and soils plots were allocated using a combination of elevation intervals and soil rock fragment classes (see Section 3.2.3, Hubbard et al. in review). All of Fort Bowie NHS occurs within one strata (402) of 4,500–6,000' in elevation, with all surface soils containing 35–90% rock fragments. Therefore, inference from

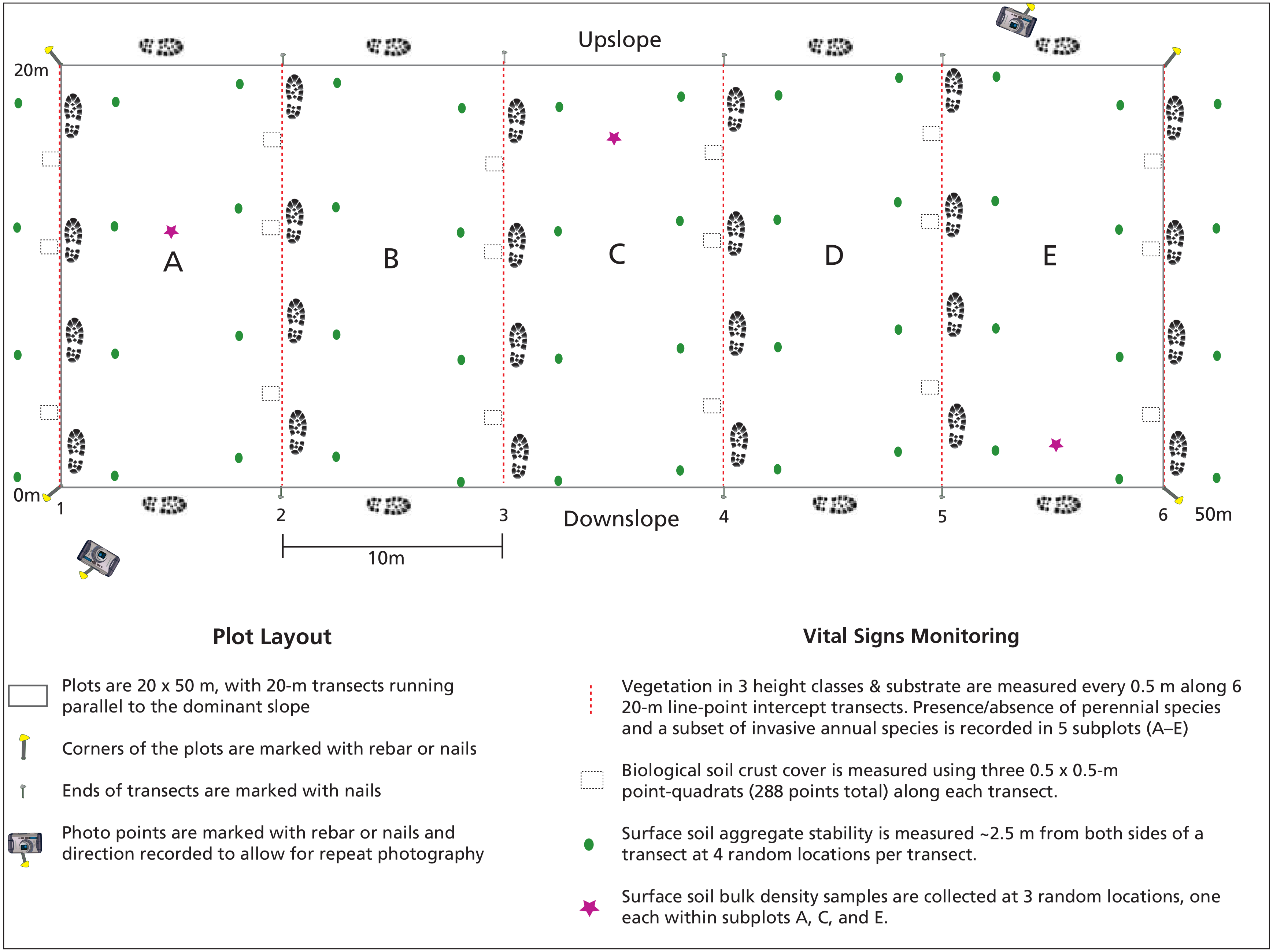

Figure 2.1. Terrestrial vegetation and soils monitoring plot design.

the plots at Fort Bowie NHS is to all terrestrial areas of the park, except for the areas discussed in Section 2.2.3, below.

We allocated a total of 10 monitoring plots in a spatially balanced arrangement (see Section 2.2.2), based on a priori expectations of required sample size to meet our criteria for statistical power and detectability (see Sections 2.2.5–2.2.6). To help determine whether 10 plots would be adequate, we added three "test" plots using the same design, and evaluated the need for incorporating these (and possibly other plots) into our long-term monitoring strategy.

2.2.2 Spatial balance

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

Spatially balanced designs, such as RRQRR (for polygon data) and the Generalized Random Tessellation Stratified (GRTS; for points and lines) approach (Stevens and Olsen 2004), are increasingly being applied to ecosystem monitoring (e.g., the U.S. Environmental Protection Agency Ecological Monitoring and Assessment Program) because they provide the advantages of a probabilistic design (Stehman 1999) and ensure spatial

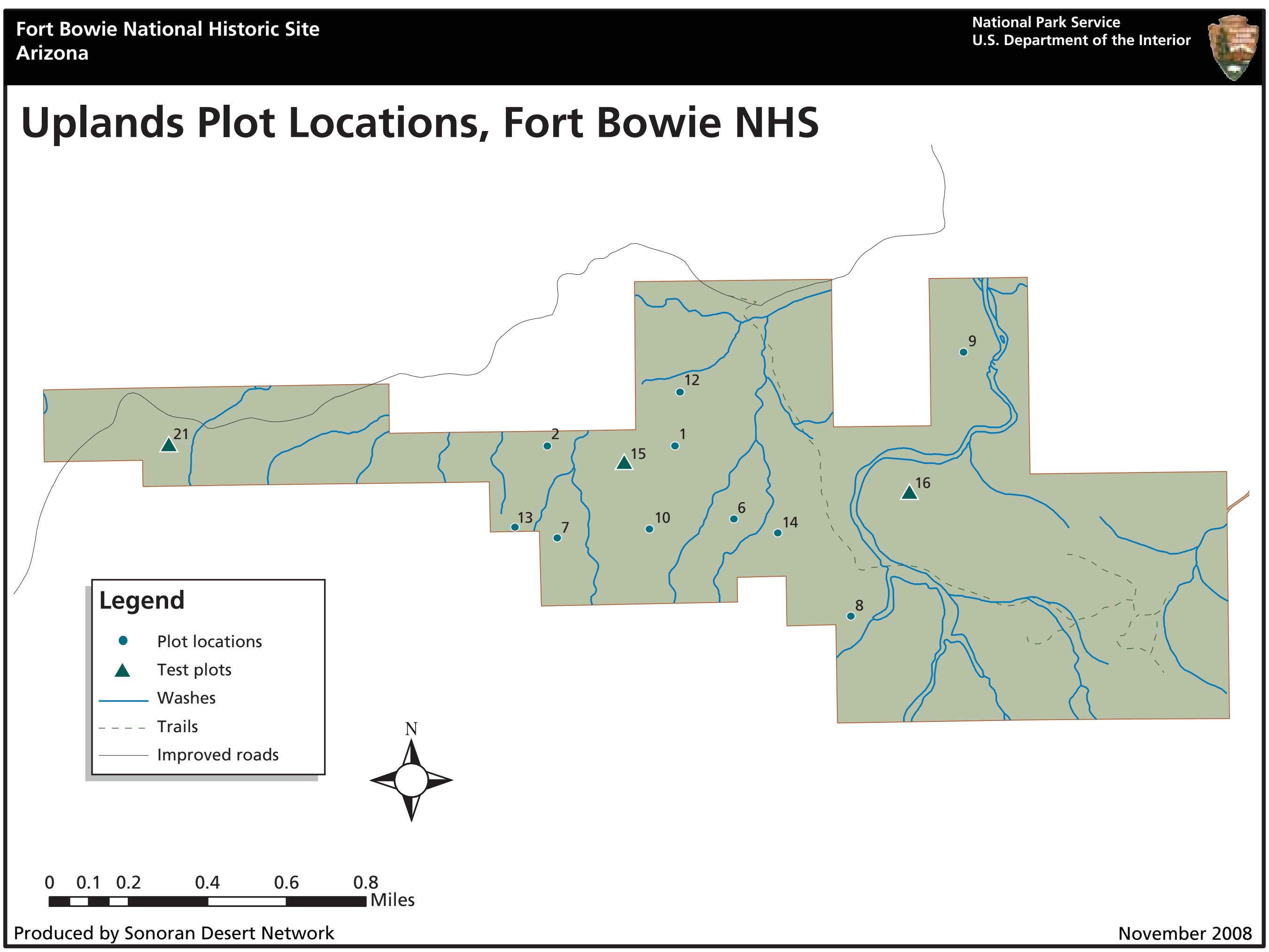

Figure 2.2.1. Allocation of monitoring plots at Fort Bowie National Historic Site.

balance regardless of overall sample size. RRQRR designs allow the user to add or remove 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. in review) and (2) future changes in technology, objectives, and budgets may necessitate increasing or decreasing sample sizes.

2.2.3 Sampling frame

The sampling frame for Fort Bowie NHS includes all terrestrial areas within park boundaries, except for the following (Figure 2.2.3):

- Slopes of ≥45° (for crew safety);
- Roads and buildings (including 100-m buffer);
- Trails (including Butterfield Stage Road), washes, and streams (including 50-m buffer);
- Selected fragile cultural features (the first and second forts, cemetery, Indian Agent and Butterfield stations).

The total area excluded under these criteria was 543 acres (~220 ha), or 56% of the park area.

2.2.4 Management assessment points as the link between science and management

To achieve our core mission of resource protection, resource management and monitoring must be explicitly linked (Bingham et al. 2007). We advocate the use of management assessment points as a bridge between science and management. Management assessment points are ". . . preselected points along a continuum of resource-indicator values where scientists and managers

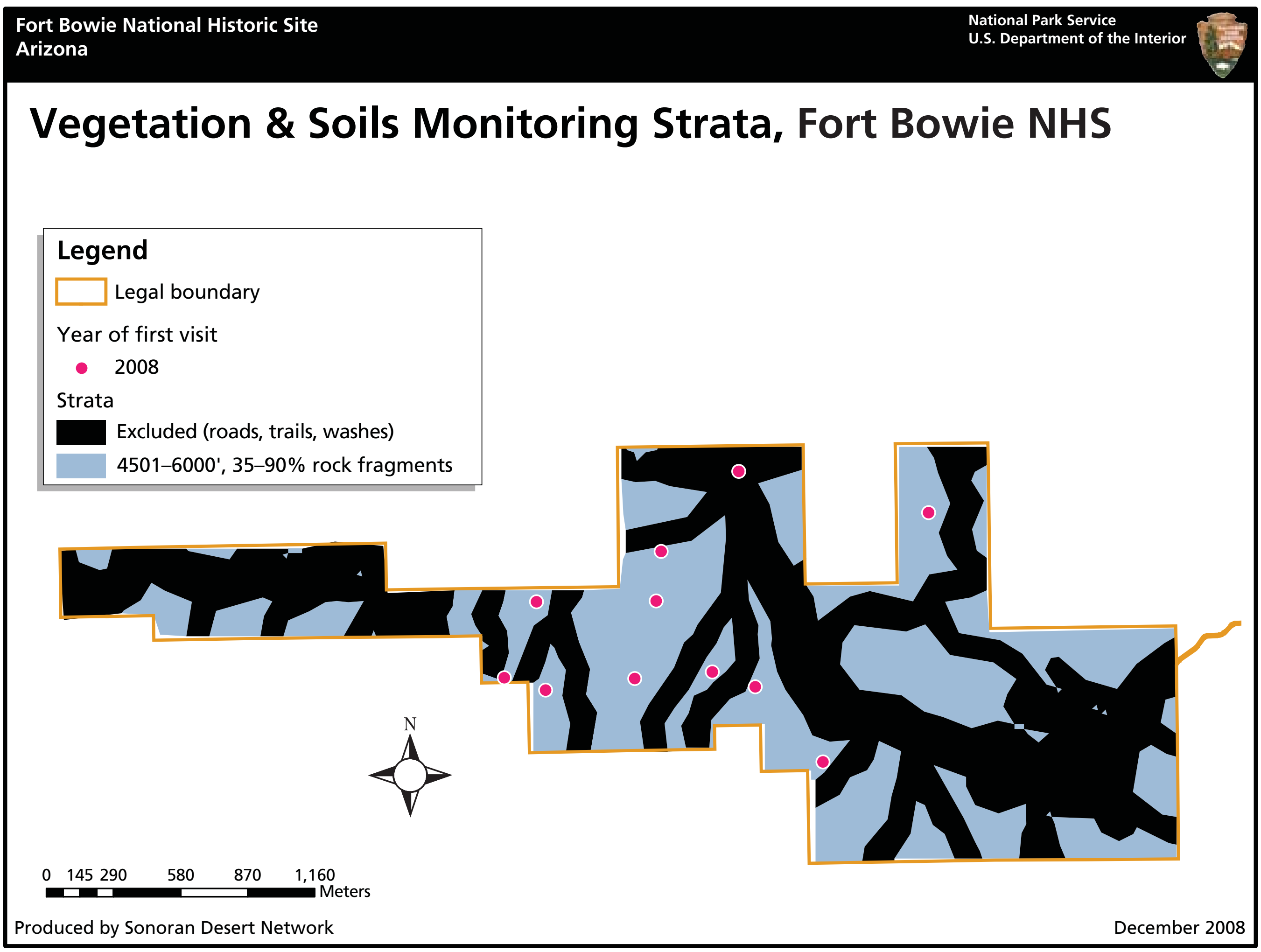

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Figure 2.2.3. Sampling frame for terrestrial vegetation and soils monitoring at Fort Bowie National Historic Site.

Table 2.2.4. Proposed management assessment points for terrestrial vegetation and soils parameters monitored at Fort Bowie National Historic Site.

Issue	Management assessment point*	Information source
Erosion hazard	1 Bare ground cover is >30%	La Cienegas National Conservation Area Management Plan (2003, as cited in Gori and Schussman 2005)
	2 Percentage of surface soil aggregates in "very stable" (6) class is <20%	Value is based on professional judgment of authors; issue is described in Herrick et al. 2005b
Site stability	3 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. 2005a
	4 Proportion of foliar grass cover (%) 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	5 Shrub foliar cover in field and/or subcanopy layer(s) is >35%	McAullife 1995; McPherson 1997; Pellant et al. 2000
Mesquite invasion	6 Mesquite (*Prosopis* spp.) foliar cover in subcanopy and/or canopy layer(s) is >20%	
Exotic plant dispersal	7 Extent (plot frequency) of invasive exotic plants in any layer is >20%	Professional judgment of authors; see SODN Monitoring Plan (NPS 2005) for an overview of the issue
Exotic plant invasion	8 Proportion of foliar plant cover (%) contributed from exotic plants in field layer (etc.) is >10%	

*If current status measurements fall within the levels indicated, then additional review and consideration of the resource issue is needed.

have agreed to stop and assess the status or trend of a resource relative to program goals, natural variation, or potential concerns" (Bennetts et al. 2007).

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

To date, no management assessment points have been formally established for Fort Bowie NHS. Here, we propose eight assessment points based on the ecological literature and our knowledge of these ecosystems and park management goals. We intend these to (1) initiate a discussion of potential indicators and assessment points—a conversation that will expand as the park completes a natural resource condition assessment (see Section 1.2.8.2) and commences additional park planning; and (2) to 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 2.2.4 and discussed in the corresponding sections of Chapter 4 in this report.

2.2.5 Statistical power to distinguish status from management assessment points

Estimating our statistical power to determine current conditions (i.e., status) relative to management assessment points (see Section 2.2.4) is important for both protocol design (especially in terms of determining adequate sample sizes) and data interpretation. Adequate sample size (number of plots) was estimated by Herrick and others (2005a):

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

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%), and

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

Bonham (1989), Elzinga and others (1998), and Herrick and others (2005a) 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%), and
- *MDC* = minimum detectable change size between time 1 and time 2 (set at 5–20%)

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

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

Where:

- S_1 = Sample standard deviation among sampling units at first time period, and
- $corr_{diff}$ = estimated correlation coefficient between time 1 and time 2, set at 0.75.

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

3 Results

3.1 Vegetation monitoring results

3.1.1 Cover and frequency of plant lifeforms

All major lifeforms were encountered on the monitoring plots, with the greatest cover and frequency occurring in the "field" elevation stratum (<0.5 m height; Figure 3.1.1; figures and tables begin on page 19). See Appendix A, Table A1 for a list of species found in the park.

3.1.2 Cover and frequency of perennial plant species

Several native perennial plant species were both ubiquitous (widespread) and occurred in thick patches of relatively high foliar cover, as summarized in Table 3.1.2. Appendix A details the cover (Tables A2–A4) and within-plot and landscape frequencies (Table A5) for all perennial plant species and plots.

3.1.3 Cover and frequency of exotic species

Only two exotic plant species, Lehmann lovegrass and stinkgrass (*Eragrostis cilianensis*), were sampled on the monitoring plots (Table 3.1.3). Both were ubiquitous throughout the park, although always at relatively low foliar cover.

Two additional exotic species, redstem storksbill (*Erodium cicutarium*) and Russian thistle (*Salsola kali*), were detected on frequency subplots within one of the three test plots (see Section 2.2.1 and Appendix A, Tables A6 and A7) at relatively low frequencies.

3.2 Soil monitoring results

3.2.1 Soil cover

Soil substrate cover was dominated by gravel and plant litter. Less than 1% of the soil surface was bare soil without vegetative cover (Table 3.2.1). Plot-specific information is provided in Appendix A, Tables A8 and A9. Only 21.5% of samples not taken from under vegetation cover were found to be in Category 6, as opposed to 37.8% of samples taken from under vegetation cover.

3.2.2 Soil stability

All sites had a surface soil stability rating of at least 3 (somewhat stable). Eight of the sites had a surface stability rating of at least 3.5, the midpoint between "very stable" and "very unstable." About one-third of the samples were in the 6 (very stable) category. Samples collected under vegetation tended to have higher stability values than those collected in open spaces (see Table 3.2.1). Plot-specific information is provided in Appendix A, Tables A8, A9.

3.3 Management assessment points

Most indicators did not approach management assessment points. However, some individual plots had values that suggested the potential for site-specific issues (Appendix A, Tables A10, A11). In addition, there were two parkwide exceptions: (1) the extent of invasive non-native plants; and (2) the proportion of perennial to annual grasses, reflecting a relatively high abundance of annual grasses sampled at Fort Bowie NHS in 2008 (Table 3.3). However, we had less power to determine that the latter assessment point had been met (see Section 3.4.1), as the actual value fell within 10% of the assessment point.

3.4 Estimates of power and species detectability

3.4.1 Power to distinguish monitoring data from management assessment points

Our design permitted us to detect a 5% difference from the management assessment point for most parameters, and a 10% difference for the rest, with 90% power and a 10% chance of a false-change error (see Table 3.3).

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

Our proposed sampling design greatly exceeded our expectations for statistical power to detect trends in lifeforms and common perennial species based on our design criteria (90% power with 10% chance of a false-change error). Our data indicate that we will be able to detect a 5% change (absolute foliar cover) for all detected perennial species and 7 of 10 plant lifeforms with 10 or fewer plots (Table 3.4.2; Appendix A, Tables A2–A4). However, we will only be assured of detecting a 10% change (our original sampling objective) in annual forbs, annual grasses, and perennial grass lifeforms using our criteria, as these species are more variable in their foliar cover.

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

Line-point intercepts on the original 10 monitoring plots detected 72 species. Employment of the frequency subplots added 38 species (Appendix A, Table A6). Pooling cover and frequency data from the test plots (plots 15, 16, 21) detected an additional 4 and 21 species, respectively (Figure 3.4.3; Appendix A, Table A7).

Our design met or exceeded our sampling objectives for detecting trends in uncommon species (i.e., to detect at least a 10% change in within-plot frequency with 90% power and 10% chance of false-change error) for all species encountered in frequency subplots, with the exception of hairyseed bahia (*Bahia absinthifolia*), for which we could only detect a 12% change (Appendix A, Table A6).

3.4.4 New species

Two new perennial grass species were identified during this field sampling season: single threeawn (*Aristida schiedeana*) and woolyspike balsamscale (*Elionurus barbiculmus*) (Figure 3.4.4). Both species are fairly common in the region and are thought to have been present at the park historically, but not previously recognized or sampled. Samples were collected, pressed to herbarium standards, and verified and stored at the University of Arizona herbarium. It is common for field crews to find new species while conducting this level of sampling, in large part because of the intensity and precision of the field method. Also, sampling inevitably occurs at different times of the year across different studies, and certain species are more phenologically likely to be identified during some periods than others. Finally, as part of an ongoing project to update and rigorously verify the species listings for all SODN parks, a park-specific field guide has been developed for FOBO. This guide provides field-crew members, who are all highly trained botanists, with a listing of known species, making it easier for any potentially new species to be identified, collected, and used as voucher specimens.

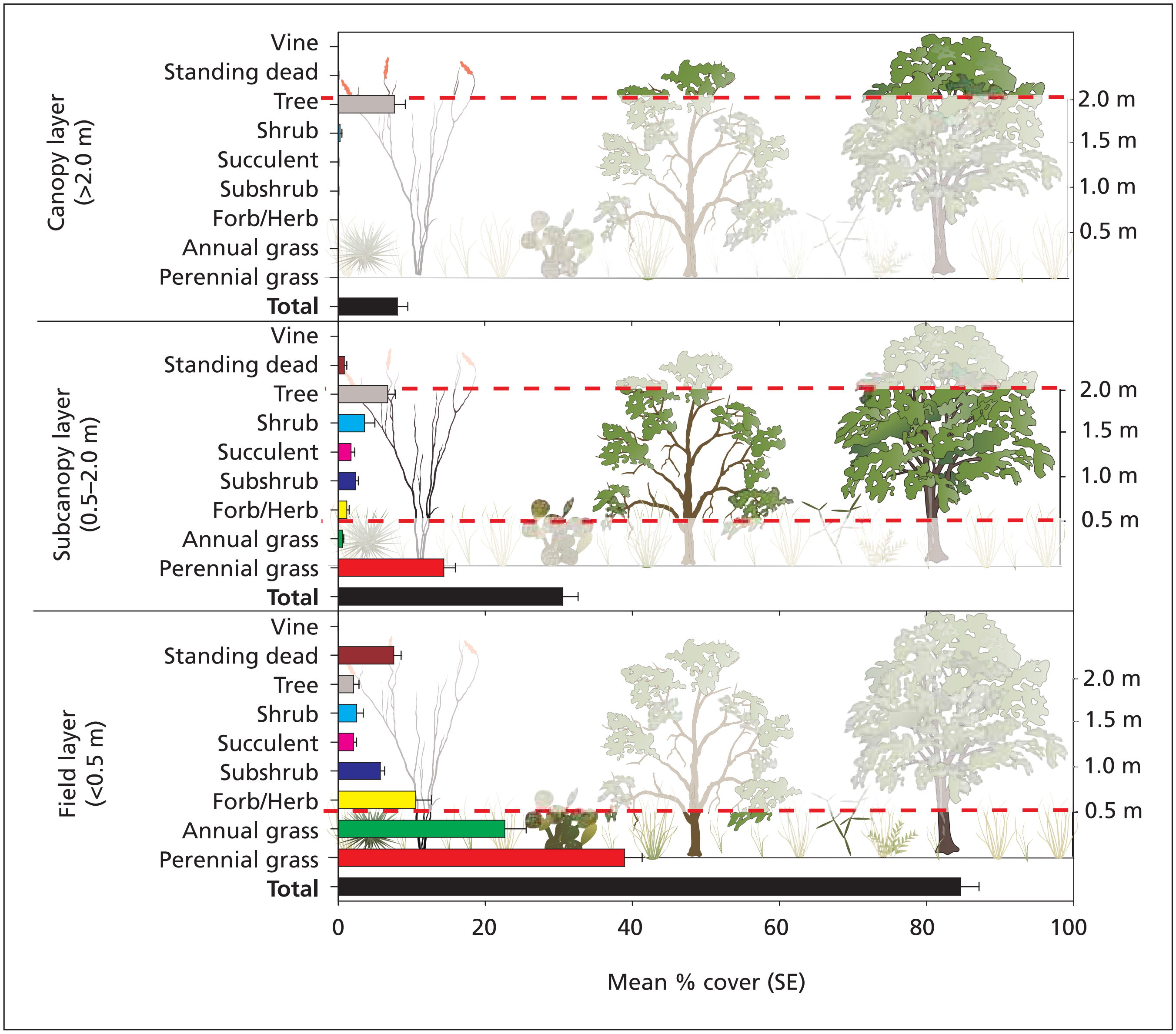

Figure 3.1.1. Lifeform cover in terrestrial vegetation monitoring plots at Fort Bowie NHS, 2008. The greatest cover and frequency occurred in the “field” stratum.

Table 3.1.2. Percent frequency of ubiquitous native species observed on monitoring and test plots, Fort Bowie NHS, 2008.

Species	Common name	# field sites detected	Mean within-plot frequency	SE within-plot frequency
Graminoids				
Aristida ternipes	spidergrass	13 (100%)	80%	13.33%
Bothriochloa barbinodis	cane bluestem	13 (100%)	58%	11.01%
Bouteloua curtipendula	sideoats grama	13 (100%)	86%	8.23%
Bouteloua eriopoda	black grama	13 (100%)	72%	14.30%
Muhlenbergia emersleyi	bullgrass	13 (100%)	56%	13.98%
Aristida purpurea	purple threeawn	11 (85%)	52%	15.06%
Bouteloua hirsuta	hairy grama	11 (85%)	68%	15.78%
Bouteloua repens	slender grama	10 (77%)	60%	19.44%
Chloris virgata	feather fingergrass	10 (77%)	36%	15.49%
Subshrubs				
Ericameria laricifolia	turpentine bush	12 (92%)	76%	16.87%
Gutierrezia sarothrae	broom snakeweed	12 (92%)	72%	13.50%
Nolina microcarpa	sacahuista	12 (92%)	80%	14.91%
Eriogonum wrightii	bastardsage	10 (77%)	32%	18.38%
Succulents				
Opuntia phaeacantha	tulip pricklypear	13 (100%)	60%	12.47%
Opuntia spinosior	walkingstick cactus	13 (100%)	76%	11.35%
Dasylirion wheeleri	common sotol	11 (85%)	42%	17.29%
Yucca baccata	banana yucca	11 (85%)	52%	15.06%
Agave palmeri	Palmer's century plant	10 (77%)	32%	13.50%
Shrubs				
Arctostaphylos pungens	pointleaf manzanita	11 (85%)	48%	14.30%
Mimosa aculeaticarpa	catclaw mimosa	11 (85%)	28%	9.66%
Trees				
Prosopis glandulosa	honey mesquite	11 (85%)	56%	20.44%
Quercus emoryi	Emory oak	11 (85%)	58%	16.63%
Juniperus monosperma	one-seed juniper	10 (77%)	36%	13.17%

Table 3.1.3. Frequency and cover (mean and SE%) of non-native plants sampled in terrestrial vegetation monitoring plots at Fort Bowie NHS, 2008.

Characteristic/Parameter	Data/Measurements	
Scientific name	*Eragrostis lehmanniana*	*Eragrostis cilianensis*
Common name	Lehmann lovegrass	stinkgrass
Lifeform	Graminoid	Graminoid
Number of field sites detected	13 (100%)	9 (69%)
Within-site frequency	62 ± 13%	24 ± 10%
Field cover	3.21 ± 0.90%	0.13 ± 0.07%
Subcanopy cover	1.41 ± 0.58%	0.03 ± 0.03%
Canopy cover	–	–

Table 3.2.1. Park-wide dynamic soil function vital signs, Fort Bowie NHS 2008.

	Soil substrate	% cover mean ± SE
Decreasing erosion hazard ↓	Bare soil (<2 mm), no overhead vegetative cover	0.38% ± 0.07
	Bare soil (<2 mm), under vegetation	4.00% ± 0.78
	Duff (partially decomposed organic matter)	0.42% ± 0.17
	Litter (intact organic matter)	31.30% ± 2.00
	Plant base	5.60% ± 0.66
	Gravel (2–75 mm)	49.10% ± 3.40
	Biological soil crust: moss	0.06% ± 0.04
	Rock (76–600 mm)	6.90% ± 1.80
	Lichen on rock	0.19% ± 0.13
	Bedrock	2.00% ± 0.80

Surface Soil Aggregate Stability

Parameter	Mean ± SE	
	Average soil stability, categories 1–6	% samples in category 6
All samples (n=591)	3.80 ± 0.09	36.1% ± 4.1
Under vegetation	3.94 ± 0.09	37.8% ± 4.2
No vegetation cover	2.63 ± 0.26	21.5% ± 4.8

Category 1 = very unstable; category 6 = very stable

Table 3.3. Terrestrial vegetation and soils monitoring data in the context of proposed management assessment points, Fort Bowie NHS, 2008.

Issue		Management assessment point*	Parkwide mean	SE	MDC	n=	Point met?	Recommendation
Erosion hazard	1	Bare ground cover is >30%	0.39%	0.08%	5%	1	No	Continue monitoring
	2	Percentage of surface soil aggregates in "very stable" (6) class is <20%	36%	4.16%	10%	10	No	Continue monitoring
Site stability	3	Foliar cover of perennial grasses in field layer is <25%	39%	2.47%	10%	4	No	Continue monitoring
	4	**Proportion of foliar grass cover (%) of annuals in field layer is >33%**	**36%**	**4.17%**	**10%**	**10**	**YES**	**Meet and consider**
Shrub encroachment	5	Shrub foliar cover is >35% (field)	2.6%	0.88%	5%	2	No	Continue monitoring
	5	Shrub foliar cover is >35% (subcanopy)	3.6%	1.43%	5%	5	No	Continue monitoring
Mesquite invasion	6	Mesquite (*Prosopis* sp.) foliar cover is >20% (field)	3.0%	1.06%	5%	3	No	Continue monitoring
	6	Mesquite (*Prosopis* sp.) foliar cover is >20% (subcanopy)	1.6%	0.79%	5%	2	No	Continue monitoring
Exotic plant dispersal	**7**	**Extent (plot frequency) of invasive exotic plants in any layer is >20%**	**100%**	**n/a**	**n/a**	**n/a**	**YES**	**Meet and consider**
Exotic plant invasion	8	Proportion of foliar plant cover (%) contributed from exotic plants in field layer (etc.) is >10% (field)	3.78%	0.94%	5%	2	No	Continue monitoring
	8	Proportion of foliar plant cover (%) contributed from exotic plants in field layer (etc.) is >10% (subcanopy)	5.12%	1.96%	5%	9	No	Continue monitoring
	8	Proportion of foliar plant cover (%) contributed from exotic plants in field layer (etc.) is >10% (canopy)	0%	0%	n/a	n/a	No	Continue monitoring

*If current status measurements fall within the levels indicated, then additional condition assessments are needed.
SE = standard error
MDC = minimum detectable change (%). See Section 2.2.5 for formula and defintions.
n = number of plots required to meet power assumptions

Table 3.4.2. Estimated power to detect change (trends) in within-plot frequency based on 2008 data.

Issue		Management assessment point*	MDC	Number of plots
Erosion hazard	1	Bare ground cover is >30%	1%	1
	2	Percentage of surface soil aggregates in “very stable” (6) class is <20%	12%	13
Site stability	3	Foliar cover of perennial grasses in field layer is <25%	8%	11
	4	Proportion of foliar grass cover (%) of annuals in field layer is >33%	10%	10
Shrub encroachment	5	Shrub foliar cover is >35% (field)	5%	3
	5	Shrub foliar cover is >35% (subcanopy)	5%	9
Mesquite invasion	6	Mesquite (*Prosopis* sp.) foliar cover is >20% (field)	5%	5
	6	Mesquite (*Prosopis* sp.) foliar cover is >20% (subcanopy)	5%	3
Exotic plant dispersal	7	Extent (plot frequency) of invasive exotic plants in any layer is >20%	n/a	n/a (no variance)
Exotic plant invasion	8	Proportion of foliar plant cover (%) contributed from exotic plants in field layer (etc.) is >10% (field)	5%	2
	8	Proportion of foliar plant cover (%) contributed from exotic plants in field layer (etc.) is >10% (subcanopy)	5%	9
	8	Proportion of foliar plant cover (%) contributed from exotic plants in field layer (etc.) is >10% (canopy)	5%	n/a (none detected)

*If current status measurements fall within the levels indicated, then additional condition assessments are needed.
MDC = minimum detectable change. See Section 2.2.6 for formula and defintions.

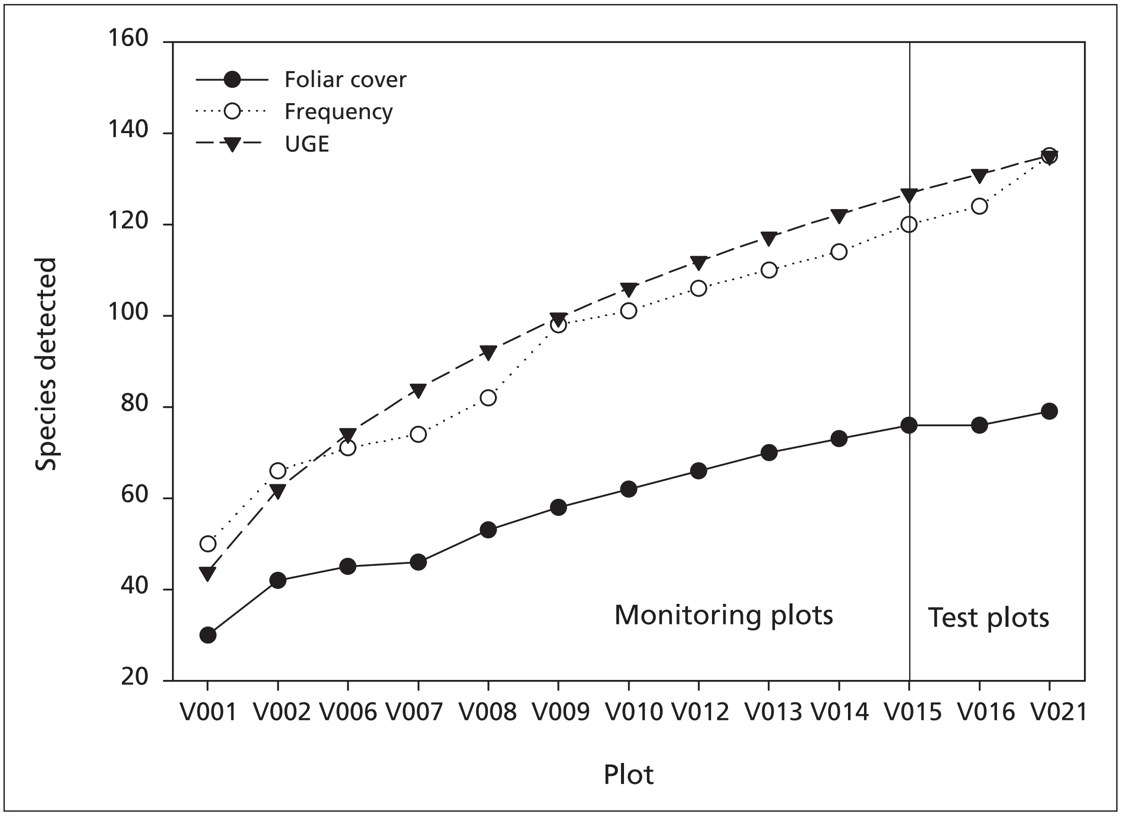

Figure 3.4.3. Species area curves for cover and frequency data collected on terrestrial vegetation and soils plots, Fort Bowie NHS, 2008. Curves show cumulative numbers of species detected as plots are added. UGE = mean species accumulation curve with samples entered in random order (Ugland et al. 2003).


NPS/B. FALLON


NPS/B. FALLON

Figure 3.4.4. Two new species for the park were identified during field sampling: single threeawn (*Aristida schiedeana,* top) and woolyspike balsamscale (*Elionurus barbiculmus*, bottom).

4 Discussion

4.1 Classifying the Fort Bowie landscape

Both frequency and lifeform data illustrated a diverse ecosystem with substantial representation of all primary vegetation lifeforms at Fort Bowie NHS in 2008. This mix of vegetation types may seem incongruous with our traditional views of grasslands, where grasses and other herbs dominate. However, there are critical differences between semi-desert grasslands and the more mesic grasslands of the Great Plains and elsewhere. A comparison of our 2008 vegetation lifeform data from Fort Bowie NHS with that from shortgrass prairie at Fort Union National Monument, New Mexico, and mixed-grass prairie from northern Texas, illustrates this divergence in "grassland" types (Figure 4.1-1).

As noted by McClaran (1995), semi-desert grasslands are distinguished from other grassland types by their unusual abundance of shrubs, trees, subshrubs, and succulents relative to grasses. Burgess (1995) expanded on this concept, suggesting that semi-desert "grasslands" are so named because of the dominance of low-statured plants (including, but not limited to, grasses) and the primary use of these lands for livestock grazing. Instead, Burgess suggested that "Apacherian mixed-shrub savanna" is a more apt description: a designation that our data from Fort Bowie NHS clearly support.

Burgess (1995) attributed the peculiar coexistence of lifeforms in semi-desert grasslands to the profound importance of available soil moisture, and classified semi-desert grassland plants into three functional groups based on water-use strategies:

- ***intensive exploiters:*** Plants that develop dense near-surface roots to efficiently exploit limited and variable shallow soil moisture;
- ***extensive exploiters:*** Plants that invest in large, extensive root systems to access relatively stable moisture contained in deeper soil layers; and
- ***water storers:*** Plants with adaptations that permit the storage of relatively large amounts of water internally to buffer against drought stress.

Each of these functional groups (which are not necessarily mutually exclusive) employs a suite of adaptations, including photosynthetic pathways, patterns of seasonal shoot and leaf production, and (especially) rooting habits, to maximize water balance and carbon gain by partitioning available soil moisture temporally and spatially (Figure 4.1-2).

The result is the coexistence of diverse species and lifeforms in a delicate equilibrium that is subject to the powerful influences of highly variable and typically limited soil-moisture conditions. Interacting disturbances (such as fire and herbivory) and fine-scale variance in soil properties mediate the effects of variable precipitation, which is often very localized in Apache Highlands ecosystems (Gori and Enquist 2003). These shifting soil-moisture conditions favor particular

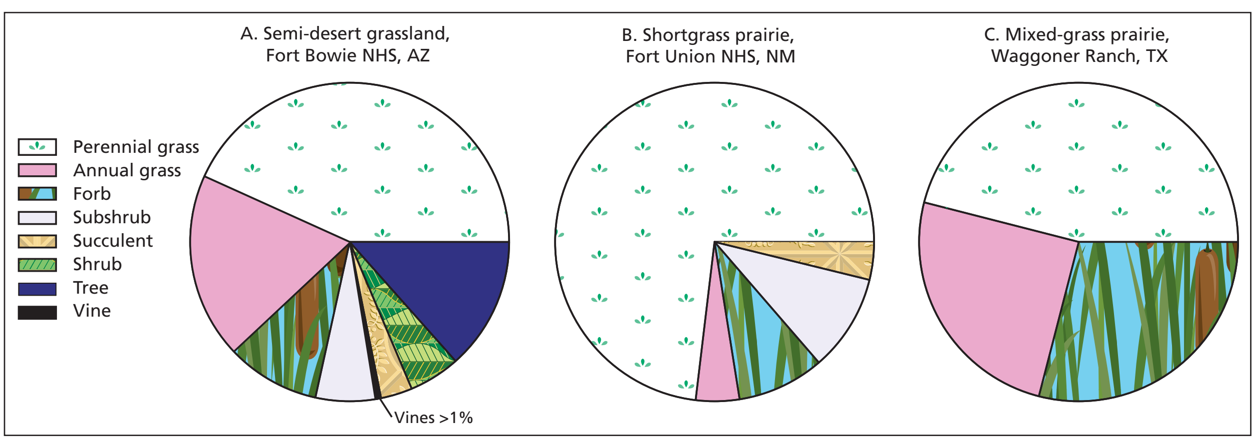

Figure 4.1-1. Vegetation lifeform data collected from (a) Fort Bowie NHS, AZ, (b) Fort Union NHS, NM, and (c) the Waggoner Ranch, TX, illustrate the dramatic differences between semi-desert grassland, shortgrass prairie, and mixed-grass prairie, respectively. Data are from this report, NPS Southern Plains Network (unpublished data), and Hubbard (2003).

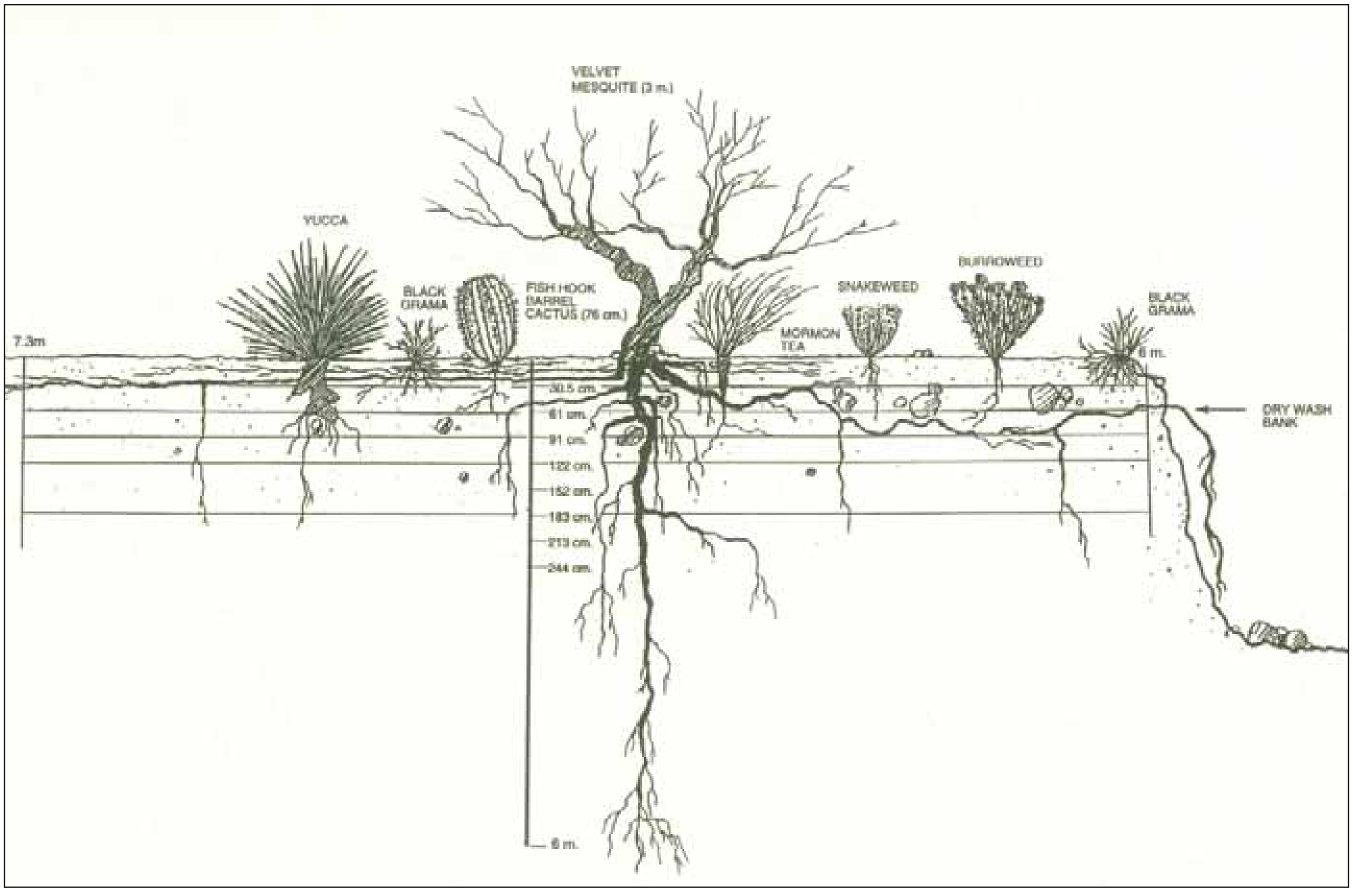

Figure 4.1-2. Root distribution of common plants in desert grasslands of southern Arizona. Black grama (*Bouteloua eriopoda*) and snakeweed (*Gutierrezia sarothrae*) are intensive exploiters. Velvet mesquite (*Prosopis velutina*) and Mormon tea (*Ephedra* sp.) are extensive exploiters. Burroweed (*Isocoma tenuisecta*) uses an intermediate strategy. Fishhook barrel cactus (*Ferocactus wislizenii*) and yucca (*Yucca* sp.) are water storers. Adapted from Cannon 1911, Cable 1969, and examples from the washes of the San Xavier District of the Tohono O'odham Nation. From *The Desert Grassland* by M. P. McClaran and T. R. Van Devender, editors.

functional groups and lifeforms at the expense of others (Figure 4.1-3) at patch scales. As a consequence, the Apache Highlands, including Fort Bowie NHS, are characterized by heterogeneous assemblages of dynamic vegetation formations (semi-desert grassland, savanna, desert, shrubland, woodland) distributed at fine scales across landscapes, but composed of varied mixtures of largely the same species (Burgess 1995).

4.2 Annual grass cover

Although diverse lifeforms are both normal and important in semi-desert grassland, there are potential problems associated with the particular abundance (23% ± 3; see Figure 3.1.1) of annual grasses at Fort Bowie NHS. Specifically, the presence of a high proportion of annual to perennial grasses (see Table 3.3) can have important consequences for site stability, especially in terms of soil erosion.

The annual grasses recorded are native, play important roles in ecosystem function, and are to be expected as an important constituent of functioning semi-desert grassland. However, annuals die off at the end of each growing season, and their future production is subject to variations in precipitation, temperature extremes, and disturbances. The uncertainty of future production, coupled with meager root allocation (typically well less than 1:1 root:shoot production; Grime 1977) increase the odds of potential soil erosion as compared to perennial species, which sustain (albeit senescent) root and shoot architectures even during dormant periods, are usually relatively long-lived, and typically maintain extensive root systems (>1:1 root:shoot allocation).

Minimizing soil erosion at Fort Bowie NHS is important for both natural and cultural resources. Topsoil retention is critical for soil water-holding capacity and soil fertility, with key long-term

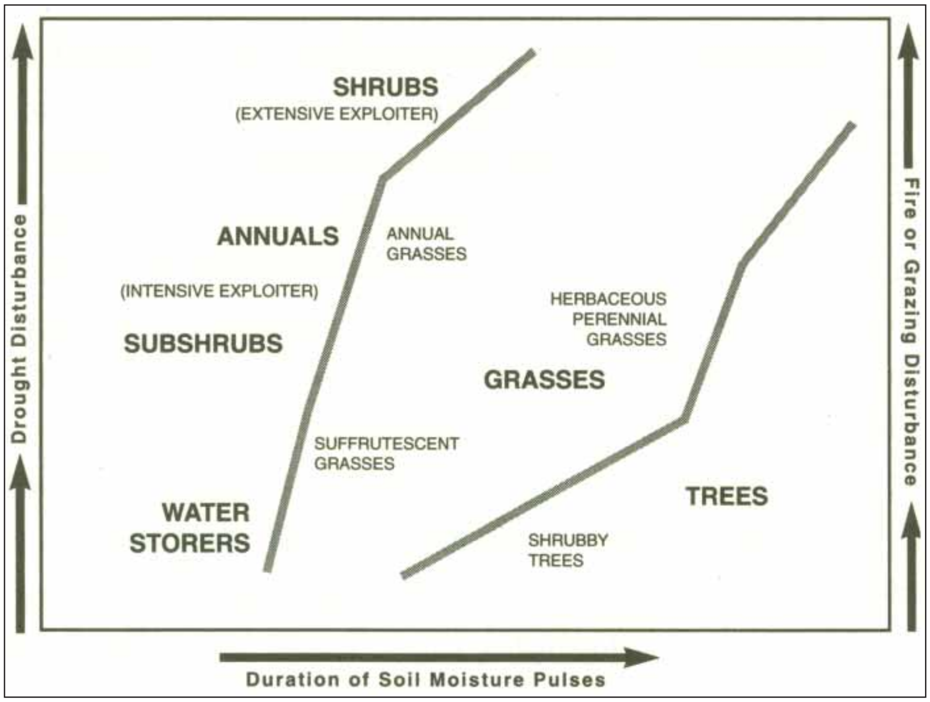

Figure 4.1-3. Phase diagram of growth form dominance along moisture and disturbance gradients. The horizontal axis represents a gradient of increasing duration of soil moisture pulses. The vertical axis is a gradient of disturbance. The severity of disturbance (the amount of living tissue likely to be lost) increases toward the top. Fire disturbance is more likely when the duration of the soil moisture pulses decreases. In the upper left corner, droughts are too severe to support vascular plants. From *The Desert Grassland* by M. P. McClaran and T. R. Van Devender, editors.

consequences for site productivity, nutrient and water cycles, and plant composition. In addition, Fort Bowie NHS contains many distributed, subsurface, cultural resources (Pinto et al. 2000) that could be vulnerable to degradation from soil erosion. Although the proportion of perennial:annual grasses measured at the park in 2008 fell within the error range for our statistical power, its exceedance of Management Assessment Point #4 (see Table 3.3) indicates that managing for perennial vegetative cover could be an effective way to mitigate erosion potential in an increasingly uncertain climatic regime.

4.3 Integrity of the cultural landscape

The Cultural Landscape Inventory for Fort Bowie NHS (Pinto et al. 2000) defined and assessed the park's cultural landscapes through qualitative comparisons of historical accounts, period photos, and published research on semi-desert grassland ecology and land use. After comparing the Fort Bowie landscape in its historical and contemporary periods, the authors of that report rated qualities most closely tied to the natural landscape and its resources as medium to high in terms of integrity. Our quantitative data support those conclusions. Despite some exotic-plant introductions and the retirement of grazing within the park, the landscape retains the open, heterogeneous mix of plant lifeforms described by early accounts, with one exception.

Repeat photographs (Figures 4.3-1–4.3-3, from Pinto et al. 2000) illustrate striking recent increases in woody plants, with the magnitude of change much more pronounced in riparian drainages than in the terrestrial uplands that are the focus of the current monitoring. This likely reflects recovery from the local impacts of historic fuelwood cutting (see Section 1.4.7, Pinto et al. 2000) rather than woody-plant encroachment, as our results indicate relatively low upland tree and shrub cover (see Section 4.4) as compared to many other semi-desert grasslands (or fomerly semi-desert grasslands) in the American Southwest (Gori and Enquist 2003).

4.4 Mesquite invasion and conversion to shrubland

The data in this report do not indicate that mesquite invasion of terrestrial uplands at Fort Bowie NHS is currently occurring. Mesquite and total shrub cover were only 1.6%±1.06 and 3.6%±1.43 in the subcanopy (0.5–2.0 m), respectively—well below our management assessment points for these variables (20% and 35%, respectively). Foliar cover of mesquite seedlings and saplings (<0.5 m) was nearly twice as much as that of established adults, but still only amounted to 3.0%±1.06—much less than even the most restrictive management thresholds for semi-desert grasslands or prairie ecosystems.

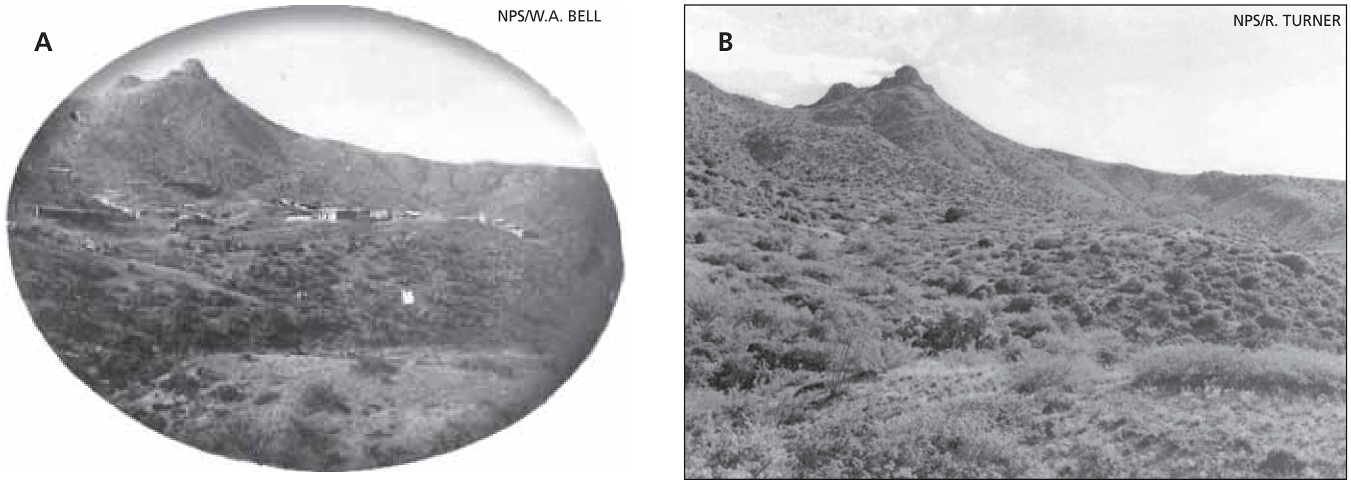

Figure 4.3-1. Site of first fort as viewed from Overlook Ridge (looking south) in (a)1867 and (b) 1998 (Pinto et al. 2000).

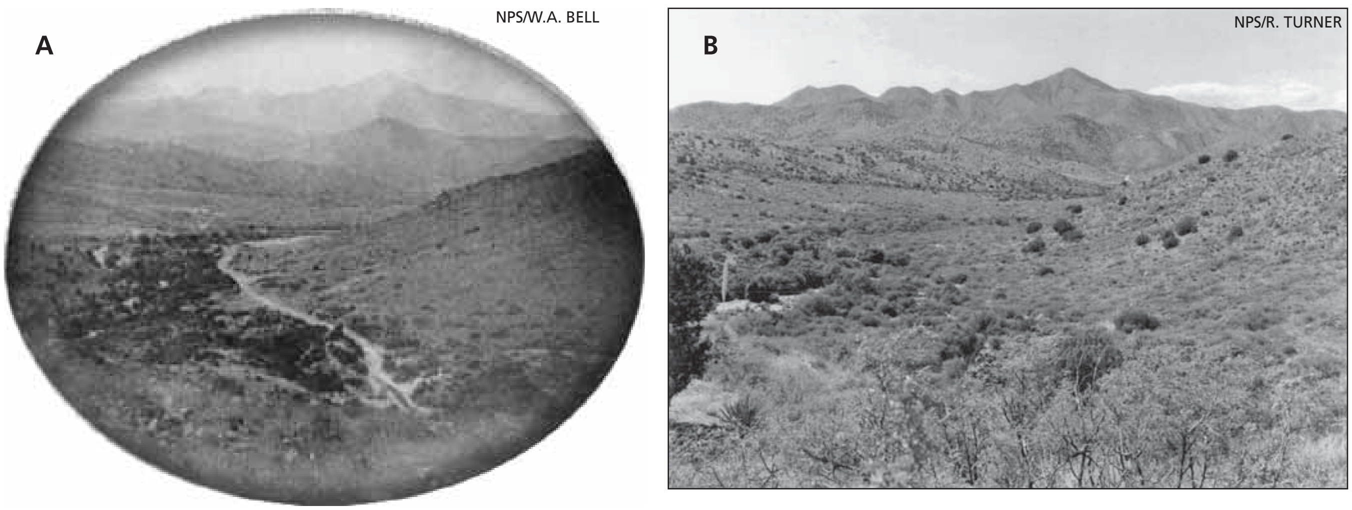

Figure 4.3-2. Apache Wash and the Triangular Valley as viewed from the site of the second fort (looking west) in (a) 1867 and (b) 1998 (Pinto et al. 2000).

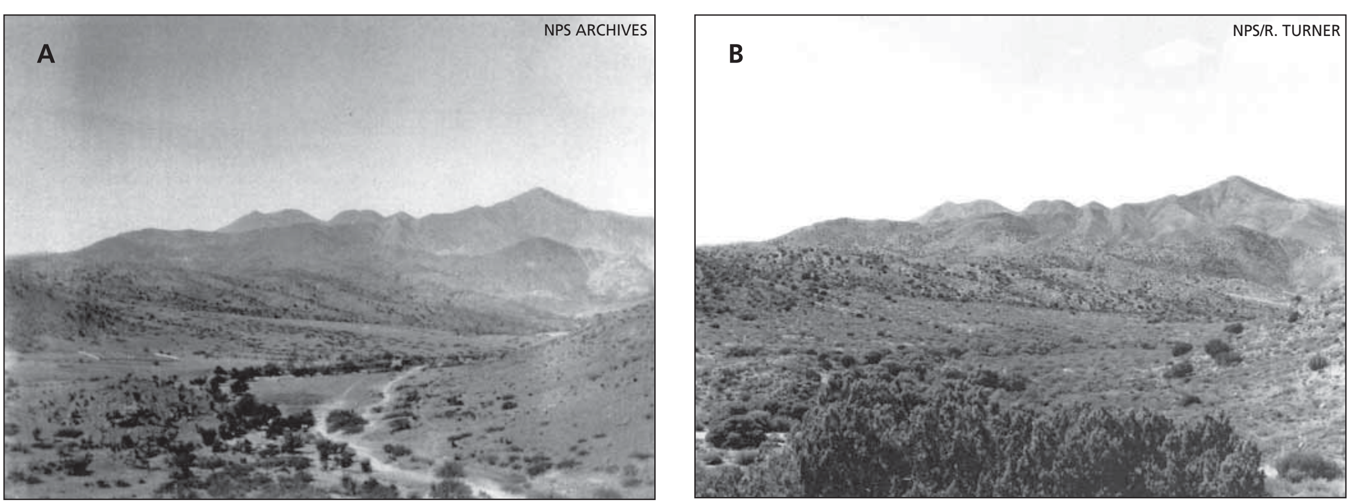

Figure 4.3-3. Apache Wash and the Triangular Valley as viewed from the site of the second fort (looking west) in (a) 1893 or 1894 and (b) 1998 (Pinto et al. 2000).

The negligible woody-plant abundance in terrestrial uplands at Fort Bowie NHS contrasts with most other current or former semi-desert grasslands sites in the Apache Highlands ecoregion (Gori and Enquist 2003). Although this rare, excellent grassland condition has been attributed to three decades of mesquite control actions at the park (NPS 1975), no direct quantitative assessment of those management effects (nor a comprehensive administrative record of those actions), is available, and the answer is likely more complex.

Mesquite invasion, and subsequent conversion to shrubland or woodland, has been a common phenomenon in the American Southwest and southern Great Plains over the past century (Archer 1989). Archer (1995) developed a conceptual model to synthesize the rates, patterns, and processes of this widespread trend in seasonally dry grasslands and savannas.

The process is initiated through "herbaceous retrogression," a decrease in herbaceous plant abundance that is often the result of intensive livestock grazing. Fire occurrence also decreases as fine fuel loads are similarly diminished. Livestock and native herbivores disseminate mesquite seeds from nearby drainages into herb-dominated uplands, depositing the seeds in droppings that provide nearly ideal seedbed conditions.

Mesquite seedlings both escape fire (due to insufficient fine fuels) and are conferred a competitive advantage by herbaceous retrogression, permitting many individuals to grow into adult shrubs and trees. These established plants are effectively decoupled from competition with grasses for light, water, and soil nutrients through resource partitioning via rooting depth and foliage height.

The addition of other woody species is supported through both passive (serving as habitat for birds and other seed-dispersing animals) and active (through soil and microclimate modification) facilitation, continuing the momentum toward woody-plant dominance that may be irreversible without major inputs of management action. It is interesting to note that mesquite may drop out of late-successional systems due to asymmetrical competition (see Section 4.5) from other woody species.

Ansley and Jacoby (1998) demonstrated that effective mesquite control requires moderate-to-low livestock stocking rates (minimizing herbaceous retrogression) and the use of fire that mimics pre-settlement fire regimes. Frequent (every 7–10 years) warm-season ground fires easily kill most mesquite seeds (Cox et al. 1993) and seedlings up to 1 cm in stem diameter (Glendening and Paulsen 1955). Such fires have been absent from the Fort Bowie landscape in recent memory (Carrie Dennett, personal communication), which suggests that mesquite seedlings should be common in the field layer in upland areas of the park. However, such is not the case, indicating that recent and historic livestock grazing have been sufficiently moderate to minimize herbaceous retrogression and limit mesquite seed dispersal.

For areas that have already suffered significant mesquite invasion, an initial treatment of established trees and shrubs, typically involving expensive chemical or mechanical treatments, is required. Mesquite-control efforts at Fort Bowie NHS have focused on initial treatment (cutting and herbicide treatment; Figure 4.4) of the relatively few established adult plants in the Triangle Valley grasslands. Based on the currently low abundance of established mesquite and other woody plants, management efforts could now be efficiently redirected toward restricting mesquite seedling establishment, thereby maintaining the current small pool of propagules. This may best be achieved through continued vigilance against trespass livestock (which encourage seed dispersal and reduce competition from grasses) and reintroduction of fire, which is a very effective killer of mesquite seedlings (Cox et al. 1993).

NPS/J.A. HUBBARD

Figure 4.4. Brush piles from mesquite cutting in Triangle Valley, Fort Bowie NHS, 2006.

4.5 Exotic invasive plants

Exotic-plant encroachment typically occurs in two phases: (1) colonization, the process by which a problematic species gradually disperses into suitable habitats, recruits into the system, and competes for resources with other members of the plant community; and (2) 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 never actually occur, which is why many exotic species are relatively innocuous under some environmental conditions. Determining which phase—colonization or domination—has occurred in a given community is crucial for devising successful management strategies and monitoring designs.

Our data indicate that two exotic grasses, Lehmann lovegrass and stinkgrass, have completed the colonization phase at Fort Bowie NHS. Both are well distributed throughout upland portions of the park (see Table 3.1.3), suggesting that dispersal of these species is not limited to suitable habitats (i.e., sites that are likely to be colonized have been colonized). However, both species occur at relatively low foliar cover values (3.2%±0.90, 0.13%±0.07, respectively), indicating that neither is a major influence on grassland structure at Fort Bowie NHS, nor are they dominating native flora. It appears that native species can effectively compete with these invasive exotics under current conditions.

NPS/S. STUDD

Figure 4.6. An example of fine-fuel loading, Fort Bowie NHS, 2006.

Because neither of these species exhibits alleopathy or other traits that can have disproportionate impacts to ecosystem function at low abundances (unlike tamarisk, for instance, which dramatically increases soil and soil water salinity; Hua Yin et al. 2009), it appears that their impact on terrestrial ecosystems at Fort Bowie NHS is currently negligible. However, information from a concurrent vegetation characterization and mapping effort indicates that both species are prevalent in floodplains along Siphon Canyon and high-visitation locations around the second fort (SODN, unpublished data). In addition, these species, particularly Lehmann lovegrass, possess notable potential for explosive growth and dominance under certain combinations of disturbance and drought (Geiger 2006). Continued vigilance, and the development of a containment strategy that could be employed in the event of a future increase in these potentially problematic species, are recommended.

4.6 The missing factor: Fire

Fire is a "pervasive and powerful force in desert grasslands" (McPherson 1995), second only to available soil moisture in its influence on ecosystem structure and function. Fire effects have a direct bearing on the relative abundances of lifeforms (see Sections 4.1–4.2), the open character of the cultural landscape (see Section 4.3), and, especially, on the encroachment of exotic invasive grasses (see Section 4.5) and native shrubs and trees (see Section 4.4). Understanding the consequences of fire regimes in the context of management is critical for addressing these issues.

Fires were historically common in semi-desert grasslands (Bahre 1991; Humphrey 1958), likely occurring on a given site every 7–10 years prior to the introduction of widespread livestock grazing (which reduced fine fuels) in the 1880s (McPherson 1995). However, under NPS management (1970s–present), wildfires have been absent and fire use has been considered as a management tool, but not applied (C. Dennett, personal communication). Fire occurrence (and reoccurrence) in these systems is inevitable due to the dependable combination of fine fuels (Figure 4.6-1) and ignition sources (McPherson 1995). Prescribed fire planning and use provide managers with the ability to influence the timing, rates, and extent of fire—factors that may have more direct influence on natural resources than any other land-management tool.

The interaction of life-history traits and the timing of fire occurrence greatly influence the life-form composition of semi-desert grassland. As described in Section 4.4, ground fires are the most critical step in limiting the recruitment of mesquite and other woody plants into semi-desert grassland (Archer 1995), promoting an open, heterogeneous landscape with high patch diversity, as described in Pinto and others (2000).

It is important to note that fire—especially frequent fire—often favors the occurrence and even dominance of annual grasses and forbs, as well as the troublesome exotic invasive *Eragrostis* spp. (Ruyle et al. 1988) already detected throughout the park. Any fire plan would need to consider that some fire-use approaches may exacerbate these problems (although fire use during active growth but before seeds are set may restrict these prolific seed producers from gaining any advantage).

4.7 Site stability

Our data on the dynamic factors of water erosion indicated that the sites are fairly stable. However, three plots (V001, V002, and V006) had rills or gullies—signs of water erosion (Figure 4.7). In general, the sites did not show signs of disturbance, and the overall soil aggregate stability of the sites was moderate to high, indicating that the sites can resist raindrop and surface-flow erosion. Total cover of the sites was very high, with little exposed bare soil. However, a large amount of cover comes from annual grasses and litter, which could leave the sites susceptible to erosion if fire or drought removed those materials.

4.8 Protocol assessment

Because this effort entailed some of the first terrestrial vegetation and soils monitoring conducted in the SODN, 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 individual plots were sampled within 3–5 hours, including tasks that will not need to be repeated in successive visits (initial plot layout, permanent marking and mapping, and collection of in situ soil and landscape parameters).

NPS/C.L. FILIPPONE

Figure 4.7. Three plots showed signs of water erosion.

Although the sampling design was greatly simplified by the occurrence of only one stratum in this small park, comparison with vegetation-mapping data (SODN unpublished data) suggests that we may be undersampling some of the limestone-dominated areas (1 of 10 monitoring plots). Warren and others (1992) indicated that this parent material can help to differentiate Chihuahuan Desert types from Apache Highlands plant assemblages. Given the small area of this limestone type (Figure 4.8), the spatially balanced random allocation of plots was unlikely to locate more than a few plots in this parent material. We suggest that additional plots be included if it is determined that this area is of particular interest to park management.

Our design greatly exceeded the statistical power thresholds established in the monitoring objectives. Based on power alone, it would be possible to monitor fewer than the 10 plots allocated, let alone the three additional test plots sampled in 2008. However, we consider the tradeoff in species detectability (see Figure 3.4.3) and relatively minor per-plot time investment to be worth the effort of collecting data on all 10 plots for the long-term monitoring design. We detected approximately one-quarter of the documented flora of the park (Powell et al. 2005)—a reasonable amount, considering that we grouped all annual grasses and forbs, and did not sample within riparian zones (those areas are sampled in the SODN Washes and Seeps/Springs/Tinajas protocols).

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

Based on the vital signs for species composition, community structure, and dynamic soil function, we conclude that terrestrial vegetation and soils at Fort Bowie NHS are well within the range of natural variability. Recognizing the limitations of historical data, the current park conditions compare very favorably with those described in local and regional accounts. In fact, in a recent assessment, Gori and Enquist (2003) concluded that only about 15% of the more than 13 million acres of current or former semi-desert grassland in the Apache Highlands ecoregion are composed of native grassland with low shrub cover, such as we documented at Fort Bowie NHS. As such, it is important to recognize the special role Fort Bowie NHS plays in protecting an intact section (albeit small) of an iconic yet imperiled ecosystem of the American Southwest.

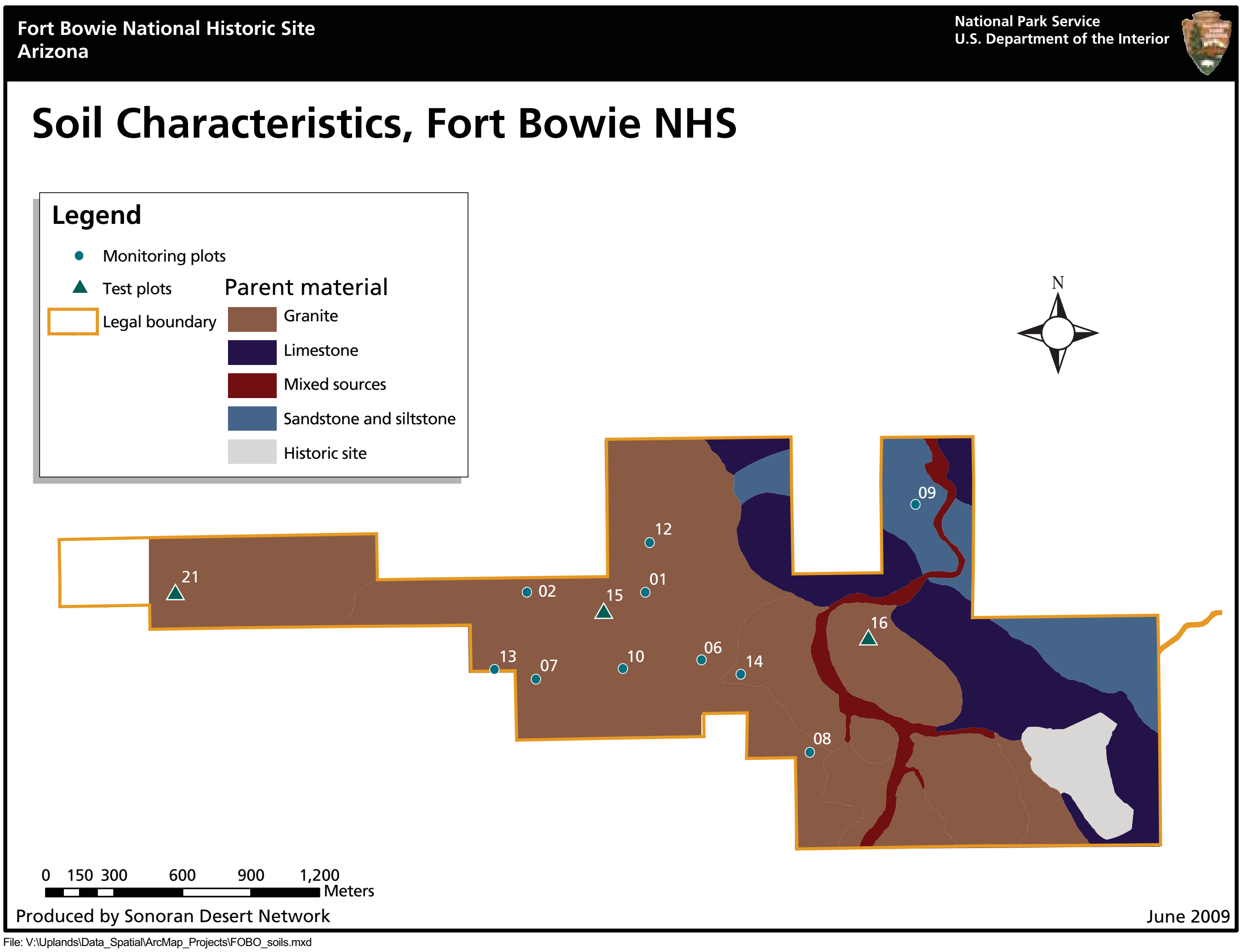

Figure 4.8. Soil parent material at Fort Bowie NHS. From Denney and Peacock (2000).

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Appendix A. Supplementary Data Tables

Table A1. List of species detected during monitoring and vegetation codes.

Veg code	Scientific name	Common name
Forb/Herbs		
ACANEO	*Acalypha neomexicana*	New Mexico copperleaf
AMARANTHUS	*Amaranthus*	amaranth sp.
AMAPAL	*Amaranthus palmeri*	carelessweed
AMBRO	*Ambrosia*	ragweed
ARTLUD	*Artemisia ludoviciana*	white sagebrush
BAHABS	*Bahia absinthifolia*	hairyseed bahia
BOECOC	*Boerhavia coccinea*	scarlet spiderling
BOEERE	*Boerhavia erecta*	erect spiderling
CHASOR	*Chamaesaracha sordida*	hairy five eyes
CHEILANTHES	*Cheilanthes*	lipfern
DALEA	*Dalea*	prairie clover
DALPOG	*Dalea pogonathera*	bearded prairie clover
DALWRI	*Dalea wrightii*	Wright's prairie clover
DATWRI	*Datura wrightii*	sacred thorn apple
DICCAP	*Dichelostemma capitatum*	bluedicks
ERILOB	*Erigeron lobatus*	lobed fleabane
ERIWRI	*Eriogonum wrightii*	desert trumpet
EROCIC	*Erodium cicutarium*	redstem storksbill
HEDOBL	*Hedeoma oblongifolia*	oblong false pennyroyal
IPOMOEA	***Ipomoea***	**morning-glory vine**
LOTGRE	*Lotus greenei*	Green's bird's-foot trefoil
LOTWRI	*Lotus wrightii*	Wright's deervetch
MENTZ	*Mentzelia*	blazingstar
NICOBT	*Nicotiana obtusifolia*	desert tobacco
PSECANCAN	*Pseudognaphalium canescens* ssp. *canescens*	Wright's cudweed
SALKAL	***Salsola kali***	**Russian thistle**
VERENC	*Verbesina encelioides*	golden crownbeard
VERROT	*Verbesina rothrockii*	Rothrock's crownbeard
Graminoids		
ARISTIDA	*Aristida*	threeawn
ARIPAN	*Aristida pansa*	Wooton's threeawn
ARIPUR	*Aristida purpurea*	purple threeawn
ARISCH	*Aristida schiedeana*	single threeawn
ARITER	*Aristida ternipes*	spidergrass
BOTBAR	*Bothriochloa barbinodis*	cane bluestem
BOUELU	*Bouteloua eludens*	Santa Rita Mountain grama
BOUTELOUA	*Bouteloua*	grama
BOUARI	*Bouteloua aristidoides*	needle grama
BOUBAR	*Bouteloua barbata*	sixweeks grama
BOUCHO	*Bouteloua chondrosioides*	sprucetop grama
BOUCUR	*Bouteloua curtipendula*	sideoats grama

Table A1. Species list and vegetation codes, cont.

Veg code	Scientific name	Common name
Graminoids, cont.		
BOUERI	*Bouteloua eriopoda*	black grama
BOUGRA	*Bouteloua gracilis*	blue grama
BOUHIR	*Bouteloua hirsuta*	hairy grama
BOUREP	*Bouteloua repens*	slender grama
CHLVIR	*Chloris virgata*	feather fingergrass
DASPUL	*Dasyochloa pulchella*	fluffgrass
DIGCAL	*Digitaria californica*	Arizona cottontop
ELIBAR	*Elionurus barbiculmis*	woolyspike balsamscale
ERAGROSTIS	Eragrostis	lovegrass
ERACIL	***Eragrostis cilianensis***	**stinkgrass**
ERAINT	Eragrostis intermedia	plains lovegrass
ERALEH	***Eragrostis lehmanniana***	**Lehmann lovegrass**
ERILEM	*Eriochloa lemmonii*	canyon cupgrass
HETCON	*Heteropogon contortus*	tanglehead
LEPDUB	*Leptochloa dubia*	green sprangletop
LYCPHL	*Lycurus phleoides*	common wolfstail
LYCSET	*Lycurus setosus*	bristly wolfstail
MUHEME	*Muhlenbergia emersleyi*	bullgrass
MUHFRA	*Muhlenbergia fragilis*	delicate muhly
MUHPOR	*Muhlenbergia porteri*	bush muhly
MUHRIG	*Muhlenbergia rigens*	deer muhly
PANHIR	*Panicum hirticaule*	Mexican panicgrass
PANOBT	*Panicum obtusum*	vine mesquite
SCHCIR	*Schizachyrium cirratum*	Texas bluestem
SETARIA	*Setaria*	bristlegrass
SETGRI	*Setaria grisebachii*	Griseback's bristlegrass
SETLEU	*Setaria leucopila*	streambed bristlegrass
SPOAIR	*Sporobolus airoides*	alkali sacaton
SPOCRY	*Sporobolus cryptandrus*	sand dropseed
Shrubs		
ALOWRI	*Aloysia wrightii*	Wright's beebrush
ARCPUN	*Arctostaphylos pungens*	pointleaf manzanita
ARTEMISIA	*Artemisia*	sagebrush
CALLIANDRA	*Calliandra*	fairyduster
CALERI	*Calliandra eriophylla*	fairyduster
FOUSPL	*Fouquieria splendens*	ocotillo
GARWRI	*Garrya wrightii*	Wright's silktassel
MIMACU	*Mimosa aculeaticarpa*	catclaw mimosa
MIMACUBIN	*Mimosa aculeaticarpa* var. *biuncifera*	catclaw mimosa
SHRUB LIFEFORM		
PARINC	*Parthenium incanum*	mariola
RHUMIC	*Rhus microphylla*	littleleaf sumac
RHUTRIPIL	*Rhus trilobata* var. *pilosissima*	skunkbush sumac

Table A1. Species list and vegetation codes, cont.

Veg code	Scientific name	Common name
Shrubs, cont.		
RHUVIR	*Rhus virens*	evergreen sumac
SIDLAN	*Sideroxylon lanuginosum*	gum bully
Subshrubs		
BRIBAC	*Brickellia baccharidea*	resinleaf brickellbush
BRICAL	*Brickellia californica*	California brickellbush
BRIVEN	*Brickellia venosa*	veiny brickellbush
CHANIC	*Chamaecrista nictitans*	sensitive partridge pea
CROPOT	*Croton pottsii*	leatherweed
DASWHE	*Dasylirion wheeleri*	sotol
ERILAR	*Ericameria laricifolia*	turpentine bush
ERIWRI	*Eriogonum wrightii*	bastardsage
GUTMIC	*Gutierrezia microcephala*	threadleaf snakeweed
GUTSAR	*Gutierrezia sarothrae*	broom snakeweed
ISOCOR	*Isocoma coronopifolia*	common goldenbush
ISOTEN	*Isocoma tenuisecta*	burroweed
NOLMIC	*Nolina microcarpa*	beargrass
SOLELA	*Solanum elaeagnifolium*	silverleaf nightshade
SPHAERALCEA	*Sphaeralcea* sp.	globemallow
SPHLAX	*Sphaeralcea laxa*	caliche globemallow
STEPAU	*Stephanomeria pauciflora*	brownplume wirelettuce
TRICAL	*Trixis californica*	American threefold
ZINGRA	*Zinnia grandiflora*	Rocky mountain zinnia
Succulents		
AGAPAL1	*Agave palmeri*	Palmer’s century plant
AGAPAR	*Agave parryi*	Parry’s century plant
ECHINOCEREUS	*Echinocereus*	hedgehog cactus
ECHPEC	*Echinocereus pectinatus*	rainbow cactus
ECHRIG	*Echinocereus rigidissimus*	rainbow hedgehog cactus
FERWIS	*Ferocactus wislizeni*	candy barrelcactus
MAMMI	*Mammillaria*	globe cactus
OPUNTIA	*Opuntia*	cactus
OPUENG	*Opuntia engelmannii*	cactus apple
OPUMAC1	*Opuntia macrocentra*	purple pricklypear
OPUPHA	*Opuntia phaeacantha*	brown-spined pricklypear
OPUSPI	*Opuntia spinosior*	walkingstick cactus
YUCBAC	*Yucca baccata*	banana yucca
Trees		
ACAGRE	*Acacia greggii*	catclaw acacia
CELLAERET	*Celtis laevigata* var. *reticulata*	netleaf hackberry
JUNCOA	*Juniperus coahuilensis*	redberry juniper
JUNMON	*Juniperus monosperma*	oneseed juniper
MORMIC	*Morus microphylla*	Texas mulberry
PINEDU	*Pinus edulis*	twoneedle pinon

Table A1. Species list and vegetation codes, cont.

Veg code	Scientific name	Common name
Trees, cont.		
PROGLA	*Prosopis glandulosa*	honey mesquite
QUEEMO	*Quercus emoryi*	Emory oak
QUETUR	*Quercus turbinella*	Sonoran scrub oak
Vines		
GALWRI2	*Galactia wrightii*	Wright's milkpea
IPOHED	*Ipomoea hederifolia*	ivyleaf morning glory
JANGRA	*Janusia gracilis*	slender janusia
PHASE	*Phaseolus*	bean

Bolded species are invasive exotics.

Table A2. Within-plot cover values for species and lifeforms measured in the "field" (<0.5 m stature) layer of terrestrial vegetation and soils plots at Fort Bowie NHS, 2008.

Veg code	Monitoring plots										Test plots			Parkwide values			
	V001	V002	V006	V007	V008	V009	V010	V012	V013	V014	V015	V016	V021	AVG	SE	MDC	n=
SPECIES																	
Forbs/Herbs																	
ACANEO	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.03%	0.03%	5%	1
BOECOC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.22%	0.15%	5%	1
BOEERE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.4%	1.3%	0.0%	0.0%	0.0%	0.16%	0.10%	5%	1
BOMHIS	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.03%	0.03%	5%	1
DICCAP	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.03%	0.03%	5%	1
IPOMOEA	**0.0%**	**0.0%**	**0.4%**	**0.0%**	**3.8%**	**0.0%**	**0.0%**	**0.4%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.35%**	**0.29%**	**5%**	**1**
Graminoids																	
ARIPAN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	0.0%	0.0%	0.06%	0.06%	5%	1
ARIPUR	0.8%	0.8%	0.4%	5.4%	0.0%	0.0%	2.5%	3.3%	10.8%	5.4%	5.0%	0.0%	2.1%	2.82%	0.88%	5%	2
ARISTIDA	0.0%	0.0%	0.0%	0.0%	6.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.51%	0.51%	5%	1
ARITER	3.8%	2.9%	2.1%	1.7%	3.8%	0.4%	4.2%	2.5%	6.3%	10.4%	0.4%	0.8%	0.4%	3.04%	0.78%	5%	2
BOTBAR	0.8%	0.8%	0.4%	0.0%	0.4%	0.0%	1.7%	0.0%	0.0%	2.9%	0.0%	0.8%	0.0%	0.61%	0.24%	5%	1
BOUARI	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.03%	0.03%	5%	1
BOUBAR	0.0%	1.3%	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%	1.3%	0.0%	0.0%	0.0%	0.29%	0.15%	5%	1
BOUCHO	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.03%	0.03%	5%	1
BOUCUR	3.8%	5.4%	4.2%	1.3%	5.4%	4.6%	4.6%	12.5%	3.8%	12.5%	2.9%	11.7%	3.8%	5.87%	1.05%	5%	3
BOUELU	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.03%	0.03%	5%	1
BOUERI	0.0%	15.0%	2.5%	20.4%	19.2%	3.8%	3.3%	4.6%	16.7%	1.7%	5.8%	16.3%	5.0%	8.78%	2.06%	5%	10
BOUGRA	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	1.3%	0.8%	0.0%	0.8%	0.0%	0.0%	13.3%	1.38%	1.01%	5%	3
BOUHIR	2.1%	5.8%	4.6%	3.3%	0.4%	0.0%	7.1%	3.8%	5.8%	0.4%	5.4%	0.0%	0.8%	3.04%	0.71%	5%	2
BOUREP	0.0%	0.0%	2.1%	0.4%	0.0%	0.0%	1.3%	0.0%	0.8%	0.0%	2.1%	0.0%	0.0%	0.51%	0.22%	5%	1
BOUTELOUA	0.0%	0.0%	0.0%	0.4%	4.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.42%	0.35%	5%	1
CHLVIR	0.0%	1.3%	0.0%	0.4%	0.0%	0.0%	0.0%	0.4%	0.0%	1.3%	0.0%	0.4%	0.0%	0.29%	0.13%	5%	1
DIGCAL	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.13%	0.10%	5%	1
ERACIL	**0.0%**	**0.0%**	**0.8%**	**0.0%**	**0.4%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.4%**	**0.13%**	**0.07%**	**5%**	**1**
ERAINT	1.3%	0.0%	0.0%	0.4%	2.1%	0.0%	2.1%	0.0%	0.0%	0.8%	1.7%	0.0%	2.1%	0.80%	0.25%	5%	1
ERALEH	**0.0%**	**8.3%**	**1.3%**	**0.0%**	**3.3%**	**0.8%**	**6.3%**	**0.0%**	**3.3%**	**4.2%**	**1.3%**	**10.0%**	**2.9%**	**3.21%**	**0.90%**	**5%**	**2**
HETCON	3.3%	0.0%	0.4%	0.4%	0.0%	1.3%	0.4%	5.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.87%	0.43%	5%	1
LEPDUB	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.8%	0.4%	0.0%	0.0%	0.0%	0.0%	0.19%	0.09%	5%	1

Table A2. Within-plot cover values for species and lifeforms measured in the "field" (<0.5 m stature) layer of terrestrial vegetation and soils plots at Fort Bowie NHS, 2008, cont.

Veg code	Monitoring plots										Test plots			Parkwide values			
	V001	V002	V006	V007	V008	V009	V010	V012	V013	V014	V015	V016	V021	AVG	SE	MDC	n=
Graminoids, cont.																	
LYCSET	0.4%	0.0%	0.8%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.13%	0.07%	5%	1
MUHEME	10.0%	0.0%	18.3%	0.4%	0.0%	0.0%	0.8%	1.3%	0.0%	0.0%	7.5%	0.8%	4.6%	3.37%	1.54%	5%	6
MUHFRA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.9%	0.0%	0.4%	0.0%	0.0%	0.26%	0.22%	5%	1
MUHPOR	0.4%	0.0%	0.0%	0.0%	0.8%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.8%	0.0%	0.19%	0.09%	5%	1
PANICUM	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.03%	0.03%	5%	1
PANOBT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	0.10%	0.10%	5%	1
SCHCIR	3.3%	0.0%	1.3%	0.0%	0.0%	1.7%	0.0%	1.7%	0.0%	0.0%	0.4%	0.0%	0.0%	0.64%	0.29%	5%	1
SETARIA	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.29%	0.21%	5%	1
SETLEU	1.7%	0.0%	0.0%	0.0%	0.0%	1.7%	0.0%	4.2%	0.0%	0.0%	0.0%	0.4%	0.0%	0.61%	0.34%	5%	1
SPOAIR	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.4%	0.0%	0.0%	0.19%	0.13%	5%	1
SPOCRY	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	0.0%	0.0%	0.0%	0.06%	0.06%	5%	1
Shrubs																	
ALOWRI	0.0%	0.0%	0.0%	0.0%	0.8%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	10.0%	0.0%	0.90%	0.76%	5%	2
ARCPUN	0.0%	0.0%	0.4%	3.3%	0.0%	0.0%	1.3%	3.3%	0.8%	0.0%	0.4%	0.0%	0.8%	0.80%	0.33%	5%	1
ARTEMISIA	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.03%	0.03%	5%	1
CALERI	0.0%	0.0%	0.0%	0.0%	0.4%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.16%	0.13%	5%	1
MIMACU	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.4%	0.0%	0.4%	0.0%	0.10%	0.05%	5%	1
MIMACUBIN	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	5.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.45%	0.38%	5%	1
PARINC	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.03%	0.03%	5%	1
RHUTRIPIL	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.10%	0.10%	5%	1
Snags																	
SNAG	12.9%	7.5%	7.5%	7.9%	10.4%	5.8%	11.7%	1.7%	10.4%	2.1%	6.3%	5.0%	9.6%	7.60%	0.95%	5%	3
Subshrubs																	
BRICAL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.03%	0.03%	5%	1
BRIVEN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.03%	0.03%	5%	1
CROPOT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.1%	0.0%	0.0%	0.0%	0.16%	0.16%	5%	1
ERILAR	1.3%	4.2%	1.7%	2.9%	0.4%	0.0%	0.8%	1.7%	0.4%	1.7%	2.5%	2.5%	2.5%	1.73%	0.33%	5%	1
ERIWRI	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.4%	1.3%	0.0%	0.0%	0.16%	0.10%	5%	1
GUTSAR	0.4%	2.1%	0.0%	0.4%	0.4%	0.0%	2.5%	2.5%	2.5%	0.4%	1.3%	0.8%	0.0%	1.03%	0.28%	5%	1
ISOTEN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.03%	0.03%	5%	1
SOLELA	0.0%	1.3%	0.0%	2.1%	0.0%	0.0%	0.0%	0.0%	0.0%	2.1%	0.0%	0.4%	0.0%	0.45%	0.22%	5%	1

Table A2. Within-plot cover values for species and lifeforms measured in the "field" (<0.5 m stature) layer of terrestrial vegetation and soils plots at Fort Bowie NHS, 2008, cont.

Veg code	Monitoring plots										Test plots			Parkwide values			
	V001	V002	V006	V007	V008	V009	V010	V012	V013	V014	V015	V016	V021	AVG	SE	MDC	n=
Succulents																	
AGAPAL1	0.4%	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	0.19%	0.11%	5%	1
AGAPAR	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.03%	0.03%	5%	1
DASWHE	2.9%	0.0%	0.0%	0.0%	1.3%	1.7%	1.7%	0.0%	0.0%	1.7%	2.1%	3.3%	0.0%	1.12%	0.33%	5%	1
FOUSPL	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.03%	0.03%	5%	1
NOLMIC	4.2%	2.1%	2.1%	1.3%	3.3%	0.0%	1.7%	3.3%	2.1%	0.0%	0.0%	2.1%	3.3%	1.96%	0.38%	5%	1
OPUENG	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.03%	0.03%	5%	1
OPUPHA	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.4%	0.4%	0.0%	0.0%	0.0%	0.0%	0.10%	0.05%	5%	1
OPUSPI	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.06%	0.04%	5%	1
YUCBAC	0.0%	0.4%	0.4%	1.3%	0.0%	0.0%	2.1%	0.0%	0.0%	0.0%	2.5%	0.0%	0.0%	0.51%	0.24%	5%	1
Trees																	
ACAGRE	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.06%	0.06%	5%	1
JUNCOA	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.10%	0.10%	5%	1
JUNMON	0.4%	0.4%	0.4%	0.0%	1.3%	0.0%	0.0%	0.0%	0.0%	2.9%	0.0%	0.0%	0.0%	0.42%	0.23%	5%	1
PINEDU	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.03%	0.03%	5%	1
PROGLA	1.3%	2.5%	0.8%	0.8%	2.5%	0.0%	1.7%	0.0%	0.0%	7.1%	0.0%	0.8%	0.0%	1.35%	0.54%	5%	1
QUEEMO	0.0%	0.0%	0.8%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.13%	0.09%	5%	1
QUETUR	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.03%	0.03%	5%	1
Vine																	
PHASE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.03%	0.03%	5%	1
LIFEFORMS																	
Annual Forb	8.8%	2.5%	20.4%	20.4%	7.9%	0.0%	7.9%	5.8%	15.0%	5.0%	7.9%	0.4%	24.6%	10%	2.21%	10%	3
Annual Grass	9.6%	29.2%	12.1%	28.8%	15.8%	47.1%	23.8%	16.3%	13.8%	18.3%	35.0%	18.8%	26.3%	23%	2.92%	10%	5

Table A2. Within-plot cover values for species and lifeforms measured in the "field" (<0.5 m stature) layer of terrestrial vegetation and soils plots at Fort Bowie NHS, 2008, cont.

Veg code	Monitoring plots										Test plots			Parkwide values			
	V001	**V002**	**V006**	**V007**	**V008**	**V009**	**V010**	**V012**	**V013**	**V014**	**V015**	**V016**	**V021**	**AVG**	**SE**	**MDC**	**n=**
Perennial Forb	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	0.4%	0.4%	2.9%	0.0%	0.0%	0.0%	0%	0.24%	5%	1
Perennial Grass	32.9%	43.3%	39.2%	34.6%	48.3%	15.4%	40.0%	42.9%	51.7%	43.3%	34.6%	42.5%	37.1%	39%	2.47%	10%	4
Shrub	1.3%	0.4%	0.4%	3.3%	1.7%	2.9%	1.3%	8.3%	1.3%	0.8%	0.4%	10.4%	0.8%	3%	0.88%	5%	2
Snag	12.9%	7.5%	7.5%	7.9%	10.4%	5.8%	11.7%	1.7%	10.4%	2.1%	6.3%	5.0%	9.6%	8%	0.95%	5%	3
Subshrub	1.7%	7.9%	1.7%	5.4%	1.7%	0.0%	4.2%	4.6%	3.3%	6.7%	5.4%	3.8%	2.9%	4%	0.62%	5%	1
Succulent	7.9%	2.9%	2.5%	2.5%	5.0%	3.8%	5.4%	3.8%	2.9%	1.7%	4.6%	5.4%	4.2%	4%	0.46%	5%	1
Tree	1.7%	2.9%	2.5%	1.7%	3.8%	2.1%	1.7%	0.0%	0.0%	10.0%	0.4%	0.8%	0.0%	2%	0.73%	5%	2
Vine	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0%	0.03%	5%	1
Total	77.5%	96.7%	86.3%	104.6%	94.6%	77.1%	97.5%	83.8%	99.2%	90.8%	94.6%	87.1%	105.4%	92%	2.55%	10%	4
Exotics	0.8%	8.3%	2.1%	0.0%	3.8%	0.8%	6.7%	0.8%	3.8%	4.2%	1.3%	10.0%	3.3%	4%	0.87%	5%	2
Natives	63.8%	80.8%	76.7%	96.7%	80.4%	70.4%	79.2%	81.3%	85.0%	84.6%	87.1%	72.1%	92.5%	81%	2.47%	10%	4

AVG = average; SE = standard error; MDC = minimum detectable change (% cover); n = required number of plots for power criteria (see text).
Bolded species are invasive exotics.

Table A3. Within-plot cover values (%) for species and lifeforms measured in the subcanopy (0.5–2.0 m stature) layer of terrestrial vegetation and soils plots at Fort Bowie NHS, 2008.

Veg code	Monitoring plots										Test plots			Parkwide values			
	V001	V002	V006	V007	V008	V009	V010	V012	V013	V014	V015	V016	V021	AVG	SE	MDC	n=
SPECIES																	
Forb/Herbs																	
AMARANTHUS	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.03%	0.03%	5%	1
ARTLUD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.03%	0.03%	5%	1
BOECOC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%	1.3%	0.0%	0.0%	0.0%	0.19%	0.13%	5%	1
IPOMOEA	**0.0%**	**0.0%**	**0.8%**	**0.0%**	**1.3%**	**0.0%**	**2.1%**	**0.8%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.38%**	**0.19%**	**5%**	**1**
Graminoids																	
ARIPUR	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	3.3%	0.8%	0.0%	0.0%	0.0%	0.35%	0.26%	5%	1
ARITER	0.8%	2.5%	0.0%	1.7%	2.1%	0.0%	0.8%	2.1%	1.7%	6.3%	0.0%	0.4%	0.8%	1.47%	0.46%	5%	1
BOTBAR	0.0%	0.4%	0.0%	0.0%	0.8%	0.0%	0.8%	1.3%	0.4%	1.7%	0.0%	0.4%	0.0%	0.45%	0.15%	5%	1
BOUBAR	0.0%	0.8%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.13%	0.07%	5%	1
BOUCUR	1.3%	0.4%	1.7%	2.5%	3.8%	3.8%	2.9%	5.4%	2.5%	9.2%	1.3%	7.1%	2.9%	3.43%	0.69%	5%	2
BOUERI	0.0%	0.4%	0.8%	3.3%	3.3%	0.0%	0.4%	0.0%	5.8%	1.7%	0.8%	1.3%	2.1%	1.54%	0.48%	5%	1
BOUGRA	0.0%	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.7%	0.61%	0.51%	5%	1
BOUHIR	0.0%	0.8%	0.4%	0.0%	0.8%	0.0%	2.9%	0.8%	1.3%	0.4%	0.0%	0.0%	0.8%	0.64%	0.22%	5%	1
BOUREP	0.0%	0.4%	0.4%	0.0%	0.0%	0.4%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.22%	0.13%	5%	1
BOUTELOUA	0.0%	0.0%	0.0%	0.0%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.19%	0.19%	5%	1
DIGCAL	0.0%	0.4%	0.0%	0.0%	0.0%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.10%	0.07%	5%	1
ERACIL	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.4%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.03%**	**0.03%**	**5%**	**1**
ERAINT	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.4%	0.8%	1.3%	0.0%	0.8%	0.38%	0.14%	5%	1
ERALEH	**0.0%**	**4.2%**	**0.4%**	**0.8%**	**0.0%**	**0.0%**	**7.1%**	**0.0%**	**2.5%**	**0.8%**	**0.0%**	**1.7%**	**0.8%**	**1.41%**	**0.58%**	**5%**	**1**
HETCON	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.06%	0.04%	5%	1
LEPDUB	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.4%	0.8%	0.0%	0.0%	0.0%	0.16%	0.08%	5%	1
MUHEME	6.7%	0.0%	18.3%	0.0%	0.0%	0.0%	0.8%	2.1%	0.4%	0.0%	6.7%	0.0%	3.8%	2.98%	1.45%	5%	5
MUHPOR	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.03%	0.03%	5%	1
SCHCIR	0.0%	0.0%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.10%	0.07%	5%	1
SETARIA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.03%	0.03%	5%	1
SPOAIR	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.03%	0.03%	5%	1
Shrubs																	
ALOWRI	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	10.8%	0.0%	0.93%	0.83%	5%	2
ARCPUN	0.0%	0.0%	0.8%	7.1%	0.0%	0.0%	0.0%	8.8%	5.4%	0.0%	0.0%	0.0%	1.3%	1.79%	0.86%	5%	2

Table A3. Within-plot cover values (%) for species and lifeforms measured in the subcanopy (0.5–2.0 m stature) layer of terrestrial vegetation and soils plots at Fort Bowie NHS, 2008, cont.

Veg code	Monitoring plots										Test plots			Parkwide values			
	V001	V002	V006	V007	V008	V009	V010	V012	V013	V014	V015	V016	V021	AVG	SE	MDC	n=
Shrubs, cont.																	
MIMACU	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	1.3%	0.0%	0.13%	0.10%	5%	1
MIMACUBIN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7.1%	0.0%	1.3%	0.0%	0.0%	0.0%	0.64%	0.55%	5%	
RHUTRIPIL	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.10%	0.10%	5%	1
Snags																	
SNAG	2.1%	0.8%	3.3%	0.0%	1.7%	0.0%	0.0%	0.4%	0.4%	0.4%	1.7%	0.4%	0.0%	0.87%	0.28%	5%	1
Subshrubs																	
ERILAR	0.4%	2.1%	0.4%	2.5%	0.0%	0.0%	0.8%	0.0%	0.0%	0.0%	0.4%	0.4%	1.3%	0.64%	0.23%	5%	1
GUTSAR	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.13%	0.10%	5%	1
Succulents																	
AGAPAL1	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.4%	0.13%	0.07%	5%	1
DASWHE	2.5%	0.0%	0.0%	0.0%	1.7%	1.3%	2.1%	0.0%	0.0%	2.1%	1.3%	3.8%	0.0%	1.12%	0.34%	5%	1
FOUSPL	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.13%	0.13%	5%	1
NOLMIC	3.3%	1.3%	0.4%	0.8%	2.9%	0.0%	0.8%	2.1%	2.9%	0.0%	0.0%	1.3%	4.2%	1.54%	0.39%	5%	1
OPUPHA	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.03%	0.03%	5%	1
YUCBAC	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.8%	0.0%	0.0%	0.0%	2.5%	0.0%	0.0%	0.38%	0.22%	5%	1
Trees																	
ACAGRE	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.13%	0.13%	5%	1
JUNCOA	0.0%	0.0%	0.0%	0.0%	0.0%	8.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.64%	0.64%	5%	1
JUNMON	0.4%	3.3%	2.1%	0.0%	2.1%	0.0%	0.0%	0.0%	0.0%	3.3%	0.0%	0.0%	0.0%	0.87%	0.37%	5%	1
PINEDU	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.1%	0.0%	0.0%	0.16%	0.16%	5%	1
PROGLA	0.0%	6.3%	0.0%	3.8%	5.8%	0.0%	5.0%	0.0%	0.0%	11.7%	0.0%	6.7%	0.0%	3.01%	1.06%	5%	3
QUEEMO	2.1%	0.8%	5.4%	1.3%	0.8%	0.0%	0.0%	3.3%	1.3%	0.8%	0.0%	0.0%	2.1%	1.38%	0.44%	5%	1
QUETUR	2.1%	0.0%	1.3%	0.0%	0.0%	0.0%	0.0%	2.1%	0.0%	0.0%	0.0%	0.0%	1.3%	0.51%	0.23%	5%	1

Table A3. Within-plot cover values (%) for species and lifeforms measured in the subcanopy (0.5–2.0 m stature) layer of terrestrial vegetation and soils plots at Fort Bowie NHS, 2008, cont.

Veg code	Monitoring plots										Test plots			Parkwide values			
	V001	V002	V006	V007	V008	V009	V010	V012	V013	V014	V015	V016	V021	AVG	SE	MDC	n=
LIFEFORMS																	
Annual Forb	0.4%	0.0%	0.0%	1.3%	0.4%	0.0%	0.4%	0.4%	0.8%	0.4%	0.8%	0.0%	2.5%	0.58%	0.19%	5%	1
Annual Grass	0.4%	0.0%	0.0%	0.0%	0.4%	0.0%	1.7%	0.8%	0.0%	0.0%	1.7%	0.0%	2.5%	0.58%	0.23%	5%	1
Perennial Forb	0.0%	0.0%	0.8%	0.0%	1.3%	0.0%	3.3%	1.3%	0.0%	1.3%	0.0%	0.0%	0.4%	0.64%	0.27%	5%	1
Perennial Grass	10.4%	11.7%	23.3%	8.3%	13.8%	5.0%	20.0%	12.1%	19.6%	22.5%	10.0%	10.8%	19.2%	14.36%	1.63%	5%	6
Shrub	1.3%	0.0%	0.8%	7.1%	0.0%	1.3%	0.0%	15.8%	5.8%	1.3%	0.0%	12.1%	1.3%	3.59%	1.43%	5%	5
Snag	2.1%	0.8%	3.3%	0.0%	1.7%	0.0%	0.0%	0.4%	0.4%	0.4%	1.7%	0.4%	0.0%	0.87%	0.28%	5%	1
Subshrub	0.4%	2.1%	0.4%	2.5%	0.0%	0.0%	1.3%	1.3%	0.0%	0.0%	0.4%	0.4%	1.3%	0.77%	0.23%	5%	1
Succulent	5.8%	1.3%	0.4%	2.5%	4.6%	4.2%	3.8%	2.1%	2.9%	2.1%	3.8%	5.4%	4.6%	3.33%	0.45%	5%	1
Tree	4.6%	10.4%	8.8%	5.0%	8.8%	10.0%	5.0%	5.4%	1.3%	15.8%	2.1%	6.7%	3.3%	6.70%	1.11%	5%	3
Total	24.6%	26.3%	37.9%	25.4%	30.0%	20.4%	33.3%	38.3%	30.0%	43.3%	17.9%	35.8%	30.0%	30.26%	2.05%	5%	10
Exotics	0.4%	4.2%	0.4%	0.8%	0.0%	0.0%	7.5%	0.0%	3.3%	1.7%	0.0%	1.7%	0.8%	1.60%	2.21%	5%	1
Natives	22.9%	21.3%	34.2%	25.8%	29.2%	20.4%	27.9%	39.2%	27.1%	41.7%	18.8%	33.8%	34.2%	28.94%	7.25%	5%	9

Bolded species are invasive exotics.

Table A4. Within-plot cover values (%) for species and lifeforms measured in the canopy (>2.0 m stature) layer of terrestrial vegetation and soils plots at Fort Bowie NHS, 2008.

Veg code	Monitoring plots										Test plots			Parkwide values			
	V001	V002	V006	V007	V008	V009	V010	V012	V013	V014	V015	V016	V021	AVG	SE	MDC	n=
SPECIES																	
Shrubs																	
ARCPUN	0.0%	0.0%	0.0%	2.5%	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	**0.29%**	**0.21%**	5%	1
Snags																	
SNAG	0.0%	0.0%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**0.06%**	**0.06%**	5%	1
Succulents																	
FOUSPL	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**0.06%**	**0.06%**	5%	1
NOLMIC	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**0.03%**	**0.03%**	5%	1
Trees																	
ACAGRE	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**0.03%**	**0.03%**	5%	1
JUNCOA	0.0%	0.0%	0.0%	0.0%	0.0%	10.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**0.80%**	**0.80%**	5%	2
JUNMON	2.5%	0.8%	4.2%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	6.7%	0.0%	0.0%	0.0%	**1.12%**	**0.58%**	5%	1
PROGLA	0.0%	3.3%	0.0%	0.0%	2.9%	0.0%	0.8%	0.0%	0.0%	9.6%	0.0%	4.6%	0.0%	**1.63%**	**0.79%**	5%	2
QUEEMO	7.1%	0.8%	10.8%	0.4%	0.0%	0.0%	4.6%	4.6%	2.9%	3.3%	5.8%	0.0%	10.8%	**3.94%**	**1.07%**	5%	3
QUETUR	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	0.0%	0.0%	0.0%	0.0%	0.4%	**0.13%**	**0.07%**	5%	1
LIFEFORMS																	
Shrub	0.0%	0.0%	0.0%	2.5%	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	**0.29%**	**0.21%**	5%	1
Snag	0.0%	0.0%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**0.06%**	**0.06%**	5%	1
SubShrub	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	**0.03%**	**0.03%**	5%	1
Succulent	0.0%	0.0%	0.0%	0.0%	0.4%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**0.10%**	**0.07%**	5%	1
Tree	10.0%	5.0%	15.0%	0.4%	2.9%	11.3%	5.4%	5.4%	2.9%	19.6%	5.8%	4.6%	11.3%	**7.66%**	**1.51%**	5%	6
Total	10.0%	5.0%	15.8%	2.9%	3.3%	12.1%	5.4%	6.7%	2.9%	20.0%	5.8%	4.6%	11.3%	**8.14%**	**1.48%**	5%	5

Table A5. Within-plot and landscape frequency (%) for all plots and species sampled on monitoring plots in 2008.

		Within-plot frequency (0–5)†													Parkwide values		
		Monitoring plots										Test plots					
Common name	Nativity	V001	V002	V006	V007	V008	V009	V010	V012	V013	V014	V015	V016	V021	Mean within-plot frequency (%)	SE within-plot frequency (%)	Landscape frequency
Forb/Herbs																	
ACANEO	Native	0	0	0	0	0	0	0	1	0	0	0	0	0	2%	1.5%	1 (8%)
AMARANTHUS	N/A	0	1	0	0	0	0	0	0	2	2	0	0	3	12%	5.8%	4 (31%)
AMAPAL	Native	0	0	0	0	0	0	0	0	0	0	0	0	1	2%	1.5%	1 (8%)
AMBRO	N/A	0	1	0	0	0	0	0	0	0	0	0	0	0	2%	1.5%	1 (8%)
ARTLUD	Native	0	0	0	2	0	0	0	2	0	0	0	1	0	8%	4.3%	3 (23%)
BAHABS	Native	0	0	0	0	0	4	0	0	0	0	0	0	0	6%	6.2%	1 (8%)
BOECOC	Native	0	0	0	0	0	0	2	0	0	2	0	0	0	6%	4.2%	2 (15%)
BOEERE	Native	0	0	0	0	0	0	1	0	1	0	0	0	0	3%	2.1%	2 (15%)
CHASOR	Native	0	0	0	0	0	0	0	0	0	1	0	0	0	2%	1.5%	1 (8%)
CHELIANTHES	N/A	0	0	0	0	0	0	0	0	0	0	0	0	1	2%	1.5%	1 (8%)
DALEA	N/A	1	0	0	0	0	0	1	0	0	0	0	0	0	3%	2.1%	2 (15%)
DALPOG	Native	0	0	0	0	0	0	0	0	0	0	0	0	1	2%	1.5%	1 (8%)
DALWRI	Native	0	0	0	0	0	0	0	0	0	0	1	0	0	2%	1.5%	1 (8%)
DATWRI	Native	0	0	0	0	0	0	0	0	0	1	0	0	0	2%	1.5%	1 (8%)
DICCAP	Native	1	0	0	0	0	0	0	0	0	0	0	0	0	2%	1.5%	1 (8%)
ERILOB	Native	0	0	0	0	0	0	0	0	0	0	1	0	0	2%	1.5%	1 (8%)
EROCIC	Non-native	0	0	0	0	0	0	0	0	0	0	0	0	2	3%	3.1%	1 (8%)
HEDOBL	Native	0	0	0	0	0	0	0	0	0	0	1	0	0	2%	1.5%	1 (8%)
IPOMOEA	**N/A**	**0**	**0**	**3**	**1**	**5**	**0**	**3**	**0**	**0**	**2**	**0**	**0**	**0**	**22%**	**9.2%**	**5 (38%)**
LOTGRE	Native	0	0	0	0	0	0	0	1	0	0	0	0	1	3%	2.1%	2 (15%)
LOTWRI	Native	0	0	0	0	0	0	0	0	0	0	0	0	1	2%	1.5%	1 (8%)
MENTZ	N/A	1	0	0	0	0	0	0	0	0	0	0	0	0	2%	1.5%	1 (8%)
NICOBT	Native	0	0	0	0	0	0	0	0	0	0	0	2	0	3%	3.1%	1 (8%)
PSECANCAN	Native	0	0	1	0	0	0	0	0	0	0	0	0	0	2%	1.5%	1 (8%)
SALKAL	**Non-native**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**2%**	**1.5%**	**1 (8%)**
VERENC	Native	0	0	0	0	0	0	0	0	0	0	0	1	0	2%	1.5%	1 (8%)
VERROT	Native	0	0	0	0	0	2	0	0	0	0	0	0	0	3%	3.1%	1 (8%)

Table A5. Within-plot and landscape frequency (%) for all plots and species sampled on monitoring plots in 2008, cont.

		Within-plot frequency (0–5)†													Parkwide values		
		Monitoring plots										Test plots					
Common name	Nativity	V001	V002	V006	V007	V008	V009	V010	V012	V013	V014	V015	V016	V021	Mean within-plot frequency (%)	SE within-plot frequency (%)	Landscape frequency
Graminoids																	
ARISTIDA	N/A	0	0	0	0	4	0	0	0	0	0	0	0	0	6%	6.2%	1 (8%)
ARIPAN	Native	0	0	0	0	0	0	0	0	0	0	1	0	0	2%	1.5%	1 (8%)
ARIPUR	Native	2	2	3	4	0	1	3	2	5	4	3	0	4	51%	8.7%	11 (85%)
ARISCH*	Native	0	0	0	1	0	0	0	0	0	0	0	0	0	2%	1.5%	2 (15%)
ARITER	Native	5	5	3	4	4	1	5	3	5	5	2	4	5	78%	7.3%	13 (100%)
BOTBAR	Native	3	4	3	2	3	2	3	3	1	5	1	4	4	58%	6.6%	13 (100%)
BOUTELOUA	N/A	0	0	0	0	3	0	0	0	0	0	1	0	0	6%	4.7%	2 (15%)
BOUARI	Native	0	0	0	0	0	0	0	0	0	1	1	0	0	3%	2.1%	2 (15%)
BOUBAR	Native	0	2	0	0	0	0	1	0	1	2	0	0	0	9%	4.3%	4 (31%)
BOUCHO	Native	0	0	0	0	0	0	0	0	2	0	0	0	0	3%	3.1%	1 (8%)
BOUCUR	Native	3	4	5	3	5	5	4	5	4	5	3	5	5	86%	4.7%	13 (100%)
BOUERI	Native	1	4	3	5	5	3	3	2	5	5	2	5	5	74%	8.0%	13 (100%)
BOUGRA	Native	0	2	0	1	0	0	1	1	1	4	0	2	5	26%	8.9%	9 (69%)
BOUHIR	Native	3	5	5	4	2	0	4	5	3	3	4	0	3	63%	9.3%	11 (85%)
BOUREP	Native	4	5	5	2	0	3	4	2	5	0	5	0	1	55%	11.4%	10 (77%)
CHLVIR	Native	1	2	0	3	1	2	3	1	0	5	0	3	2	35%	8.2%	10 (77%)
DASPUL	Native	0	0	0	0	0	0	1	0	0	3	0	0	0	6%	4.7%	2 (15%)
DIGCAL	Native	1	1	0	0	0	1	0	0	0	0	0	2	0	8%	3.6%	4 (31%)
ELIBAR**	Cultivated	1	0	0	0	0	0	0	0	0	0	0	1	0	3%	2.1%	2 (15%)
ERAGROSTIS	N/A	0	0	0	0	1	0	0	0	0	0	0	0	0	2%	1.5%	1 (8%)
ERACIL	**Non-native**	**0**	**2**	**2**	**1**	**3**	**0**	**0**	**1**	**2**	**1**	**0**	**1**	**1**	**22%**	**5.3%**	**9 (69%)**
ERAINT	Native	2	1	0	2	1	0	3	0	2	1	4	0	4	31%	8.0%	9 (69%)
ERALEH	**Non-native**	**2**	**4**	**3**	**2**	**4**	**2**	**5**	**1**	**4**	**4**	**3**	**4**	**3**	**63%**	**6.3%**	**13 (100%)**
ERILEM	Native	1	0	0	1	0	0	0	0	0	1	0	0	0	5%	2.4%	3 (23%)
HETCON	Native	2	1	3	0	0	5	2	4	2	0	0	1	0	31%	9.2%	8 (62%)
LEPDUB	Non-native	5	0	1	0	0	2	3	2	2	4	1	1	2	35%	8.5%	10 (77%)
LYCPHL	Native	1	1	0	1	0	0	2	0	2	0	1	0	0	12%	4.3%	6 (46%)
LYCSET	Native	1	1	0	0	0	0	2	0	1	0	2	0	3	15%	5.6%	6 (46%)

Table A5. Within-plot and landscape frequency (%) for all plots and species sampled on monitoring plots in 2008, cont.

		Within-plot frequency (0–5)†													Parkwide values		
		Monitoring plots										Test plots					
Common name	Nativity	V001	V002	V006	V007	V008	V009	V010	V012	V013	V014	V015	V016	V021	Mean within-plot frequency (%)	SE within-plot frequency (%)	Landscape frequency
Graminoids, cont.																	
MUHEME	Native	5	2	5	3	2	1	2	4	2	2	5	2	5	62%	8.3%	13 (100%)
MUHFRA	Native	0	0	0	0	0	0	0	0	2	0	1	0	0	5%	3.3%	2 (15%)
MUHRIG	Native	0	0	0	0	0	0	0	0	0	0	1	0	0	2%	1.5%	1 (8%)
MUHPOR	Native	1	0	0	0	3	1	0	0	0	1	0	2	0	12%	5.3%	5 (38%)
PANHIR	Native	0	0	0	0	0	0	0	0	0	0	0	0	1	2%	1.5%	1 (8%)
PANOBT	Native	0	0	0	0	0	0	0	0	0	0	0	0	2	3%	3.1%	1 (8%)
SCHCIR	Native	5	0	3	2	0	1	2	2	0	0	5	0	4	37%	10.6%	8 (62%)
SETARIA	N/A	0	0	0	0	4	0	3	0	0	2	0	0	0	14%	7.6%	3 (23%)
SETGRI	Native	1	0	0	0	0	0	0	0	0	0	0	0	2	5%	3.3%	2 (15%)
SETLEU	Native	4	1	0	0	0	1	2	3	0	1	0	1	3	25%	7.6%	8 (62%)
SPOAIR	Native	1	0	0	0	0	0	1	1	0	0	1	0	0	6%	2.7%	4 (31%)
SPOCRY	Native	0	1	0	0	4	0	1	0	0	2	0	0	0	12%	6.6%	4 (31%)
Shrubs																	
ALOWRI	Native	0	0	0	0	3	5	0	0	0	0	0	4	0	18%	10.0%	3 (23%)
ARCPUN	Native	2	1	4	3	1	0	3	4	4	2	4	0	5	51%	9.2%	11 (85%)
ARTEMISIA	N/A	0	0	0	0	3	0	0	0	0	0	0	0	0	5%	4.6%	1 (8%)
CALLIANDRA	Native	0	1	0	0	0	0	0	0	0	0	0	0	0	2%	1.5%	1 (8%)
CALERI	Native	0	2	0	3	0	3	0	0	1	1	0	0	0	15%	6.5%	5 (38%)
FOUSPL	Native	0	0	0	0	0	3	0	0	0	0	0	0	0	5%	4.6%	1 (8%)
GARWRI	Native	0	0	0	0	0	1	0	2	0	0	0	0	0	5%	3.3%	2 (15%)
MIMACU	Native	2	2	1	1	1	0	2	0	2	3	1	2	3	31%	5.4%	11 (85%)
MIMACUBIN	Native	1	0	0	2	0	0	0	4	1	1	1	0	1	17%	6.3%	6 (46%)
PARINC	Native	0	0	0	0	0	5	0	0	0	0	1	0	0	9%	7.7%	2 (15%)
RHUMIC	Native	0	0	0	0	1	0	0	0	0	1	0	1	0	5%	2.4%	2 (15%)
RHUTRIPIL	Native	1	0	0	0	0	0	0	2	0	0	0	1	0	6%	3.5%	3 (23%)
RHUVIR	Native	1	0	0	0	0	0	0	0	0	0	0	0	0	2%	1.5%	1 (8%)
SIDLAN	Native	0	0	0	0	0	3	0	0	1	0	0	0	0	6%	4.7%	2 (15%)

Table A5. Within-plot and landscape frequency (%) for all plots and species sampled on monitoring plots in 2008, cont.

		Within-plot frequency (0–5)†													Parkwide values		
		Monitoring plots										Test plots					
Common name	Nativity	V001	V002	V006	V007	V008	V009	V010	V012	V013	V014	V015	V016	V021	Mean within-plot frequency (%)	SE within-plot frequency (%)	Landscape frequency
Subshrubs																	
BRIBAC	Native	0	0	0	0	0	0	0	0	0	0	1	0	1	3%	2.1%	2 (15%)
BRICAL	Native	0	0	0	2	0	0	0	0	0	0	1	0	1	6%	3.5%	3 (23%)
BRIVEN	Native	0	0	0	0	0	0	0	2	0	0	0	0	0	3%	1%	2 (15%)
CHANIC	Native	0	0	1	0	0	0	0	2	0	0	0	0	1	6%	3.5%	3 (23%)
CROPOT	Native	0	0	0	0	0	3	0	0	0	3	0	5	0	17%	9.3%	3 (23%)
DASWHE	Native	5	0	1	2	4	2	4	1	0	2	2	5	2	46%	9.4%	11 (85%)
ERILAR	Native	3	5	5	5	4	0	4	5	2	5	3	4	4	75%	8.2%	12 (92%)
ERIWRI	Native	1	0	3	4	0	0	5	2	1	0	4	1	5	40%	9%	9 (69%)
GUTMIC	Native	0	0	0	0	0	3	0	1	0	0	0	0	0	6%	4.7%	2 (15%)
GUTSAR	Native	2	5	3	4	5	1	4	4	5	3	4	4	0	68%	8.6%	12 (92%)
ISOTEN	Native	1	3	0	2	0	0	2	3	0	1	0	1	4	26%	7.6%	8 (62%)
NOLMIC	Native	4	5	4	5	4	0	5	5	4	4	3	4	5	80%	7.5%	12 (92%)
SOLELA	Native	0	3	0	2	5	1	4	2	0	3	0	1	1	34%	9.2%	9 (69%)
SPHAERALCEA	Native	0	0	0	0	0	1	0	0	0	0	0	0	0	2%	1.5%	1 (8%)
SPHLAX	Native	0	0	0	0	0	0	0	0	1	0	0	2	0	5%	3.3%	2 (15%)
STEPAU	Native	0	0	0	0	0	1	0	0	0	0	0	0	0	2%	1.5%	1 (8%)
TRICAL	Native	0	0	0	0	0	1	0	0	0	0	0	0	0	2%	1.5%	1 (8%)
ZINGRA	Native	2	1	0	0	0	0	0	0	0	2	0	1	1	11%	4.3%	5 (38%)
Succulents																	
AGAPAL1	Native	3	2	2	2	0	4	0	0	2	1	3	4	2	38%	7.7%	9 (69%)
AGAPAR	Native	0	1	0	0	0	0	0	1	0	0	0	0	2	6%	3.5%	3 (23%)
ECHINOCEREUS	N/A	0	3	0	0	1	1	0	2	2	2	1	0	0	18%	5.8%	7 (54%)
ECHRIG	Native	0	0	0	0	0	1	0	0	0	0	1	1	0	5%	2.4%	3 (23%)
FERWIS	Native	0	2	1	0	0	0	0	0	0	0	0	0	0	5%	3.3%	2 (15%)
MAMMI	N/A	0	0	0	0	0	1	0	0	0	1	0	0	1	5%	2.4%	3 (23%)
OPUNTIA	N/A	1	0	1	0	0	0	1	0	0	0	0	0	0	5%	2.4%	3 (23%)
OPUENG	Native	0	1	0	0	2	4	1	0	0	2	0	2	0	18%	7.0%	6 (46%)
OPUMAC1	Native	1	0	0	0	0	0	0	0	0	0	0	0	0	2%	1.5%	1 (8%)

Table A5. Within-plot and landscape frequency (%) for all plots and species sampled on monitoring plots in 2008, cont.

		Within-plot frequency (0–5)†													Parkwide values		
		Monitoring plots										Test plots					
Common name	Nativity	V001	V002	V006	V007	V008	V009	V010	V012	V013	V014	V015	V016	V021	Mean within-plot frequency (%)	SE within-plot frequency (%)	Landscape frequency
Succulents, cont.																	
OPUPHA	Native	3	1	3	4	4	5	3	1	3	3	5	1	4	62%	7.7%	13 (100%)
OPUSPI	Native	5	3	2	5	5	4	3	3	3	5	5	5	5	82%	6.2%	13 (100%)
YUCBAC	Native	1	2	3	5	3	0	4	3	2	4	4	3	0	52%	6%	11 (85%)
Trees																	
ACAGRE	Native	0	0	0	0	0	3	0	0	0	0	0	0	0	5%	4.6%	1 (8%)
CELLAERET	Native	0	0	0	0	0	0	0	0	0	0	0	1	0	2%	1.5%	1 (8%)
JUNCOA	Native	0	0	0	0	0	5	0	0	0	0	0	0	0	8%	7.7%	1 (8%)
JUNMON	Native	3	2	3	0	1	2	1	0	2	4	0	2	3	35%	7.2%	9 (69%)
MORMIC	Native	0	0	0	0	0	0	0	0	0	0	0	1	0	2%	1.5%	1 (8%)
PINEDU	Native	0	0	1	0	0	0	1	0	0	0	2	0	0	6%	3.5%	3 (23%)
PROGLA	Native	3	5	2	1	5	1	5	1	0	5	0	4	2	52%	11.0%	12 (92%)
QUEEMO	Native	3	2	5	5	1	0	4	3	4	2	2	0	4	54%	9.4%	11 (85%)
QUETUR	Native	2	0	0	0	0	0	0	2	1	0	3	0	1	14%	5.7%	5 (38%)
Vines																	
GALWRI2	Native	1	0	0	0	0	0	0	0	0	0	0	0	0	2%	1.5%	1 (8%)
IPOHED	**Native**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**2%**	**1.5%**	**1 (8%)**
JANGRA	Native	0	0	0	0	0	1	0	0	0	0	0	0	0	2%	1.5%	1 (8%)
PHASE	Native	0	0	0	0	0	0	0	0	1	0	0	0	0	2%	1.5%	1 (8%)

Bolded species are invasive exotics.

†See Section 2.1.2 for explanation.

* Likely new species - voucher is being confirmed at time of writing.

** new species - voucher collected and verified.

Table A6. Within-plot frequency (%) for species encountered only in subplots, Fort Bowie NHS, 2008.

		Monitoring plots										Values for 10 plots			
Veg code	Nativity	V001	V002	V006	V007	V008	V009	V010	V012	V013	V014	Mean	SE	MDC	n=
Forb/Herbs															
AMBRO	N/A	0%	20%	0%	0%	0%	0%	0%	0%	0%	0%	2%	2.00%	5%	7
BAHABS	Native	0%	0%	0%	0%	0%	80%	0%	0%	0%	0%	8%	8.00%	12%	10
CHASOR	Native	0%	0%	0%	0%	0%	0%	0%	0%	0%	20%	2%	2.00%	5%	4
DATWRI	Native	0%	0%	0%	0%	0%	0%	0%	0%	0%	20%	2%	2.00%	5%	4
LOTGRE	Native	0%	0%	0%	0%	0%	0%	0%	20%	0%	0%	2%	2.00%	5%	4
MENTZ	N/A	20%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	2.00%	5%	4
PSECANCAN	Native	0%	0%	20%	0%	0%	0%	0%	0%	0%	0%	2%	2.00%	5%	4
VERROT	Native	0%	0%	0%	0%	0%	40%	0%	0%	0%	0%	4%	4.00%	10%	4
Graminoids															
ARISCH*	Native	0%	0%	0%	20%	0%	0%	0%	0%	0%	0%	2%	2.00%	5%	4
DASPUL	Native	0%	0%	0%	0%	0%	0%	20%	0%	0%	60%	8%	6.11%	10%	9
ELIBAR**	Cultivated	20%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	2.00%	5%	4
ERILEM	Native	20%	0%	0%	20%	0%	0%	0%	0%	0%	20%	6%	3.06%	5%	9
LYCPHL	Native	20%	20%	0%	20%	0%	0%	40%	0%	40%	0%	14%	5.21%	10%	7
SETGRI	Native	20%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	2.00%	5%	4
Shrubs															
GARWRI	Native	0%	0%	0%	0%	0%	20%	0%	40%	0%	0%	6%	4.27%	10%	5
RHUMIC	Native	0%	0%	0%	0%	20%	0%	0%	0%	0%	20%	4%	2.67%	5%	7
RHUVIR	Native	20%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	2.00%	5%	4
SIDLAN	Native	0%	0%	0%	0%	0%	60%	0%	0%	20%	0%	8%	6.11%	10%	9
Subshrubs															
CHANIC	Native	0%	0%	20%	0%	0%	0%	0%	40%	0%	0%	6%	4.27%	10%	5
GUTMIC	Native	0%	0%	0%	0%	0%	60%	0%	20%	0%	0%	8%	6.11%	10%	9
ISOTEN	Native	0%	0%	0%	0%	0%	0%	0%	20%	0%	0%	2%	2.00%	5%	4
SPHSP	Native	0%	0%	0%	0%	0%	20%	0%	0%	0%	0%	2%	2.00%	5%	4
SPHLAX	Native	0%	0%	0%	0%	0%	0%	0%	0%	20%	0%	2%	2.00%	5%	4
STEPAU	Native	0%	0%	0%	0%	0%	20%	0%	0%	0%	0%	2%	2.00%	5%	4
TRICAL	Native	0%	0%	0%	0%	0%	20%	0%	0%	0%	0%	2%	2.00%	5%	4
ZINGRA	Native	40%	20%	0%	0%	0%	0%	0%	0%	0%	40%	10%	5.37%	10%	7

Table A6. Within-plot frequency (%) for species encountered on the 10 monitoring plots at Fort Bowie NHS, 2008, cont.

		Monitoring plots										Values for 10 plots			
Veg code	Nativity	V001	V002	V006	V007	V008	V009	V010	V012	V013	V014	Mean	SE	MDC	n=
Succulents															
ECHPEC	Native	0%	0%	0%	0%	0%	20%	0%	0%	0%	0%	2%	2.00%	5%	4
FERWIS	Native	0%	40%	20%	0%	0%	0%	0%	0%	0%	0%	6%	4.27%	10%	5
MAMMI	N/A	0%	0%	0%	0%	0%	20%	0%	0%	0%	20%	4%	2.67%	5%	7
OPUMAC1	Native	20%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	2.00%	5%	4
Vines															
GALWRI2	Native	20%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	2.00%	5%	4
IPOHED	**Native**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**20%**	**0%**	**0%**	2%	2.00%	**5%**	**4**
JANGRA	Native	0%	0%	0%	0%	0%	20%	0%	0%	0%	0%	2%	2.00%	5%	4

Species on this list were not detected during line-point intercept sampling.
n = required number of plots for power criteria (see text).
Blue rows indicate an MDC of 10% rather than 5%; yellow row indicates MDC of >10%.
Bolded species are invasive exotics.
* Likely new species - specimen is being confirmed at time of writing.
** Confirmed new species for park - voucher collected and verified.

Table A7. Within-plot frequency (%) species encountered only in test plots, Fort Bowie NHS, 2008.

Veg code	Nativity	Test plot			Parkwide values			
		V15	V16	V21	Mean	SE	MDC	n=
Forbs/Herbs								
AMAPAL	Native	0%	0%	20%	1.54%	1.54%	5%	6
DALPOG	Native	0%	0%	20%	1.54%	1.54%	5%	6
DALWRI	Native	20%	0%	0%	1.54%	1.54%	5%	6
ERILOB	Native	20%	0%	0%	1.54%	1.54%	5%	6
ERIWRI	Native	0%	0%	20%	1.54%	1.54%	5%	6
EROCIC	Non-native	0%	0%	40%	3.08%	3.08%	10%	6
HEDOBL	Native	20%	0%	0%	1.54%	1.54%	5%	6
LOTWRI	Native	0%	0%	20%	1.54%	1.54%	5%	6
NICOBT	Native	0%	40%	0%	3.08%	3.08%	10%	6
SALKAL	**Non-native**	**0%**	**0%**	**20%**	**1.54%**	**1.54%**	**5%**	**6**
VERENC	Native	0%	20%	0%	1.54%	1.54%	5%	6
Graminoids								
MUHRIG	Native	20%	0%	0%	1.54%	1.54%	5%	6
PANHIR	Native	0%	0%	20%	1.54%	1.54%	5%	6
PANOBT	Native	0%	0%	40%	3.08%	3.08%	10%	6
Shrubs								
MIMACU	Native	0%	0%	20%	1.54%	1.54%	5%	6
Subshrubs								
BRIBAC	Native	20%	0%	20%	3.08%	2.08%	5%	10
ISOCOR	Native	0%	0%	20%	1.54%	1.54%	5%	6
Succulents								
YUCBAC	Native	0%	0%	0%	1.54%	1.54%	5%	6
Trees								
CELLAERET	Native	0%	20%	0%	1.54%	1.54%	5%	6
MORMIC	Native	0%	20%	0%	1.54%	1.54%	5%	6

Species on this list were not detected during line-point intercept sampling.
Values are based on all 13 plots (monitoring + test).
MDC = minimum detectable change (% cover)
n = required number of plots for power criteria (see text).
Blue rows indicate an MDC of 10% rather than 5%
Bolded species are invasive exotics.

Table A8. Soil substrate (% by class) by monitoring plot.

Substrate (Decreasing erosion hazard ↓)	Monitoring plots										Test plots		
	V001	V002	V006	V007	V008	V009	V010	V012	V013	V014	V015	V016	V021
Bare soil (<2 mm), no overhead cover	0.4%	0.0%	0.0%	0.4%	0.8%	0.4%	0.8%	0.4%	0.4%	0.4%	0.4%	0.4%	0.0%
Bare soil (<2 mm), under vegetation	3%	3%	6%	4%	11%	5%	5%	6%	1%	2%	4%	3%	0%
Duff (partially decomposed organic matter)	0%	0%	2%	0%	0%	0%	1%	1%	0%	1%	0%	0%	0%
Litter (intact organic matter)	37%	23%	38%	35%	33%	28%	27%	28%	21%	35%	21%	39%	44%
Plant base	5%	4%	7%	3%	8%	2%	4%	3%	6%	5%	9%	6%	10%
Gravel (2–75 mm)	36%	65%	41%	54%	45%	43%	60%	51%	65%	53%	62%	29%	33%
Rock (76–600 mm)	16%	5%	7%	3%	1%	20%	3%	4%	6%	3%	2%	18%	3%
Lichen on rock	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%
Bedrock	3%	0%	0%	0%	0%	2%	0%	6%	0%	0%	3%	4%	9%

Table A9. Surface aggregate stability class (mean and SE) and proportion of samples in "very stable" (=6) category, by monitoring plot.

Surface soil aggregate stability	Monitoring plots										Test plots		
	V001	V002	V006	V007	V008	V009	V010	V012	V013	V014	V015	V016	V021
Overall values	3.39	3.08	3.64	3.36	4.92	3.96	3.00	3.52	4.02	4.04	3.28	4.35	4.87
Average soil stability													
SE	0.34	0.32	0.37	0.30	0.28	0.31	0.29	0.33	0.31	0.29	0.33	0.32	0.27
% samples "very stable"	33%	23%	33%	18%	69%	34%	17%	30%	40%	38%	28%	48%	60%
n	46	48	39	45	48	47	47	44	48	47	47	40	45
Under vegetation cover													
Average soil stability	3.42	3.35	3.94	3.40	5.13	3.98	3.23	3.70	4.14	4.34	3.30	4.39	4.95
SE	0.35	0.35	0.37	0.30	0.28	0.34	0.33	0.35	0.32	0.30	0.34	0.33	0.26
% samples "very stable"	33%	25%	37%	17%	73%	35%	21%	33%	41%	42%	28%	47%	61%
n	43	40	35	42	40	40	39	40	44	38	43	38	44
No vegetation cover													
Average soil stability	3.00	1.75	1.00	2.67	3.88	3.86	1.88	1.75	2.75	2.78	3.00	3.50	1.00
SE	1.53	0.62	0.00	1.67	0.88	0.83	0.48	0.75	1.18	0.74	1.22	2.50	
% samples "very stable"	33%	13%	0%	33%	50%	29%	0%	0%	25%	22%	25%	50%	0%

n = number of samples collected per plot.
Values in red exceed the management assessment-point value shown in Table 3.3.

Table A10. Plot-specific monitoring data in the context of proposed management assessment points, by issue, Fort Bowie NHS, 2008.

Management assessment point*	Monitoring plots										Test plots		
	V001	V002	V006	V007	V008	V009	V010	V012	V013	V014	V015	V016	V021
Erosion hazard													
1 Bare ground cover is >30%	0.4%	0.0%	0.0%	0.4%	0.8%	0.4%	0.8%	0.4%	0.4%	0.4%	0.4%	0.4%	0.0%
2 Percentage of surface soil aggregates in "very stable" (6) class is <20%	33%	23%	33%	20%	69%	34%	17%	30%	40%	38%	28%	46%	60%
Site stability													
3 Foliar cover of perennial grasses in field layer is <25%	33%	43%	39%	35%	48%	15%	40%	43%	52%	43%	35%	43%	37%
4 Proportion of foliar grass cover (%) of annuals in field layer is >33%	23%	40%	24%	45%	25%	75%	37%	27%	21%	30%	50%	31%	41%
Shrub encroachment													
5 Shrub foliar cover is >35% (field)	1.3%	0.4%	0.4%	3.3%	1.7%	2.9%	1.3%	8.3%	1.3%	0.8%	0.4%	10.4%	0.8%
5 Shrub foliar cover is >35% (subcanopy)	1.3%	0.0%	0.8%	7.1%	0.0%	1.3%	0.0%	15.8%	5.8%	1.3%	0.0%	12.1%	1.3%
Mesquite invasion													
6 Mesquite (*Prosopis* sp.) foliar cover is >20% (field)	0%	6%	0%	4%	6%	0%	5%	0%	0%	12%	0%	7%	0%
6 Mesquite (*Prosopis* sp.) foliar cover is >20% (subcanopy)	0%	3%	0%	0%	3%	0%	1%	0%	0%	10%	0%	5%	0%
Exotic plant dispersal													
7 Extent (plot frequency) of invasive exotic plants in any layer is >20%	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Exotic plant invasion													
8 Proportion of foliar plant cover (%) contributed from exotic plants in field layer (etc.) is >10% (field)	1.08%	8.62%	2.40%	0.00%	3.81%	1.08%	6.84%	0.99%	3.78%	4.59%	1.32%	11.48%	3.16%
8 Proportion of foliar plant cover (%) contributed from exotic plants in field layer (etc.) is >10% (subcanopy)	1.69%	15.87%	1.10%	3.28%	0.00%	0.00%	22.50%	0.00%	11.11%	3.85%	0.00%	4.65%	2.78%
8 Proportion of foliar plant cover (%) contributed from exotic plants in field layer (etc.) is >10% (canopy)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Values in red exceed the management assessment-point value shown in Table 3.3.

Table A11. Parkwide monitoring data in the context of proposed management assessment points, by issue, Fort Bowie NHS, 2008.

Management assessment point*	AVG	SE	MDC	n
Erosion hazard				
1 Bare ground cover is >30%	0.4%	0.1%	5%	1
2 Percentage of surface soil aggregates in "very stable" (6) class is <20%	36.1%	4.2%	10%	10
Site stability				
3 Foliar cover of perennial grasses in field layer is <25%	38.9%	2.5%	10%	4
4 Proportion of foliar grass cover (%) of annuals in field layer is >33%	36.1%	4.2%	10%	10
Shrub encroachment				
5 Shrub foliar cover is >35% (field)	2.6%	0.9%	5%	2
5 Shrub foliar cover is >35% (subcanopy)	3.6%	1.4%	5%	5
Mesquite invasion				
6 Mesquite (*Prosopis* sp.) foliar cover is >20% (field)	3.0%	1.1%	5%	3
6 Mesquite (*Prosopis* sp.) foliar cover is >20% (subcanopy)	1.6%	0.8%	5%	2
Exotic plant dispersal				
7 Extent (plot frequency) of invasive exotic plants in any layer is >20%	n/a	n/a	n/a	n/a
Exotic plant invasion				
8 Proportion of foliar plant cover (%) contributed from exotic plants in field layer (etc.) is >10% (field)	3.78%	0.94%	5%	2
8 Proportion of foliar plant cover (%) contributed from exotic plants in field layer (etc.) is >10% (subcanopy)	5.14%	1.96%	5%	9
8 Proportion of foliar plant cover (%) contributed from exotic plants in field layer (etc.) is >10% (canopy)	0.0%	0	n/a	n/a

Values in red exceed the management assessment-point value shown in Table 3.3.
MDC = minimum detectable change (%). See Section 2.2.5 for formula and defintions.
n = number of plots necessary to meet power criteria

Appendix B. Plot Locations

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

Fort Bowie National Historic Site
Arizona

National Park Service
U.S. Department of the Interior

Plot permanent photos: V402_001


0m, 0m. 260 degrees


0m, 20m. 164 degrees


50m, 20m. 62 degrees

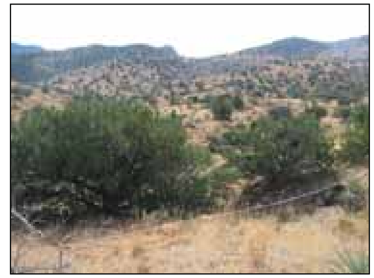

50m, 0m. 0 degrees

Produced by Sonoran Desert Network
January 2010

Plot permanent photos: V402_002


0m, 0m. 86 degrees


0m, 20m. 172 degrees


50m, 20m. 264 degrees


50m, 0m. 6 degrees

Produced by Sonoran Desert Network
January 2010

Fort Bowie National Historic Site
Arizona

National Park Service
U.S. Department of the Interior

Plot permanent photos: V402_006


0m, 0m. 304 degrees


0m, 20m. 19 degrees


50m, 20m. 116 degrees


50m, 0m. 218 degrees

Produced by Sonoran Desert Network
January 2010

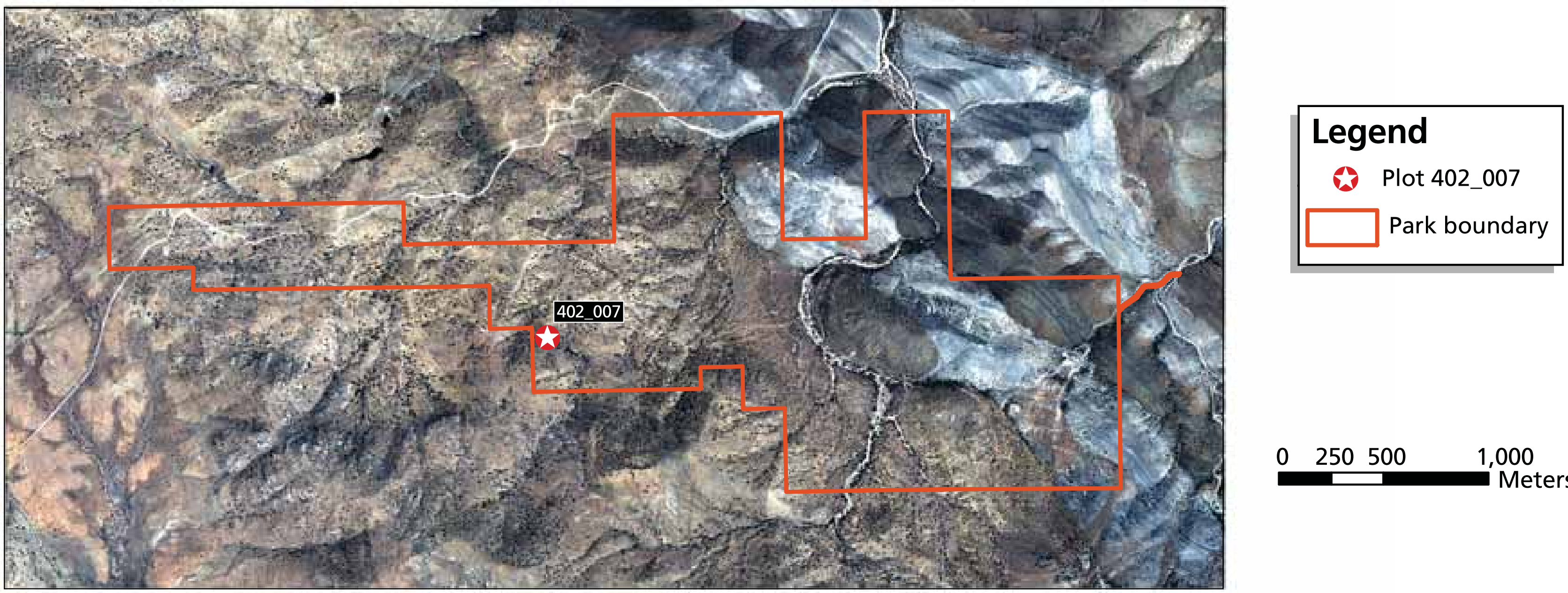
Plot permanent photos: V402_007


0m, 0m. 280 degrees


0m, 20m. 350 degrees


50m, 20m. 122 degrees


50m, 0m. 180 degrees



Produced by Sonoran Desert Network
January 2010

Fort Bowie National Historic Site
Arizona

National Park Service
U.S. Department of the Interior

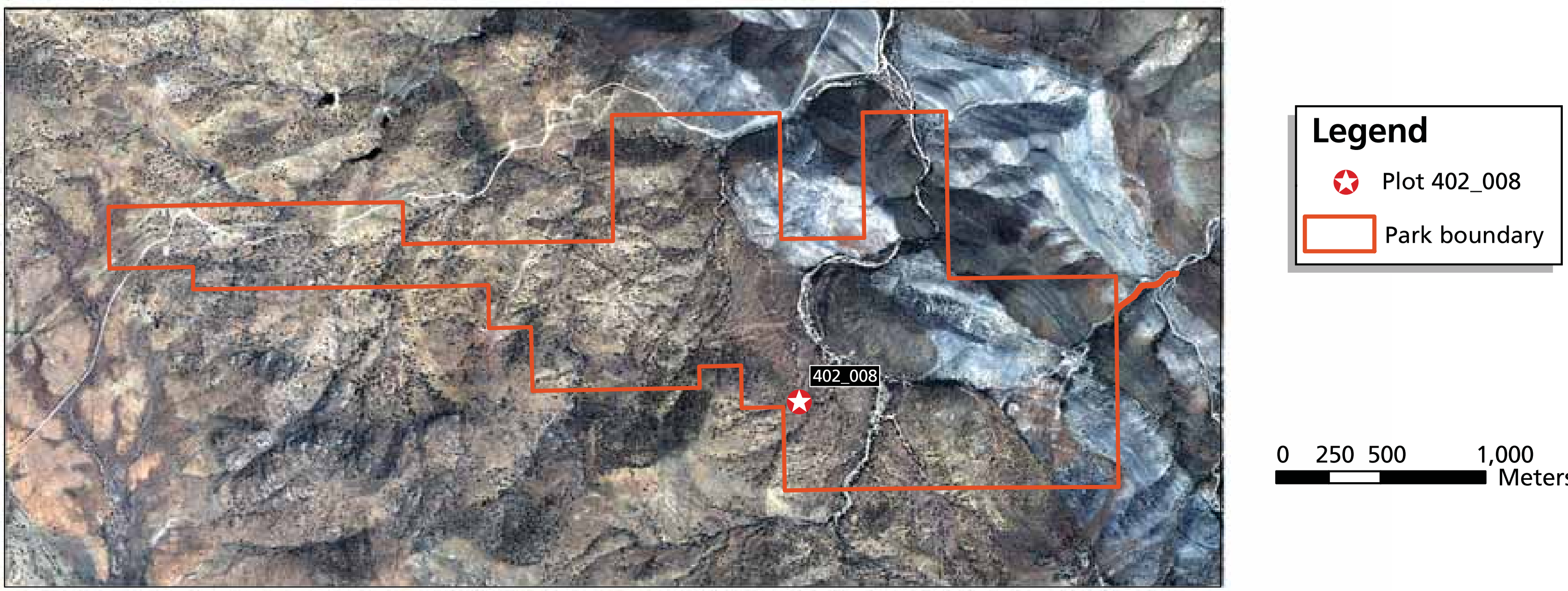
Plot permanent photos: V402_008


0m, 0m. 274 degrees


0m, 20m. 340 degrees


50m, 20m. 100 degrees


50m, 0m. 152 degrees



Produced by Sonoran Desert Network
January 2010

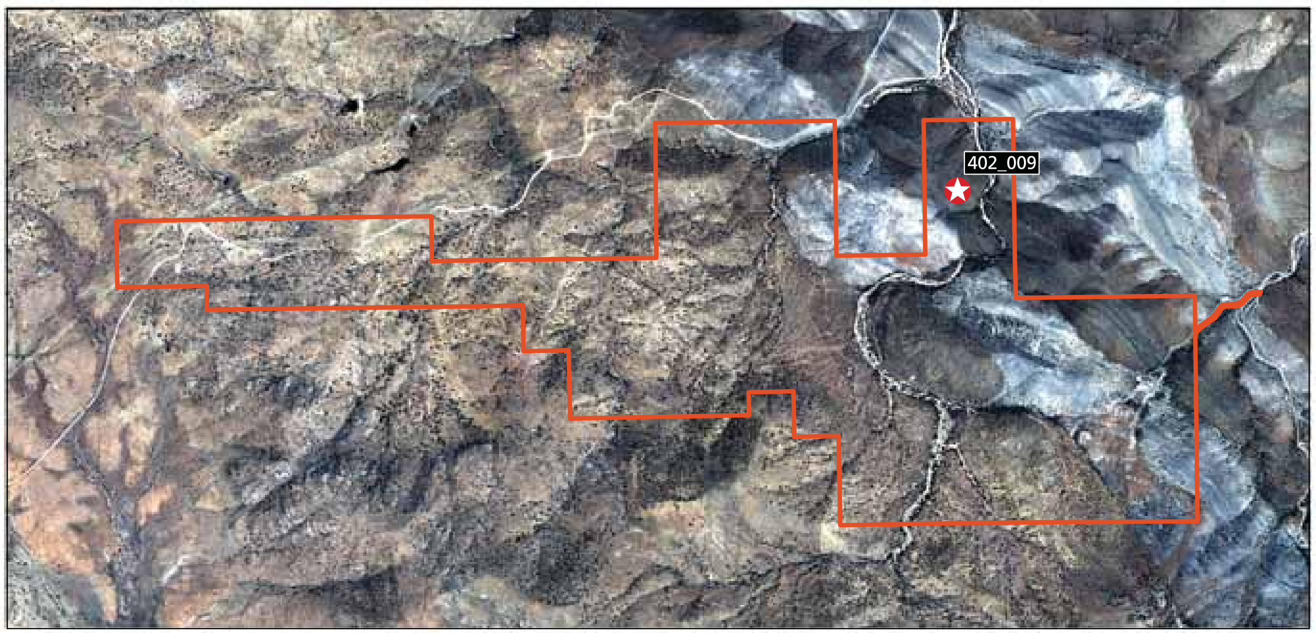
Plot permanent photos: V402_009


0m, 0m. 312 degrees


0m, 20m. 14 degrees


50m, 20m. 146 degrees


50m, 0m. 214 degrees



Legend
- Plot 402_009
- Park boundary

0 250 500 1,000
Meters

Produced by Sonoran Desert Network
January 2010

Fort Bowie National Historic Site
Arizona

National Park Service
U.S. Department of the Interior

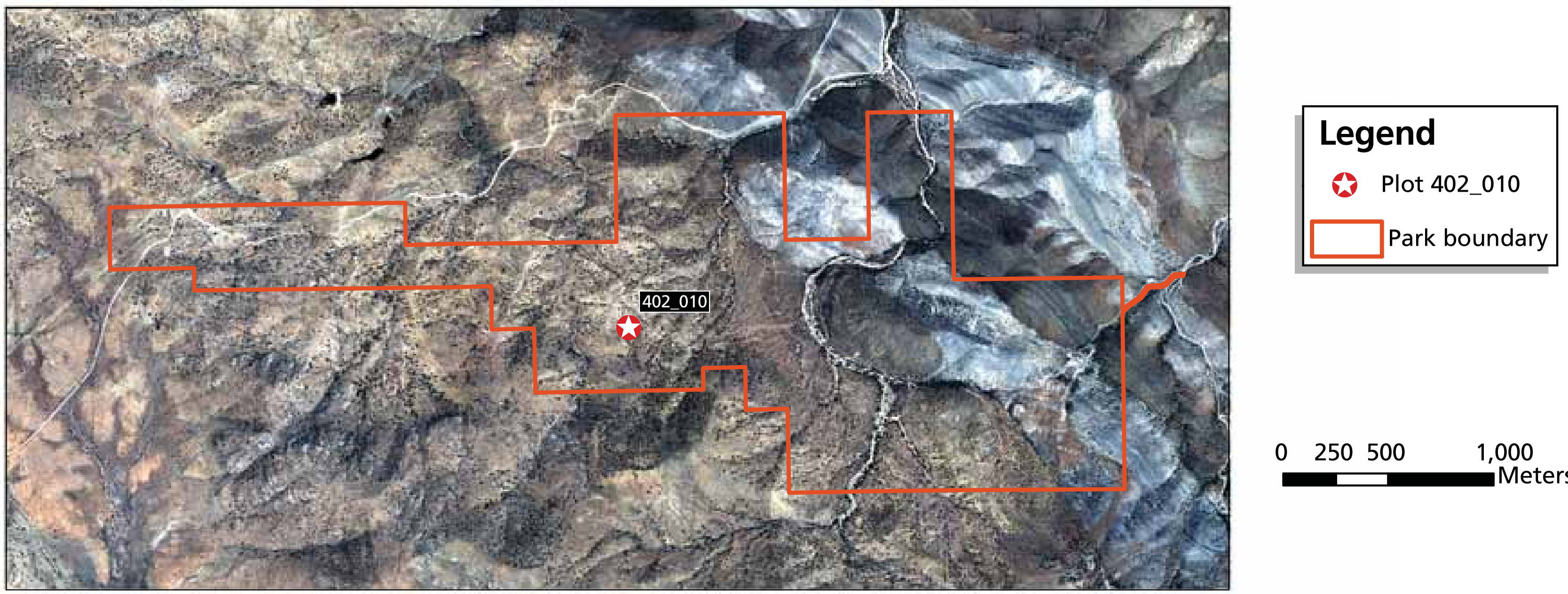
Plot permanent photos: V402_010

0m, 0m. 0 degrees

0m, 20m. 90 degrees

50m, 20m. 180 degrees

50m, 0m. 270 degrees



Produced by Sonoran Desert Network
January 2010

Fort Bowie National Historic Site
Arizona

National Park Service
U.S. Department of the Interior

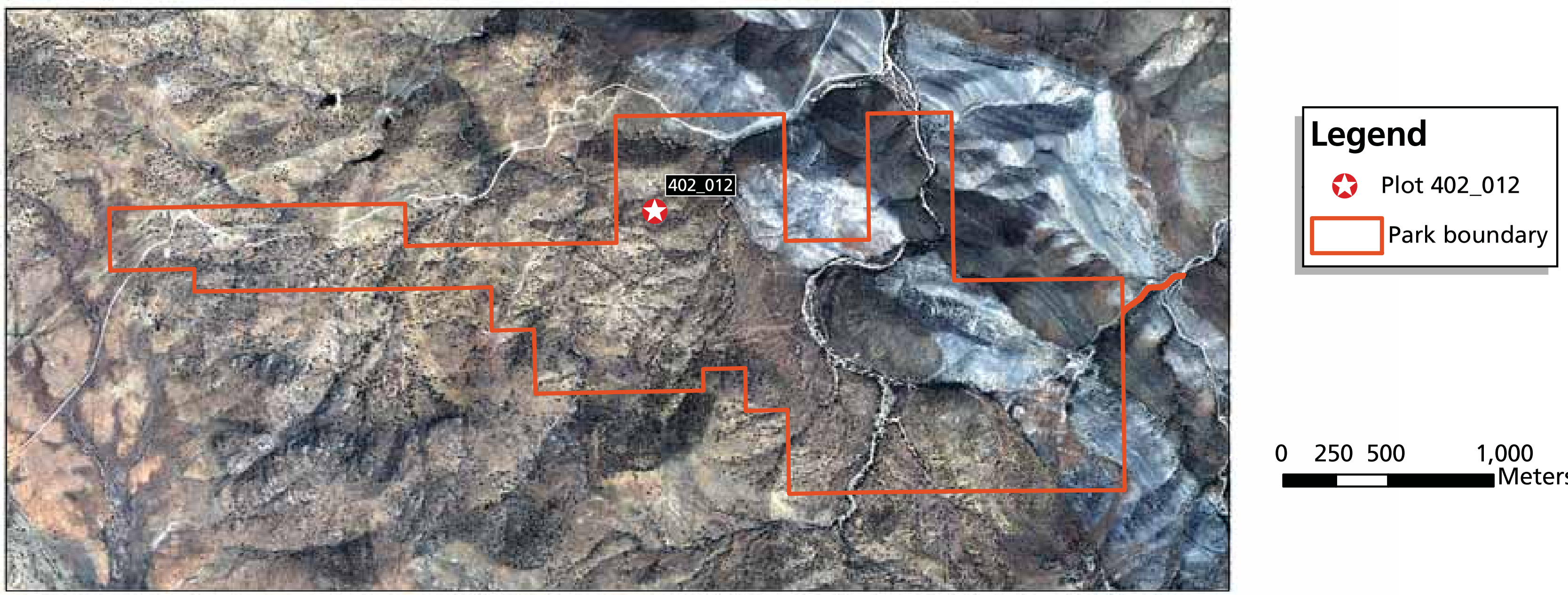
Plot permanent photos: V402_012


0m, 0m. 280 degrees


0m, 20m. 4 degrees


50m, 20m. 108 degrees


50m, 0m. 208 degrees



Produced by Sonoran Desert Network
January 2010

Fort Bowie National Historic Site
Arizona

National Park Service
U.S. Department of the Interior

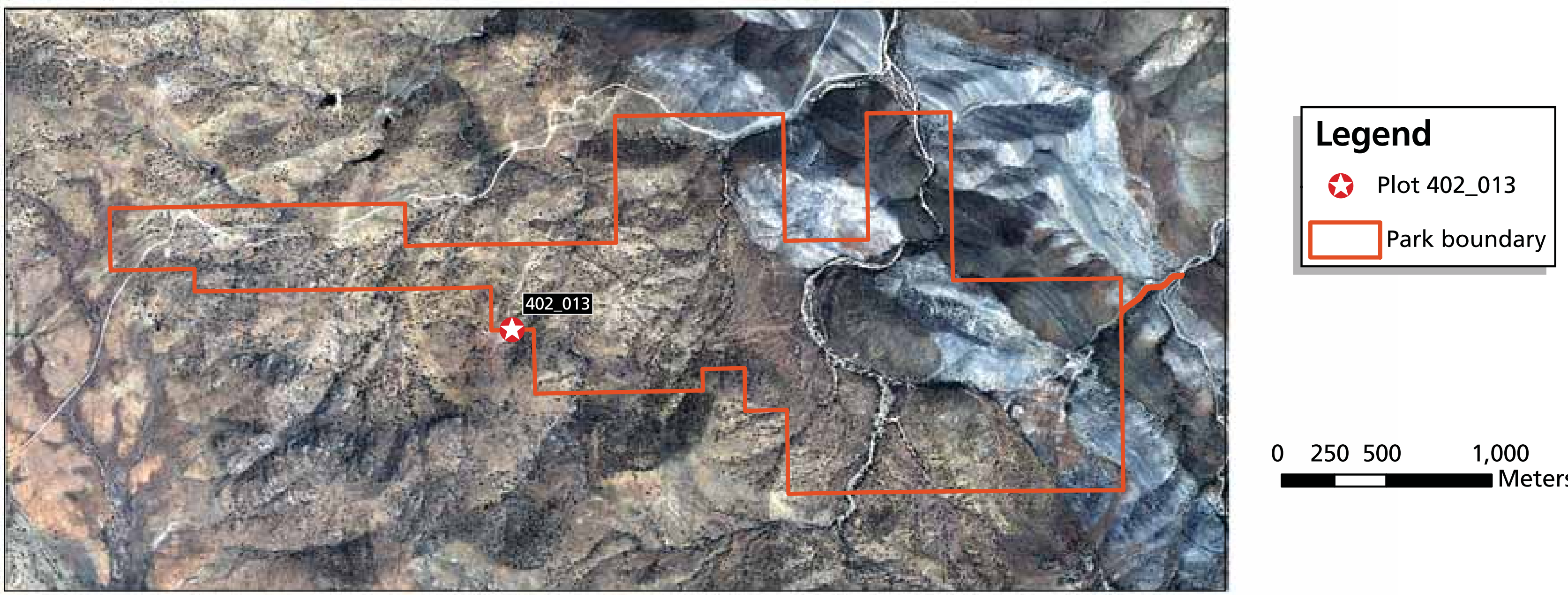
Plot permanent photos: V402_013


0m, 0m. 284 degrees


0m, 20m. 57 degrees


50m, 20m. 150 degrees


50m, 0m. 222 degrees



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Fort Bowie National Historic Site
Arizona

National Park Service
U.S. Department of the Interior

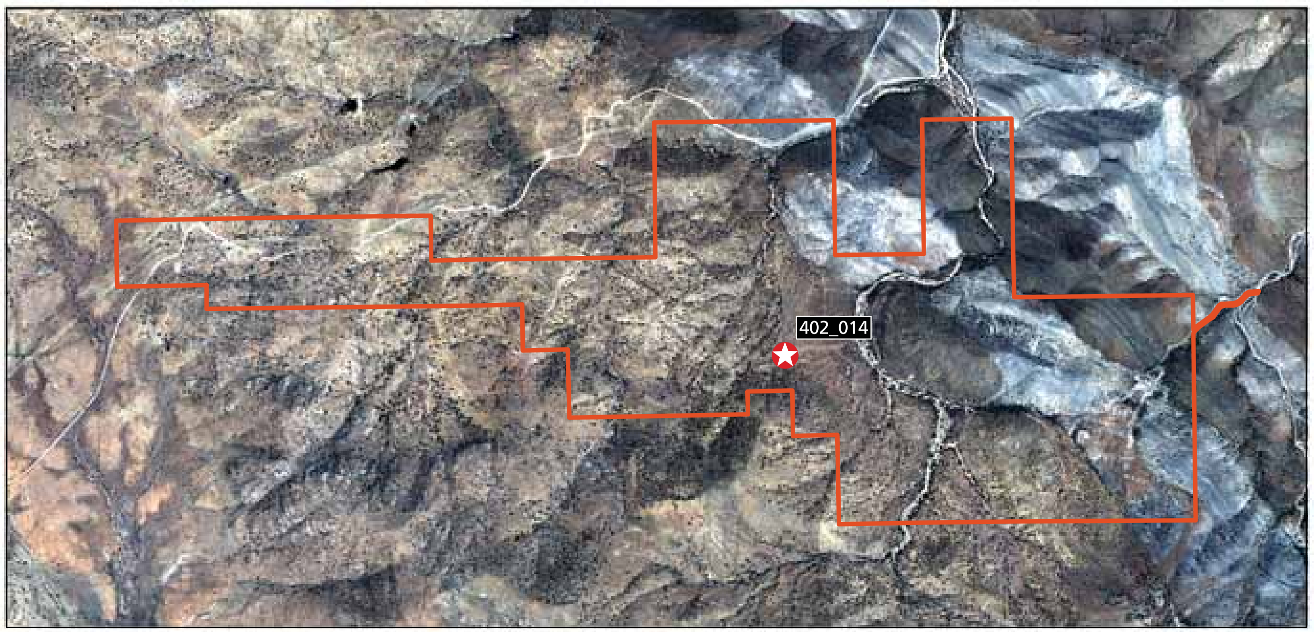
Plot permanent photos: V402_014


0m, 0m. 210 degrees


0m, 20m. 280 degrees


50m, 20m. 340 degrees


50m, 0m. 90 degrees



Legend

Plot 402_014

Park boundary

0 250 500 1,000
Meters

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Fort Bowie National Historic Site
Arizona

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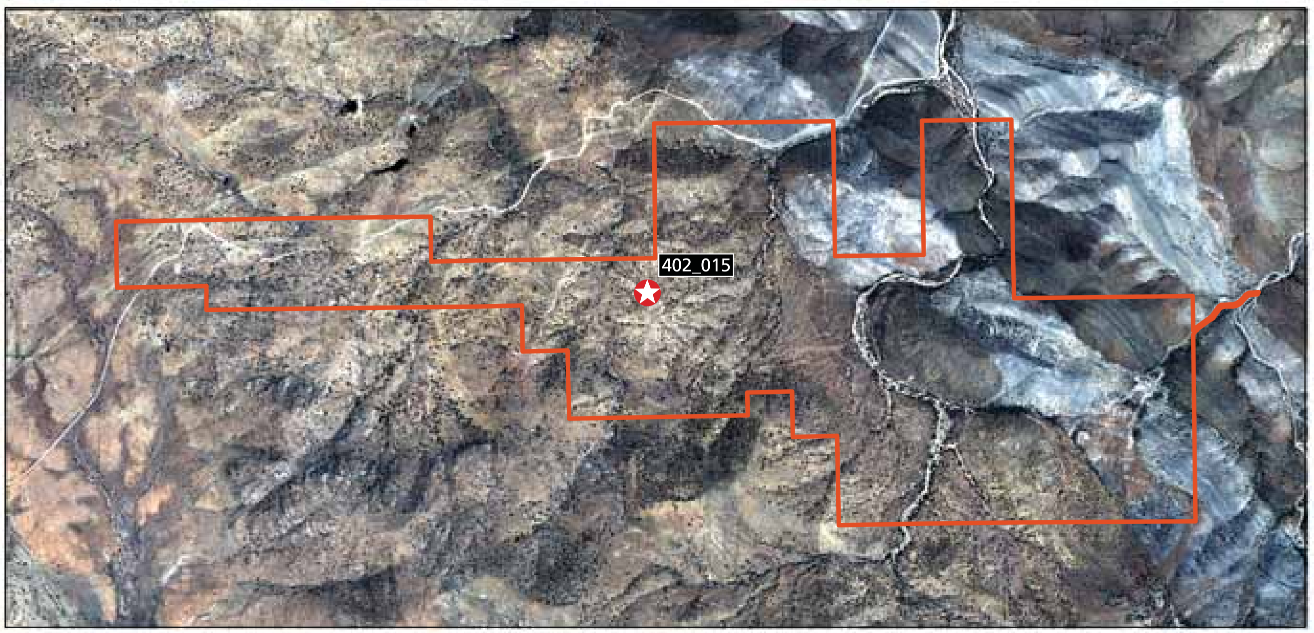
Plot permanent photos: V402_015


0m, 0m. 204 degrees


0m, 20m. 270 degrees


50m, 20m. 24 degrees


50m, 0m. 92 degrees



Legend
Plot 402_015
Park boundary

0 250 500 1,000
Meters

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January 2010

Plot permanent photos: V402_016

0m, 0m. 170 degrees

0m, 20m. 240 degrees

50m, 20m. 350 degrees

50m, 0m. 30 degrees

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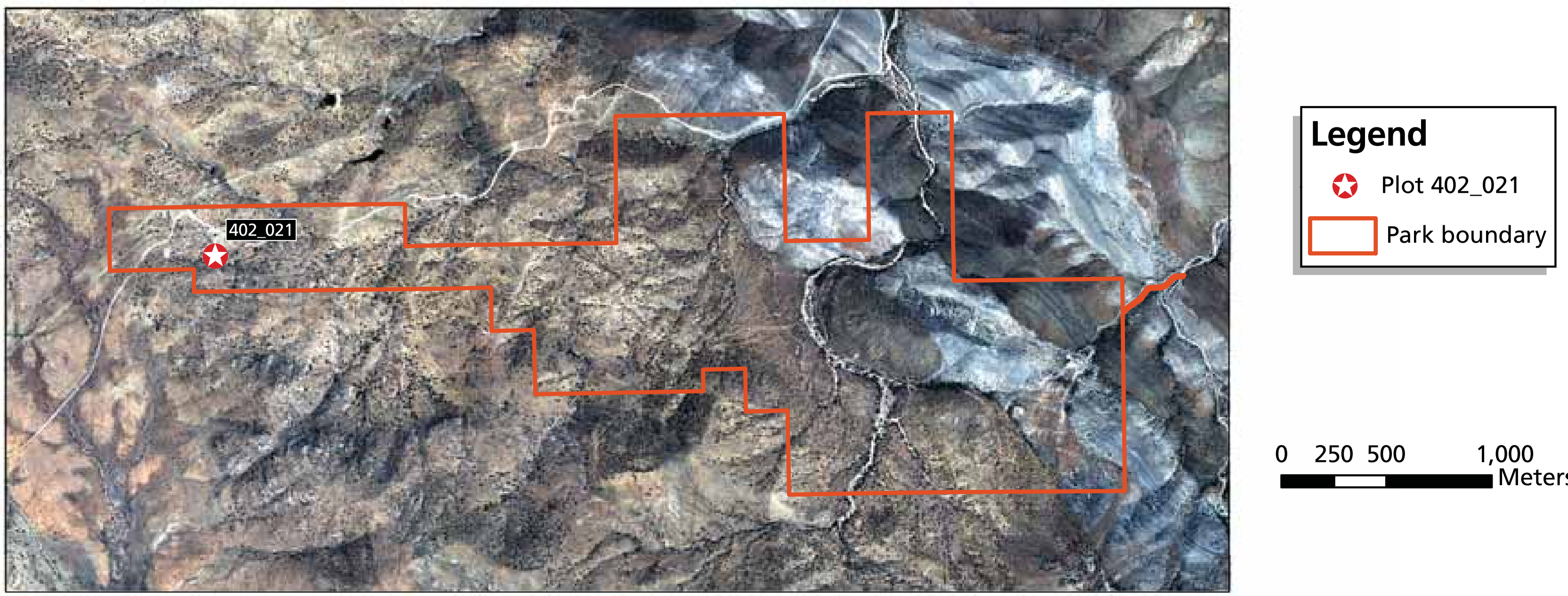
Plot permanent photos: V402_021


0m, 0m. 245 degrees


0m, 20m. 340 degrees


50m, 20m. 70 degrees


50m, 0m. 160 degrees



Produced by Sonoran Desert Network
January 2010

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

NPS 424/105492, September 2010

National Park Service
U.S. Department of the Interior

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