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Status of Terrestrial Vegetation and Soils at Leslie Canyon National Wildlife Refuge

Natural Resource Report NPS/SODN/NRR—2016/1312

ON THE COVER
Photograph of vegetation sampling at Leslie Canyon National Wildlife Refuge
Photography courtesy of U.S. Fish & Wildlife Service

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Natural Resource Report NPS/SODN/NRR—2016/1312

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Contents

Page

Figures . . . vi
Tables . . . viii
Executive Summary . . . xi
Acknowledgments . . . xiii
Acronyms . . . xiv
1. Introduction . . . 1
1.1 Background . . . 1
1.2 Goals and objectives . . . 1
1.3 How to use this report . . . 2
1.4 Overview of Leslie Canyon NWR . . . 2
1.4.1 Refuge establishment and purpose . . . 2
1.4.2 Biogeographic and physiographic context . . . 4
1.4.3 Local geology and soils . . . 5
1.4.4 Biological soil crusts . . . 5
1.4.5 Site and soil stability . . . 6
1.4.6 Climate . . . 6
1.4.7 Human habitation of Leslie Canyon NWR . . . 8
1.4.8 Other long-term monitoring and related ecological research at Leslie Canyon NWR . . . 8
1.5 Natural resource management issues at Leslie Canyon NWR . . . 9
1.5.1 Threatened and endangered species . . . 9
1.5.2 Sensitive aquatic and riparian resources . . . 11
1.5.3 Invasive non-native species . . . 11
2. Methods . . . 15
2.1 Response design . . . 15
2.1.1 Vegetation and soil cover: line-point intercept . . . 15
2.1.2 Vegetation frequency: subplots . . . 15
2.1.3 Soil aggregate stability . . . 15
2.1.4 Biological soil crust cover and frequency: Point-quadrats . . . 15
2.1.5 Soil and site characterization . . . 17
2.2 Sampling design . . . 17
2.2.1 Overview . . . 17
2.2.2 Spatial balance . . . 18

Contents (continued)

Page

2.2.3 Sampling frame . . . 18

2.2.4 Management assessment points as the link between science and management . . . 18

2.2.5 Statistical power to distinguish status from management assessment points . . . 20

2.2.6 Statistical power to detect trends . . . 21

2.2.7 Evaluation of strata . . . 21

2.2.8 Diversity of perennial plants . . . 21

3. Results . . . 23

3.1 Design considerations . . . 23

3.1.1 Evaluation of strata . . . 23

3.1.2 Power to detect trends in plant lifeforms and common perennial species . . . 23

3.1.3 Diversity of perennial plants . . . 24

3.2 Non-rocky, mid-mountain stratum (401) . . . 24

3.2.1 Vegetation formations, lifeforms, and perennial plant diversity . . . 27

3.2.2 Cover and extent of perennial plant species . . . 27

3.2.3 Frequency and extent of uncommon plant species . . . 32

3.2.4 Cover and frequency of exotic species . . . 32

3.2.5 Soil cover and biological soil crusts . . . 32

3.2.6 Soil stability . . . 35

3.2.7 Site and soil characterization . . . 35

3.2.8 Management assessment points . . . 36

3.3 Rocky, mid-mountain stratum (substratum 402-A) . . . 39

3.3.1 Vegetation formations, lifeforms, and perennial plant diversity . . . 39

3.3.2 Cover and extent of perennial plant species . . . 40

3.3.3 Frequency and extent of uncommon plant species . . . 40

3.3.4 Cover and frequency of exotic species . . . 40

3.3.5 Soil cover and biological soil crusts . . . 46

3.3.6 Soil stability . . . 46

3.3.7 Site and soil characterization . . . 47

3.3.8 Management assessment points . . . 47

3.4 Rocky, mid-mountain stratum (substratum 402-B) . . . 50

3.4.1 Vegetation formations, lifeforms, and perennial plant diversity . . . 50

3.4.2 Cover and extent of perennial plant species . . . 52

Contents (continued)

Page

3.4.3 Frequency and extent of uncommon plant species . . . 52
3.4.4 Cover and frequency of exotic species . . . 52
3.4.5 Soil cover and biological soil crusts . . . 52
3.4.6 Soil stability . . . 52
3.4.7 Site and soil characterization . . . 58
3.4.8 Management assessment points . . . 58
4. Discussion . . . 63
4.1 Terrestrial vegetation communities at Leslie Canyon NWR . . . 63
4.1.1 Non-rocky (401) vs. rocky sites (402) . . . 64
4.1.2 Intact, rocky (402-A) vs. invaded rocky (402-B) sites . . . 64
4.2 Lehmann lovegrass encroachment: soils, land use, or fire? . . . 71
4.3 Erosion potential: Implications for Leslie Creek . . . 73
4.3.1 Watershed influences on Leslie Creek . . . 73
4.3.2 Understanding upland erosion potential at Leslie Canyon NWR . . . 74
4.4 Diversity and flora . . . 77
4.5 Recommendations for additional research and monitoring . . . 78
4.6 Are terrestrial vegetation and soils within the range of natural variability? . . . 78
5. Literature Cited . . . 81
Appendix A. Permanent Plot Photos . . . 85

Figures

Page

Figure 1-1. The rare velvet ash - black walnut - willow - cottonwood forest along Leslie Creek in Leslie Canyon NWR. (USFWS) . . . 2

Figure 1-2. Location of Leslie Canyon NWR in southeastern Arizona. . . . 3

Figure 1-3. Regional Biogeography of the Sonoran and Chihuahuan Deserts Zone (USFWS) and the Sonoran Desert Network (NPS). Chihuahuan Desert Network (NPS) parks are not shown here. . . . 4

Figure 1-4. 2014 Climate data in the context of 30-year normals from the COOP station located at the Bisbee-Douglas International Airport, approximately 16 kilometers south of the refuge and lower in elevation. . . . 7

Figure 2-1. Terrestrial vegetation and soils monitoring plot design. . . . 16

Figure 2-2. Sampling frame and allocation of monitoring plots for terrestrial vegetation and soils monitoring, Leslie Canyon NWR. . . . 19

Figure 3-1. Non-metric multidimensional scaling (MDS) indicates similarity of vegetation communities by soil strata. . . . 23

Figure 3-2. Non-metric multidimensional scaling (MDS) of vegetation similarity at Leslie Canyon NWR suggests three broad vegetation types within the two *a. priori* soil strata. . . . 24

Figure 3-3. Locations of monitoring plots across the strata (401, 402-A, 402-B), Leslie Canyon National WIldlife Refuge, 2014. . . . 25

Figure 3-4. Species accumulation curves for non-rocky, mid-mountain stratum 401 suggest diminishing returns with increased sampling intensity. . . . 26

Figure 3-5. Species accumulation curves for rocky, mid-mountain substratum 402-A suggest diminishing returns with increased sampling intensity. . . . 26

Figure 3-6. Species accumulation curves for rocky, mid-mountain substratum 402-B suggest diminishing returns with increased sampling intensity. . . . 26

Figure 3-7. Lifeform cover in terrestrial vegetation monitoring plots on mid-mountain (4,501-6,000') sites with non-rocky soils (stratum 401) at Leslie Canyon NWR, 2014. . . . 28

Figure 3-8. Distribution and cover of the non-native grass, Lehmann lovegrass (*Eragrostis lehmanniana*) at Leslie Canyon NWR, 2014. . . . 34

Figure 3-9. Lifeform cover in terrestrial vegetation monitoring plots on mid-mountain (4,501-6,000') sites with rocky soils (Substratum 402- A) at Leslie Canyon NWR, 2014. . . . 41

Figure 3-10. Lifeform cover in terrestrial vegetation monitoring plots on mid-mountain (4,501-6,000') sites with rocky soils (substratum 402-B) at Leslie Canyon NWR, 2014. . . . 51

Figure 4-1. Example of the mariola/creosote bush shrublands (401 stratum) found on non-rocky (<35% surface soil rocks) locations within Leslie Canyon NWR, 2014. . . . 63

Figure 4-2. Example of the mariola/Rio Grande saddlebush/slim tridens shrub savannas (402-A substratum) found on some rocky (35-90% surface soil rocks) locations within Leslie Canyon NWR, 2014. . . . 63

Figure 4-3. Example of the Lehmann lovegrass semi-desert grasslands (402-B substratum) found on some rocky (35-90% surface soil rocks) locations within Leslie canyon NWR, 2014. . . . 64

Figure 4-4. Vegetation and soils data for non-rocky, mid-mountain (401 stratum) monitoring sites in the context of management assessment points. Leslie Canyon NWR, 2014. . . . 65

Figures (continued)

Page

Figure 4-5. Vegetation and soils data for rocky, mid-mountain (402-A substratum) monitoring sites in the context of management assessment points, Leslie Canyon NWR, 2014. 66

Figure 4-6. Vegetation and soils data for rocky, mid-mountain (402-B substratum) monitoring sites in the context of management assessment points. Leslie Canyon NWR, 2014. 67

Figure 4-7. Locations of plots in each of the three vegetation types at Leslie Canyon NWR. 68

Figure 4-8. Summary of the three primary terrestrial vegetation types at Leslie Canyon NWR, 2014 69

Figure 4-9. Distribution and cover of the non-native grass, Lehmann lovegrass (*Eragrostis lehmanniana*) at Leslie Canyon NWR, 2014. 70

Figure 4-10. Non-native species detected on monitoring plots at Leslie Canyon NWR, 2014. 71

Figure 4-11. Common native perennial plants that were absent on Lehmann lovegrass-dominated sites at Leslie Canyon NWR, 2014. 72

Figure 4-12. Lehmann lovegrass (*Eragrostis lehmanniana*) comprised about 25% cover on invaded sites - the most dominant plant species on these locations. 73

Figure 4-13. Diagram of the effects of soil erosion in uplands areas on riparian and stream systems. 75

Figure 4-14. Effect of soil cover on erosion by water. 76

Figure 4-15. Examples of the very rare species that occur at Leslie Canyon NWR.. 77

Tables

Page

Table 1-1. Known and hypothetical federal and state listed species that occur in or adjacent to San Bernardino and Leslie Canyon National Wildlife Refuges. 10

Table 1-2. Non-native plants detected in and around Leslie Canyon NWR (USFWS 2016). 11

Table 2-1. Height categories for vegetation measurement. 15

Table 2-2. Categories for aggregate stability of surface soils. 17

Table 2-3. Allocation of permanent terrestrial vegetation and soils monitoring plots by strata, Leslie Canyon NWR. 18

Table 2-4. Proposed management assessment points for terrestrial vegetation and soils monitoring at Leslie Canyon NWR. 20

Table 3-1. Cover values (%) for perennial and non-native annual species (by lifeform) measured in the field (<0.5m stature), subcanopy (0.5-2.0m), and canopy (>2.0m) layers of mid-mountain (4,501-6,000′), non-rocky (401 stratum) terrestrial vegetation and soils plots at Leslie Canyon NWR, 2014. 29

Table 3-2. Within-plot frequency (%), standard error (SE), and extent (out of 6 plots) of uncommon plant species (found only on subplots and not on transects) sampled on non-rocky, mid-mountain (401 stratum; 35-90% surface soil rock fragments, 4,501′-6,000′) monitoring plots on Leslie Canyon NWR, 2014. 32

Table 3-3. Presence/absence of non-native plants detected on vegetation monitoring plots, Leslie Canyon National Wildlife Refuge, 2014. 35

Table 3-4. Soil substrate cover (% by category) for non-rocky, mid-mountain (401 stratum; <35% surface soil rock fragments, 4,501′-6,000′) monitoring plots on Leslie Canyon NWR, 2014. 36

Table 3-5. 2014 soil and site characterization for non-rocky, mid-mountain (401 stratum) monitoring sites (Elev. 4,501-6,000′), at Leslie Canyon NWR. 37

Table 3-6. Vegetation and soils data for non-rocky, mid-mountain (401 stratum) monitoring sites in the context of management assessment points, Leslie Canyon National Wildlife Refuge. 38

Table 3-7. Cover values (%) for perennial and non-native annual species (by lifeform) measured in the field (<0.5m stature), subcanopy (0.5-2.0m), and canopy (>2.0m) layers of mid-mountain (4,501-6,000′), rocky (402-A substratum) terrestrial vegetation and soils plots at Leslie Canyon NWR, 2014. 42

Table 3-8. Within-plot frequency (%), standard error (SE), and extent (out of 7 plots) for uncommon plant species (found only on subplots and not on transects) sampled on rocky, mid-mountain (402-A substratum; 35-90% surface soil rock fragments, 4,501-6,000′) monitoring plots in Leslie Canyon NWR, 2014. 45

Table 3-9. Soil surface cover (% by category) for rocky, mid-mountain (402-A; 35%-95% surface soil rock fragments, 4500-6000′) monitoring plots on Leslie Canyon NWR, 2014. 47

Table 3-10. 2014 soil and site characterization for rocky, mid-mountain (402-A substratum) monitoring sites (Elev. 4,501-6,000′), at Leslie Canyon NWR. 48

Table 3-11. Vegetation and soils data for rocky, mid-mountain (402-A substratum) monitoring sites in the context of management assessment points, Leslie Canyon National Wildlife Refuge. 49

Table 3-12. Cover values (%) for perennial and non-native annual species (by lifeform) measured in the field (<0.5m stature), subcanopy (0.5-2.0m), and canopy (>2.0m) layers of mid-mountain (4,501-6,000′), rocky (402-B substratum) terrestrial vegetation and soils plots at Leslie Canyon NWR, 2014. 53

Tables (continued)

Page

Table 3-13. Within-plot frequency (%), standard error (SE), and extent (out of 7 plots) for uncommon plant species (found only on subplots and not on transects) sampled on rocky, mid-mountain (402-B substratum; 35-90% surface soil rock fragments, 4,501-6,000') monitoring plots in Leslie Canyon NWR, 2014. 56

Table 3-14. Soil surface cover (% by category) for rocky, mid-mountain (402-B substratum; 35%-95% surface soil rock fragments, 4500-6000') monitoring plots on Leslie Canyon NWR, 2014. 58

Table 3-15. 2014 soil and site characterization for rocky, mid-mountain (402-B substratum) monitoring sites (Elev. 4,501-6,000'), at Leslie Canyon NWR. 59

Table 3-16. Vegetation and soils data for rocky, mid-mountain (402-B substratum) monitoring sites in the context of management assessment points, Leslie Canyon National Wildlife Refuge. 60

Executive Summary

Leslie Canyon National Wildlife Refuge (NWR) in southeastern Arizona was established to protect important habitat for endangered fish species in the Yaqui watershed. The immense diversity in flora and fauna in Leslie Canyon is a result of the refuge's location in a transition area between major ecoregions. Management and protection of these unique natural resources requires an understanding of broad-scale changes in ecosystems over time. We implemented a terrestrial vegetation and soils monitoring program as a collaborative initiative between the U.S. Fish & Wildlife Service and the National Park Service to support effective management and protection of refuge natural resources. This report summarizes the first round of terrestrial vegetation and dynamic soils monitoring at Leslie Canyon NWR.

We surveyed key terrestrial vegetation and dynamic soil functional attributes including vegetation community structure, lifeform abundance, status and trends of established exotic plants, early detection of previously undetected exotic plants, and indicators of soil dynamic function and erosion resistance: cover of mineral soil and the stability of surface soil aggregates. Permanent plots were established using stratification based on elevation and soil rock-fragment classes. We suggest management assessment points to aid interpretation of ecological information within a management context and serve as a potential early warning system.

Terrestrial vegetation communities at Leslie Canyon NWR were comprised of three types based on surface soil rock content and exotic plant encroachment:

- Non-rocky (<35% surface soil rock fragments), mid-mountain (4,501–6,000 ft.) mariola/creosote bush shrublands
- Rocky (35-90% surface soil rock fragments), mid-mountain (4,501–6,000 ft.) mariola/Rio Grande saddlebush/slim tridens shrub savannas
- Rocky (35-90% surface soil rock fragments), mid-mountain (4,501-6,000 ft.) Lehman lovegrass-dominated semi-desert grasslands

The most striking differences in terrestrial vegetation at Leslie Canyon NWR appear to be driven by the varying distribution and dominance of the non-native invasive bunchgrass, Lehmann lovegrass (*Eragrostis lehmanniana*) on rocky sites. The northern part of the refuge has been extensively colonized by this grass and management assessment points related to exotic plant abundance and cover were consistently exceeded on these sites. Effective control of this species will be vital in protecting native flora and fauna and depends on developing an understanding of the root causes of this invasion.

The powerful influence of upland erosion on hydrologic function, chemistry, morphology, nutrients, and biological processes suggest that managing upland areas is critical to successful management of aquatic resources in Leslie Creek. Our data indicate that soils at Leslie Canyon NWR are currently very well armored. Vegetative cover was relatively high and biological crust cover was within our assessment point limits. The majority of soil cover consisted of highly resistant materials such as gravel and rocks. Surface soil aggregate stability across the refuge was "moderately stable". However, stability on exposed soils of rocky sites – a subset of locations that were not protected by vegetation canopies – ranged from "somewhat unstable" to "unstable", although sampling issues greatly limited our sample size. As exposed bare soil is the weakest link in the soil "armor" mitigating erosion on a site, we recommend a targeted assessment of soil aggregate stability on rocky sites.

Although species richness and taxonomic diversity were not very different between sampling sites, we were surprised at the overall floristic diversity of the refuge. We detected about 35% of the 509 known species (determined in a companion flora effort) in terrestrial vegetation plots. This is surprising given that we were not sampling riparian areas or identifying annual plants to species (except for non-natives). The sensitivity of this biodiverse flora to Lehmann lovegrass encroachment suggests the strong need for a sustained weed control effort at Leslie Canyon NWR.

Based on our terrestrial vegetation and soils monitoring results, we make five recommendations for additional research and monitoring on the refuge:

1. Compile an administrative history of land use and disturbance at Leslie Canyon NWR. Such historic data may address some of the questions posed by this report, such as the cause of Lehmann lovegrass invasion, and is invaluable to effective resource management.
2. Repeat the terrestrial vegetation and soils monitoring effort in 2019. We expect the vegetation communities and soil parameters to interact with changes in climate and other disturbances. Continuing these monitoring efforts can provide an "early warning" system that will be vital to protecting Leslie Creek from potential erosion events off of the surrounding steep, upland slopes.
3. Continue the Flora Project effort. It is likely there are substantially more rare and sensitive species to be discovered on this very floristically diverse refuge.
4. Conduct a site-specific soil inventory coupled with erosion modelling. The existing county survey is mapped at a scale that is inappropriate for the relatively small size of the refuge and does not focus on the ecosystem management mandate of the refuge. A soil inventory could provide a powerful tool for assessing potential ecosystem degradation of Leslie Creek and the surrounding watershed.
5. Consider a habitat monitoring approach to Leslie Creek. Integrating hydrology, channel morphology and riparian vegetation into monitoring efforts would greatly enhance the ecological knowledge of the condition of the aquatic and riparian species that are the focus of management at Leslie Canyon NWR.

Acknowledgments

We thank Refuge Manager Bill Radke , Refuge Specialist Chris Lohrengel and the rest of the staff of Leslie Canyon NWR for their on-site support of the field effort conducted by the Sonoran and Chihuahuan Deserts Zone (SCDZ) Inventory and Monitoring Program. Rob Hastings, Matt Christensen, Alecio Lopez-O'Day and Frankie Coburn conducted the field data collection with Bethany DeRango. Matt Christensen and staff from the Brigham Young University – Environmental Analytical Laboratory processed the soil samples. Frankie Coburn provided expert botanical expertise for crew training and identification of unknown samples while in the field. Data processing and management support was provided by SODN Data Manager Kristen Bonebrake. Lastly, many thanks to the Tucson Audubon Society who have provided several of the field personnel throughout this and many ongoing projects. Their technical and administrative support has proved invaluable during the course of this collaboration.

Photo: The 2014 vegetation monitoring crew at Leslie Canyon NWR.

Acronyms

LCNWR: Leslie Canyon National Wildlife Refuge

GRTS: Generalized Random Tessellation Stratified

I&M: Inventory and Monitoring Program

NPS: National Park Service

RRQRR: Reversed Randomized Quadrant-Recursive Raster

SCDZ: Sonoran and Chihuahuan Deserts Zone

SODN: Sonoran Desert Network

USFWS: U.S. Fish and Wildlife Service

1. Introduction

1.1 Background

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

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

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

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

The Sonoran and Chihuahuan Deserts Zone (SCDZ), as part of the US Fish & Wildlife Service's (USFWS) collaboration with the National Park Service's (NPS) 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 Leslie Canyon National Wildlife Refuge (Figure 1-1). Indicators of terrestrial vegetation integrity include vegetation community structure, lifeform abundance, status and trends of established exotic plants, and early detection of previously undetected exotic plants. Indicators of soil dynamic function and erosion resistance include the cover of mineral soil and the stability of surface soil aggregates.

1.2 Goals and objectives

The overall goal of SCDZ and NPS's Sonoran Desert and Chihuahuan Desert networks (SODN and CHDN) terrestrial vegetation and soils monitoring programs 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 refuge natural resources in a cumulative fashion, such that the results of each successive round of monitoring builds upon the knowledge gained from previous efforts and related research and monitoring activities.

Photo: Field staff recording terrestrial vegetation on the rolling hills of Leslie Canyon NWR. (USFWS)

Specific, measurable objectives for terrestrial vegetation and soils monitoring at Leslie Canyon NWR are to determine the status of and detect trends in (over five-year intervals):

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

1.3 How to use this report

This is a large report; readers with specific interests can focus on particular sections:

Just the highlights, please:

- •Executive Summary
- •Chapter 4
- •Figures 4-4, 4-5, and 4-6.

Add detail on management implications:

- •Sections 3.2.8, 3.3.8, 3.4.8
- •Tables 3-6, 3-11, 3-16

Add detail on sampling design:

- •Chapter 2
- •Section 3.1
- •Figure 2-1

This document reports and interprets the results of the first round of terrestrial vegetation and soils monitoring at Leslie Canyon NWR. Our focus is necessarily on current status, with trend evaluations to commence after the next sampling period in 2019. We do, however, interpret the information in the context of management objectives and ecological considerations.

1.4 Overview of Leslie Canyon NWR

1.4.1 Refuge establishment and purpose

Leslie Canyon NWR was established on May 31, 1988 to protect important habitat for the endangered Yaqui chub (*Gila purpurea*) and the Yaqui topminnow (*Poeciliopsis sonoriensis*). Both of these species, as well as the threatened Yaqui beautiful shiner (*Cyprinella formosa*), inhabit Leslie Creek which flows through the middle of the refuge. In addition, the refuge protects migratory waterfowl and the rare velvet ash - black walnut - willow - cottonwood forest along Leslie Creek (Figure 1-1). Additional lands were acquisitioned in 1994 and 1995, bringing the total refuge area to 1,119 hectares (2,765 acres). Situated at the junction of the Swisshelm Mountains to the north and the Pedregoso Mountains to the south (Figure 1-2), the refuge lies within the Yaqui watershed.

Figure 1-1. The rare velvet ash - black walnut - willow - cottonwood forest along Leslie Creek in Leslie Canyon NWR. (USFWS)

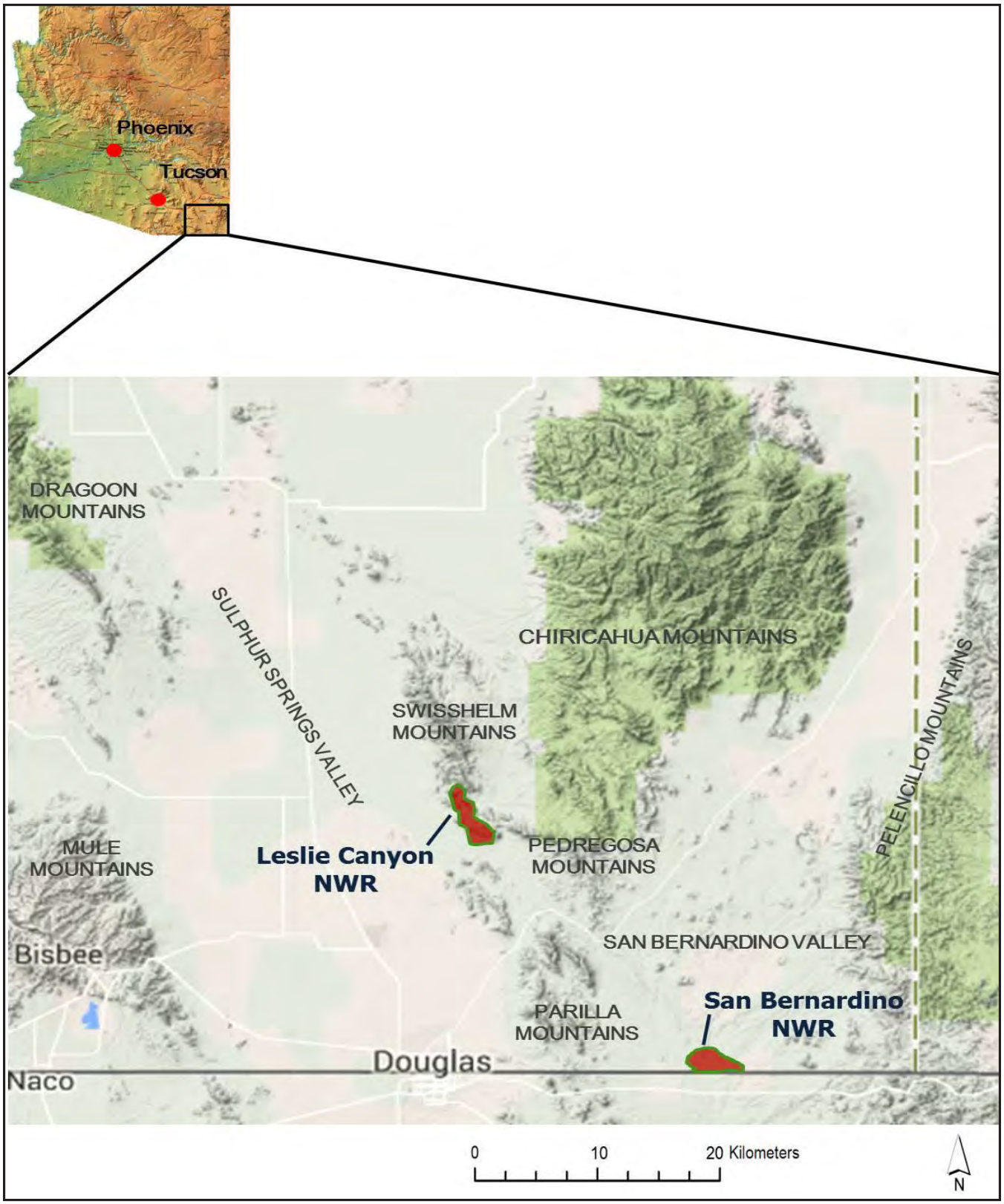


Figure 1-2. Location of Leslie Canyon NWR in southeastern Arizona.

The grasslands, riparian areas, and the once even greater water sources attracted settlers to the area. While nearby land, including what is currently San Bernardino NWR, was ranched starting in the early 1800s, exact use of the land and creek at Leslie Canyon NWR during this time period is not well documented.

The land that now makes up the refuge was acquired by The Nature Conservancy and transferred to USFWS. By protecting and preserving water flow, Leslie Canyon NWR and nearby San Bernardino NWR are internationally significant, playing critical roles in supporting populations of native fish by restoring and maintaining aquatic and riparian habitat in the United States and Mexico.

1.4.2 Biogeographic and physiographic context

Leslie Canyon NWR is located about 22 miles north of the international border with Mexico in Cochise County, southeastern Arizona. At the southern end of the Swisshelm Mountains, the refuge lies adjacent to both the Sulphur Springs and San Bernardino valleys. The refuge lies within the Apache Highlands Ecoregion (Figure 1-3), a transitional area characterized largely by canyons and valleys separated by small mountain ranges, ridges and plateaus (TNC 1999). The USFWS Landscape Conservation Cooperative (LCC) identifies the refuge as being located in the Desert region (LCC3).

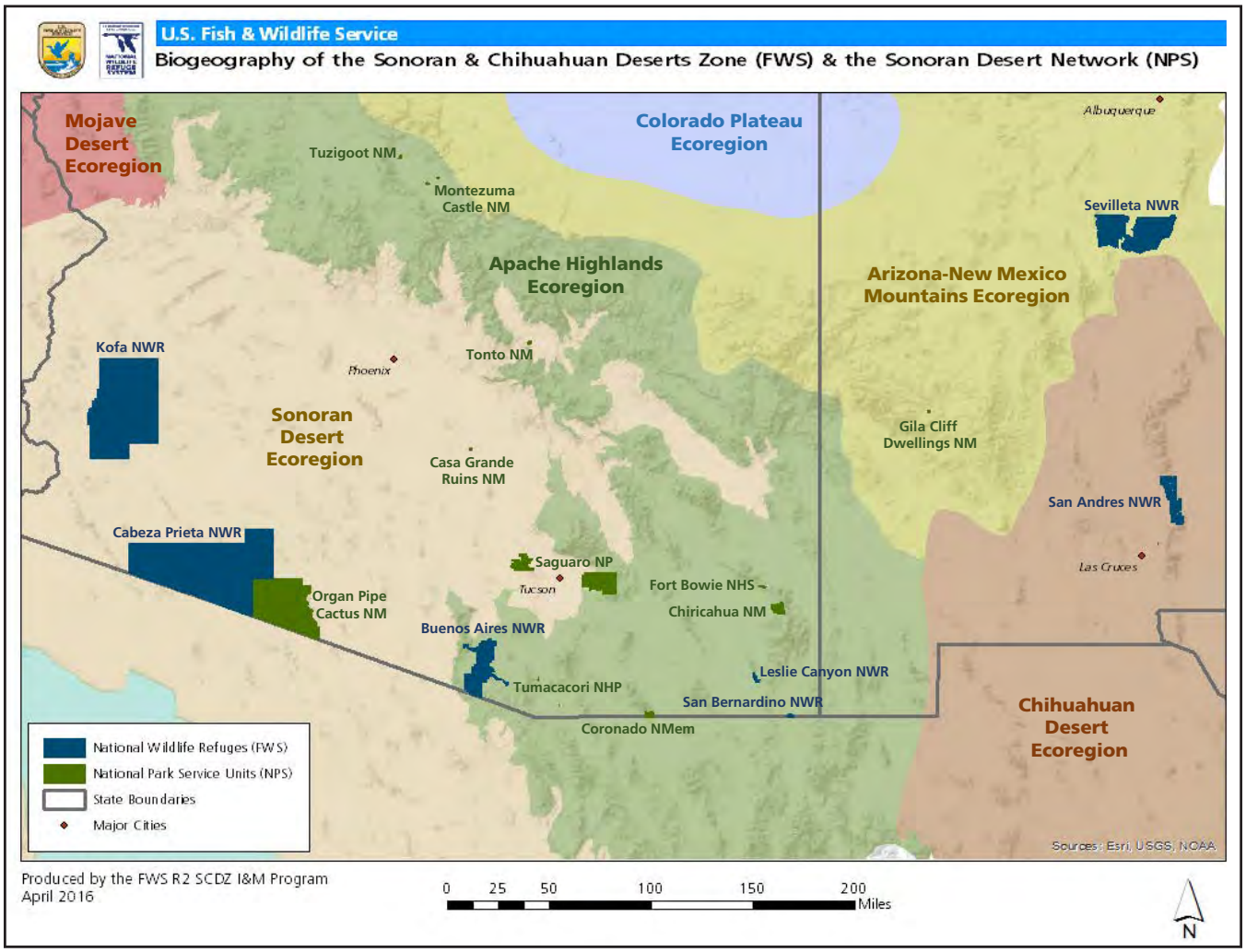


Figure 1-3. Regional Biogeography of the Sonoran and Chihuahuan Deserts Zone (USFWS) and the Sonoran Desert Network (NPS). Chihuahuan Desert Network (NPS) parks are not shown here.

Predominantly Chihuahuan desert scrub and desert grasslands, the refuge is part of the Mexican Highland section of the Basin and Range physiographic province. Refuge elevations range from about 1,400 m to about 1,675 m (~4,600 - 5,500 ft.) on peaks in the southern Swisshelm Mountains.

Leslie Canyon NWR lies within the Leslie Creek watershed that encompasses 207 km^2 (80 mi^2) and is within the uppermost headwater basin of the Rio Yaqui, the largest river system in the state of Sonora, Mexico. The perennial flows in Leslie Creek originate primarily from springs in Leslie Canyon although water from canyons and washes in the Chiricahua, Pedrogosa, and Swisshelm mountains also feed Leslie Creek. The northern half of the refuge is comprised of sweeping to undulating slopes and jagged peaks flanking well developed hydrologic corridors feeding Leslie Creek. Comparatively, the southern half of the refuge plummets out of the Swisshelms and into the valley below. Here, the topography is much more level but continues to be deeply dissected by desert washes.

The San Bernardino Valley once supported several permanently flowing creeks, springs, and marshy wetlands. Leslie Canyon NWR still offers an oasis within the semi-arid landscape of southeastern Arizona, providing resting, breeding, and year-round habitat for an amazing diversity of wildlife.

1.4.3 Local geology and soils

Leslie Canyon NWR is within the basin and range geologic region, characterized by discontinuous linear mountain ranges orientated generally northwest to southeast, and separated by wide basins/alluvial plains. Locally, the mountains are made up of volcanic and sedimentary rock including rhyolite, andesite, quartzite, limestone, sandstone and shale. The basin-fill sediments of the Leslie Creek valley floor consist of gravel, sand, cobbles, silt and clay (Broska 2009).

Upland soils within Leslie Canyon NWR are generally shallow and well drained. The southern end of the refuge has a mixture of very shallow and some very deep, mixed calcareous fan alluvium soils on flat or gentle slopes. Surface layers are primarily composed of gravelly, fine sandy loam soils. The remainder of the refuge (outside of the riparian areas) has shallow to very shallow, mostly calcareous fan and slope alluvium soils derived from sedimentary rock on moderate to very steep slopes. Surface layers are primarily composed of very gravelly or very cobbly, sandy loam to loamy soils (USDA 2002).

1.4.4 Biological soil crusts

Open spaces on the soils in arid and semi-arid regions are often covered by biological soil crusts, a community of cyanobacteria, algae, lichens, and bryophytes (Belnap et al. 2003). Lichens are a composite, symbiotic organism composed of a fungus and either a cyanobacteria or a green algae. Bryophytes are small, non-vascular plants, including mosses and liverworts.

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

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

In general, lichens with the same growth form have similar ecological functions. Squamulose lichens provide the most protection of the soil from water erosion, followed by crustose, foliose, and fruticose lichens. Gelatinous lichens provide the least protection from water erosion. Having some vertical growth allows lichens to provide additional protection from wind erosion by increasing surface roughness and decreasing the erosive power of wind. Crustose and gelatinous lichens are effective at resisting detachment, but do not provide as much resistance to wind erosion as other growth forms (Eldridge and Rosentreter 1999). All gelatinous lichens fix nitrogen,

whereas nitrogen fixation is species-dependent for the other growth forms (Belnap et al. 2001).

1.4.5 Site and soil stability

Site stability is the resistance of a site to localized wind and water erosion of soils (Herrick et al. 2005b) — with tremendous consequences for refuge ecosystems and the protection of finite aboveground and subsurface cultural resources.

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

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

1.4.6 Climate

Located within the Tropical-Subtropical Desertland climatic zone (Brown et al. 1994), Leslie Canyon NWR has a semi-arid climate. The refuge experiences climate typical of the Apache Highlands ecoregion: highly variable, bimodal precipitation with a

Photo: A monsoon storm rolls across the valley bringing torrential localized rainfall near Leslie Canyon NWR. (USFWS/W. RADKE)

considerable range in daily and seasonal air temperature, and relatively high potential evapotranspiration rates (TNC 1999). Summer rains dominate the precipitation pattern in the form of monsoon thunderstorms, which are generally localized and torrential. Winter storms are gentler and more widespread and typically longer in duration.

Annual average precipitation (1981-2010) in the refuge is slightly less than 32 cm (12.65 in), with about 52% coming in July, August, and September (www.climateanalyzer.org). Monsoon storm cells are spatially discontinuous and high summer temperatures result in high evaporation rates. About 35% of the refuge area precipitation occurs during winter months (November-April), mostly from frontal storm systems. At higher elevations, this precipitation often falls as snow. Slow water release from high elevation spring snowmelt and low evaporation rates (due to

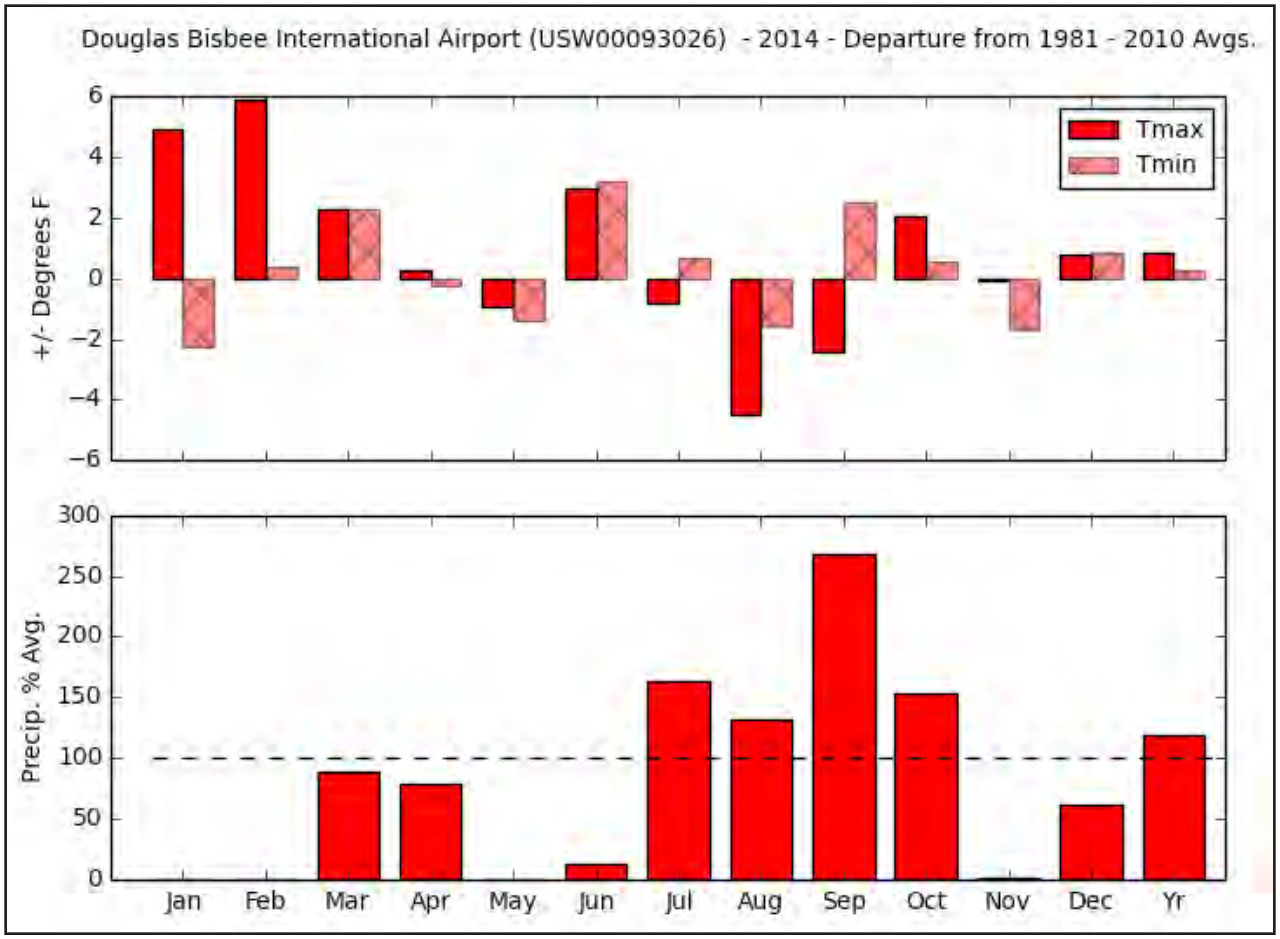


Figure 1-4. 2014 Climate data in the context of 30-year normals from the COOP station located at the Bisbee-Douglas International Airport, approximately 16 kilometers south of the refuge and lower in elevation.

lower air temperatures) make winter precipitation more hydrologically efficient because there is less runoff and greater gain to streams and aquifers.

We provide climographs of monthly minimum and maximum average air temperature and precipitation from the nearby Bisbee-Douglas International Airport in Figure 1-4. The airport is approximately 16 km south of the refuge and approximately 500 m lower in elevation than the lowest areas of the refuge. These data undergo all quality assurance and control checks prescribed by the NOAA Cooperative Observer Program, and provide a longer period of record. See www.climateanalyzer.org for details. We also report raw data from a rain gauge on Leslie Canyon NWR operated by refuge staff.

While 2014 was one of the warmest years on record for the nation and globally (http://www.nasa.gov/press/2015/january/nasa-determines-2014-warmest-year-in-modern-record), spring and summer air temperatures in the Sulphur Springs and San Bernardino valleys were close to the 1981-2010 normals. However, winter and autumn minimum and maximum temperatures were consistently above normal. Winter and spring rains were well below normal average during 2014. The refuge received significant monsoon precipitation in July, with a total of 21.6 cm (8.5 in) for the month. Hurricane Odile (September 10-19, 2014; provided a substantial amount of rain throughout the refuge and its supporting drainages (Radke 2014). Leslie Canyon NWR received 9.1 cm (3.6 in) over a three-day period, resulting in considerable streamflow (though no damage to infrastructure; Radke 2014)). Above average summer precipitation resulted in a total of 57.9 cm (22.8 in) for the year, well above the 35.6 cm (14 in) average (Radke 2014).

1.4.7 Human habitation of Leslie Canyon NWR

Indigenous hunters were the earliest inhabitants some 10,000 years ago when the area was cooler, wetter and had more vegetation. Though climatic changes over the centuries created the drier and warmer land we see today, dependable water sources have long attracted humans to the area.

As early as the 1500s, Spanish explorers visited this area followed by Jesuit priests in the 1700s and a Spanish presidio was established in the late 1770s (Radke 2014). The Apache arrived in the 1600s and used areas throughout the region for hunting and gathering. Ranching began in 1822 with the acquisition of the San Bernardino land grant and widespread cattle grazing progressed. After Apaches briefly drove out the ranchers, cattle ranching resumed on a large scale when John Slaughter established the 26,305 hectare (65,000 acre) San Bernardino Ranch in 1884 (Radke 2014).

In 1889, local bartender, gambler, cattleman, and already three-time murderer Frank Leslie shot and killed his girlfriend on the 7-UP Ranch. He escaped through Leslie Canyon, thus becoming the refuge namesake (Radke 2014). The Mexican Revolution reached this border area in 1915 when Pancho Villa and his army fought in nearby Agua Prieta. Rock fortifications remain on San Bernardino NWR and on Slaughter Ranch nearly 100 years after they sheltered U.S. Cavalry troops stationed there to protect settlers (Radke 2014).

The Heffern Co-Operative Consolidated Gold Mining and Milling Company owned and operated a 486 hectare (1,200 acre) mining operation in the hills of Leslie Canyon NWR at the start of the 20th century. The primary shaft was 149 m (490 feet) deep and sought to access small isolated pockets of high quality gold ore tucked among the limestone fissures. Ultimately the mine proved to be unprofitable and was abandoned by 1920 (reported dates vary; Bill Radke pers. comm.).

The farming, mineral extraction, fire control, and rise in livestock production that began in the 1800s created an increase in competition for precious water in the area. Cattle ranching and farming continued in the area until 1979 when The Nature Conservancy began to acquire the properties for resource protection, leading ultimately to establishment of these lands in the National Wildlife Refuges System (Radke 2014).

1.4.8 Other long-term monitoring and related ecological research at Leslie Canyon NWR

Leslie Canyon NWR is one of the few refuges administered by USFWS created specifically to protect native fish, namely the endangered Yaqui chub and Yaqui topminnow (USFWS 1994). Fish recovery efforts include stabilization of existing populations, establishment of self-sustaining populations, and extensive restoration of wetland habitat. Fish populations in Leslie Creek have been monitored since 2006 using traps or visual surveys. Groundwater levels are monitored as part of the effort to ensure that the Yaqui watershed habitat is maintained for fish species. The refuge has ongoing watershed management actions occurring in and adjacent to refuge lands and invasive, non-native species are being removed or controlled.

In addition to water resource monitoring and efforts to protect native fish populations, a vascular plant species checklist for Leslie Canyon NWR has been developed through the Flora Project, one part of a collaboration between the NPS Sonoran Desert Network and USFWS (USFWS 2016). A guide to the flora of the refuge has been completed. Leslie Canyon NWR has a documented flora of 509 plant species in 311 genera and 85 families including 16 desert-adapted ferns and 75 species endemic to the Madrean Archipelago region (USFWS 2016). In addition to this guide, USFWS is capitalizing on developed methods that will communicate current information through the SEINet Biodiversity Information portal (www.swbiodiversity.org/seinet). This collaborative project provides refuge resource managers with accurate and timely baseline studies of floristic biodiversity. A refuge-specific species list can be found at http://swbiodiversity.org/seinet/projects/index.php?proj=24.

Other long-term projects at Leslie Canyon NWR include bird, reptile, amphibian, small and large mammal, water umbel (*Lilaeopsis schaffneriana* var. *recurva*), and air quality monitoring. A MAPS (Monitoring Avian Productivity and Survivorship) bird banding station is located on the refuge that has been operating for over 13 years (Radke 2014). In 2014, refuge staff and volunteers captured 614 birds representing 61 species, 85 (14%) of which were recaptures from previous efforts (Radke et al. 2014). Reptiles, amphibians, and small mammals have been trapped each year since 2000 in an effort to understand ecological trends and to investigate population

Photo: Refuge Manager, Bill Radke, operating the MAPS bird banding station. (USFWS)

dynamics and the roles of rare species. Chiricahua leopard frog (*Lithobates chiricahuensis*) populations are monitored in Leslie Creek to ascertain population status. Since 2009, wildlife cameras have been used in riparian corridors to determine which mammal species are present and to monitor dynamics and long-term changes in the use of these corridors. Huachuca water umbel populations are monitored in Leslie Creek annually. Air quality parameters monitored include precipitation, visibility, ozone, and nitrogen and sulfur in precipitation.

1.5 Natural resource management issues at Leslie Canyon NWR

1.5.1 Threatened and endangered species

The refuge is located in a transition area between Sonoran and Chihuahuan deserts and the Rocky Mountains and Sierra Madre. The result is an incredible diversity in the refuge's flora and fauna. Between Leslie Canyon NWR and nearby San Bernardino NWR, at least 336 bird, 67 mammal, 43 reptile, 13 amphibian, and 8 fish species have been detected (Radke 2014). In Leslie Canyon NWR alone, 509 plant species have been documented (USFWS 2016) and over 500 species of bees have been identified in the San Bernardino valley (Radke 2014).

There are 38 species of plants and animals detected in or near the two refuges that are listed by the Federal or State Government as threatened, endangered, or species of special concern (Table 1-1; Radke 2014). While some of these species have not been detected within refuge boundaries, Leslie Canyon and San Bernardino NWRs may provide important habitat for maintaining their populations.

The endangered Yaqui chub and Yaqui topminnow.,and the Yaqui beautiful shiner, a federally threatened species is also present in Leslie Canyon. Fish recovery actions include stabilizing and maintaining existing populations, establishing self-sustaining populations, and restoring wetland habitat. Other high priority species at Leslie Canyon NWR include the federally endangered Huachuca water umbel and the federally threatened Chiricahua leopard frog (Radke 2014).

Photo: The endangered Yaqui Chub. (USFWS)

Table 1-1. Known and hypothetical federal and state listed species that occur in or adjacent to San Bernardino and Leslie Canyon National Wildlife Refuges.

Status	Common Name	Scientific Name	Occurrence
FT	Cochise pincushion cactus	Coryphantha robbinsorum	resident
FE	Huachuca water umbel	Lilaeopsis schaffneriana	resident
FT	San Bernardino springsnail	Pyrgulopsis bernardina	resident
FE/WC1	Yaqui chub	Gila purpurea	resident
FT/WC1	Yaqui beautiful shiner	Cyprinella formosa	resident
WC1	Yaqui sucker	Catostomus bernardini	hypothetical
FT/WC1	Yaqui catfish	Ictalurus pricei	resident
FE/WC1	Yaqui topminnow	Poeciliopsis sonoriensis	resident
FT	Chiricahua leopard frog	Lithobates chiricahuensis	resident
WC1	Plains leopard frog	Lithobates blairi	hypothetical
WC1	Lowland leopard frog	Lithobates yavapaiensis	resident
FT	Northern Mexican gartersnake	Thamnophis eques	resident
WC1	Massasauga rattlesnake	Sistrurus catenatus	hypothetical
WC1	American Bittern	Botaurus lentiginosus	rare migrant
WC1	Least Bittern	Ixobrychus exilis	rare migrant
WC1	Great Egret	Casmerodius albus	migrant
WC1	Snowy Egret	Egretta thula	rare migrant
WC1	Black-bellied Whistling Duck	Dendrocygna autumnalis	rare migrant
WC1	Osprey	Pandion haliaetus	migrant
WC1	Common Black Hawk	Buteogallus anthracinus	migrant
WC1	Gray Hawk	Asturina nitidus	nesting
WC1	Ferruginous Hawk	Buteo regalis	rare migrant
WC1	Crested Caracara	Polyborus plancus	vagrant
FE/WC1	Northern Aplomado Falcon	Falco femoralis septentrionalis	hypothetical
WC1	Peregrine Falcon	Falco peregrinus	migrant
WC1	Yellow-billed Cuckoo	Coccyzus americanus	nesting
WC1	Violet-crowned Hummingbird	Amazilia violiceps	migrant
WC1	Belted Kingfisher	Ceryle alcyon	migrant
FE/WC1	Willow Flycatcher	Empidonax traillii	migrant
WC1	Tropical Kingbird	Tyrannus melancholicus	nesting
WC1	Thick-billed Kingbird	Tyrannus crassirostris	vagrant
WC1	Rose-throated Becard	Pachyramphus aglaiae	vagrant
WC1	Gray Catbird	Dumetella carolinensis	migrant
WC1	American Redstart	Setophaga ruticilla	migrant
FE	Lesser long-nosed bat	Leptonycteris curasoae	migrant
WC1	Red Bat	Lasiurus borealis	migrant
FE	Jaguar	Panthera onca	hypothetical
FE	Ocelot	Leopardus pardalis	hypothetical

1.5.2 Sensitive aquatic and riparian resources

Leslie Canyon NWR was established to preserve native fish species mentioned in the previous section. Specifically, Leslie Canyon NWR is a major component of a larger effort designed to lead to the long-term survival of threatened and endangered fish in the Yaqui watershed. The refuge and nearby San Bernardino NWR provide the last sanctuaries in the United States for these intermediate elevation fish.

The refuge is also an important piece of an overall ecological mosaic encompassing continually dwindling desert riparian landscapes in Arizona. The Leslie Creek riparian area supports a very unique velvet ash - black walnut - willow - cottonwood forest. Leslie Creek runs through the middle of the refuge and its headwaters include various canyons and washes in the Pedregosa, Chiricahua, and Swisshelm mountains. The perennial portion of the creek arises primarily from springs in Leslie Canyon. It exists as a slow-moving, small stream for a short distance before disappearing underground. Surface water reduces to a trickle or simply wet ground during drier periods. The drainage then flows west into Whitewater Draw in the Sulphur Springs Valley, which then flows south, eventually contributing to the Rio Yaqui much further downstream in Mexico.

The San Bernardino Valley once supported permanently flowing creeks, springs, and marshy wetlands. Expanded settlement beginning in the late 1800s brought farming, mining and livestock production, all of which competed for the same precious water. The lowering water table led to severe changes in the riparian and wetland habitats and the eventual local extinctions of many species (Radke 2014). Conservation of these remaining water sources and associated habitats is the primary purpose of the refuge.

To prevent water depletion in Leslie Creek, USFWS applied for instream flow rights in 1992 and these rights were granted to be used for the purposes of wildlife, including fish and recreation, and for the maintenance of a continuous minimum instream flow (Radke 2014). Despite this effort, water needs are not being met due to extreme drought (Radke 2014).

1.5.3 Invasive non-native species

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

Sixty-three non-native plants (Table 1-2) have been detected in and around Leslie Canyon NWR, although many are limited in their distribution. Six of these non-natives are invasive species of particular concern to the refuge management because of their potential to seriously damage the native ecosystems: tamarisk (*Tamarix chinensis*), giant reed (*Arundo donax*), Lehmann lovegrass (*Eragrostis lehmanniana*), horehound (*Marrubium vulgare*), Johnsongrass (*Sorghum halapense*) and prickly Russian thistle (*Salsola tragus;* Lohrengel personal communication, September 10, 2015). Their documented presence near the refuge (Table 1-2) is cause for concern and vigilant monitoring. Another issue at the refuge is shrub encroachment on native big sacaton (*Sporobolus wrightii*) flats along the riparian areas. While the shrubs typically encroaching on these stands of sacaton are native to the area, their increasing numbers are a byproduct of anthropogenic land use and changing biological processes and they alter the function of these declining historical riparian grasslands (Van Auken 2000).

1.5.4 Adjacent land use

Properties immediately adjacent to Leslie Canyon NWR consist primarily lands owned by private ranchers, the Bureau of Land Management (BLM) and the state of Arizona. Cattle grazing occurs on much of these surrounding lands, but recent conservation easements and memorandums of understanding and other agreements may ease potential trespass livestock grazing impacts on the refuge.

The Leslie Creek Watershed spans from the west central portion of the Chiricahua Mountains to the eastern flank of the Swisshelm Mountains (USFWS 1995). Since overdevelopment of areas outside the

Table 1-2. Non-native plants detected in and around Leslie Canyon NWR (USFWS 2016).

Scientific Name	Common Name	Family	Primary Lifeform	Duration
Ailanthus altissima	tree of heaven	Simaroubaceae	Tree	Perennial
Alternanthera caracasana	washerwoman	Amaranthaceae	Forb/Herb	Perennial
Arundo donax	giant reed	Poaceae	Subshrub	Perennial
Asparagus officinalis	garden asparagus	Asparagaceae	Forb/Herb	Perennial
Bothriochloa ischaemum	yellow bluestem	Poaceae	Graminoid	Perennial
Brassica rapa	field mustard	Brassicaceae	Forb/Herb	Annual
Brassica tournefortii	Sahara mustard	Brassicaceae	Forb/Herb	Annual
Bromus catharticus	rescuegrass	Poaceae	Graminoid	Annual
Bromus rubens	red brome	Poaceae	Graminoid	Annual
Bromus tectorum	cheatgrass	Poaceae	Graminoid	Annual
Centaurea melitensis	Maltese star-thistle	Asteraceae	Forb/Herb	Annual
Chorispora tenella	crossflower	Brassicaceae	Forb/Herb	Annual
Citrullus lanatus	watermelon	Cucurbitaceae	Vine	Annual
Convolvulus arvensis	field bindweed	Convolvulaceae	Vine	Perennial
Cynodon dactylon	Bermudagrass	Poaceae	Graminoid	Perennial
Descurainia sophia	herb sophia	Brassicaceae	Forb/Herb	Annual
Echinochloa colona	jungle rice	Poaceae	Graminoid	Annual
Echinochloa crusgalli	barnyardgrass	Poaceae	Graminoid	Annual
Eragrostis barrelieri	Mediterranean lovegrass	Poaceae	Graminoid	Annual
Eragrostis cilianensis	stinkgrass	Poaceae	Graminoid	Annual
Eragrostis curvula	weeping lovegrass	Poaceae	graminoid	Perennial
Eragrostis lehmanniana	Lehmann lovegrass	Poaeceae	Graminoid	Perennial
Eragrostis superba	Wilman lovegrass	Poaceae	Graminoid	Perennial
Erodium cicutarium	redstem stork's bill	Geraniaceae	Forb/Herb	Annual
Euphorbia davidii	David's spurge	Euphorbiaceae	Forb/Herb	Annual
Euphorbia dentata	toothed spurge	Euphorbiaceae	Forb/Herb	Annual
Festuca perennis	perennial ryegrass	Poaceae	Graminoid	Perennial
Hordeum murinum subsp. glaucum	smooth barley	Poaceae	Graminoid	Annual
Hordeum murinum subsp. leporinum	hare barley	Poaceae	Graminoid	Annual
Ipomoea hederacea	ivyleaf morning-glory	Convolvulaceae	Vine	Annual
Ipomoea purpurea	tall morning-glory	Convolvulaceae	Vine	Annual
Lactuca serriola	prickly lettuce	Asteraceae	Forb/Herb	Annual
Macroptillium gibbosifolium	variableleaf bushbean	Fabaceae	Forb/Herb	Perennial
Marrubium vulgare	horehound	Lamiaceae	Subshrub	Perennial
Melilotus albus	honey-clover	Fabaceae	Forb/Herb	Annual
Melilotus indicus	annual yellow sweet clover	Fabaceae	Forb/Herb	Annual
Melilotus officinalis	sweetclover	Fabaceae	Forb/Herb	Annual
Melinis repens	rose Natal grass	Poaceae	Graminoid	Annual
Mentha spicata	spearmint	Lamiaceae	Forb/Herb	Perennial
Paspalum dilatatum	dallisgrass	Poaceae	Graminoid	Perennial
Pennisetum ciliare	bufflegrass	Poaceae	Graminoid	Perennial
Pennisetum glaucum	pearl millet	Poaceae	Graminoid	Annual
Physalis philadelphica	Mexican groundcherry	Solanaceae	Forb/Herb	Annual
Poa annua	annual bluegrass	Poaceae	Graminoid	Annual

Table 1-2 (continued). Non-native plants detected in and around Leslie Canyon NWR (USFWS 2016).

Scientific Name	Common Name	Family	Primary Lifeform	Duration
Polygonum argyrocoleon	silversheath knotweed	Polygonaceae	Forb/Herb	Annual
Polypogon monspeliensis	annual rabbitsfoot grass	Poaceae	Graminoid	Annual
Polypogon viridis	beardless rabbitsfoot grass	Poaceae	Graminoid	Perennial
Portulaca oleracea	little hogweed	Portulacaceae	Forb/Herb	Annual
Rumex crispus	curly dock	Polygonaceae	Forb/Herb	Perennial
Salsola tragus	prickly Russian thistle	Amaranthaceae	Forb/Herb	Annual
Schedonorus arundinaceus	tall fescue	Poaceae	Graminoid	Perennial
Schismus barbatus	common Mediterranean grass	Poaceae	Graminoid	Annual
Sida abutifolia	spreading fanpetals	Malvaceae	Forb/Herb	Annual
Sisymbrium irio	London rocket	Brassicaceae	Forb/Herb	Annual
Sonchus asper	spiny sowthistle	Asteraceae	Forb/Herb	Annual
Sonchus oleraceus	common sowthistle	Asteraceae	Forb/Herb	Annual
Sorghum halepense	Johnsongrass	Poaceae	Graminoid	Perennial
Tamarix chinensis	five-stamen tamarisk	Tamaricaceae	Tree	Perennial
Taraxacum officinale	common dandelion	Asteraceae	Forb/Herb	Perennial
Tragus berteronianus	spiked bur grass	Poaceae	Graminoid	Annual
Tribulus terrestris	puncturevine	Zygophyllaceae	Forb/Herb	Annual
Trifolium repens	white clover	Fabaceae	Forb/Herb	Perennial
Ulmus parvifolia	Chinese elm	Ulmaceae	Tree	Perennial

refuge could threaten the watershed, USFWS has initiated many cooperative efforts with surrounding landowners in an effort to achieve long-term protection of the Leslie Creek watershed and additional lands associated with the refuge (USFWS 1995). Conservation Easements, Memorandums of Understanding, and the Safe Harbor Program (USFWS 1995) are the primary avenues for developing conservation strategies with private landowners that help alleviate impacts from land uses such as excessive grazing, heavy water consumption, and mining. The largest ranches, the Bar Boot Ranch and the 99 Bar Ranch are partners in these efforts to protect the watershed and associated wildlife and habitats (USFWS 1995)).

Several scattered BLM tracts totaling around 1,100 hectares (~2,700 acres) are adjacent or near the refuge as well. Detailed planning studies, public involvement, and environmental assessments will continue in order to provide enhanced protection to these areas. Various protection strategies that the U.S. Fish and Wildlife Service is pursuing include

Photo: Perennial pool at Leslie Creek. (USFWS)

Partners for Wildlife cooperative efforts, cooperative agreements, conservation easements, fee title acquisition by willing sellers, and withdrawal of public domain lands.

1.5.5 Visitation

The public may visit Leslie Canyon NWR under a special use permit and certain public use activities are allowed. Birdwatching, wildlife viewing, photography and hiking are permitted. While hunting is prohibited on the refuge, some possible poaching has occurred. Visitor safety is an issue on Leslie Canyon NWR due to the steep and remote terrain.

Fishing is prohibited on the refuge due to conflicts with the threatened and endangered fishes. The main concern associated with public use is the potential for visitors to introduce and transport non-native fish species, especially mosquitofish, onto the refuge. Leslie Canyon Road bisects the refuge and is the only vehicular access to the refuge.

Leslie Canyon NWR is an isolated wildland area not far from the international border with Mexico. Illegal border activities, including theft, vandalism, and poaching, occur in the area.

2. Methods

2.1 Response design

The response design for this protocol employs permanent, 20 × 50-m sampling plots (Figure 2-1). The 50-m edges of the plot run parallel with the contours of the site. Vegetation sampling is done in conjunction with soil cover and stability measures along six transects within the plot. In the spaces between transects (subplots), within-plot frequency is estimated by noting the occurrence of any perennial or non-native annual plant species or lifeform not observed on the adjacent transects. See Hubbard and others (2012) for details on plot configuration and data collection.

2.1.1 Vegetation and soil cover: line-point intercept

Line-point intercept is a common and efficient technique for measuring the vegetation cover of plants. Line-point intercept measures the number of "hits" of a given species out of the total number of points measured (Elzinga et al. 1998; Bonham 1989). Vegetation was recorded within three height categories (Table 2-1) along each of the six transects using the line-point intercept method, with points spaced every 0.5 m (240 points total).

Table 2-1. Height categories for vegetation measurement.

Layer	Height
Field	<0.05 m
Subcanopy	0.05 - 2.0 m
Canopy	>2.0 m

Perennial vegetation was recorded to species. Annual vegetation was recorded to lifeform, with the exception of a suite of annual non-native plants that were recorded to the species level. Soil cover was recorded by substrate class (e.g., rock, gravel, litter, woody debris; see SOP #5, Hubbard et al. 2012). Litter and woody debris were recorded to fuel type (fine fuels, 1-hour fuels, 10-hour fuels, 100-hour fuels, 1000-hour fuels; Deeming et al. 1977). Biological soil crust cover was recorded to morphological group (light cyanobacteria, dark cyanobacteria, lichen, moss). Vegetation and soil cover are reported as percent cover with standard error and the minimum detectable change (MDC) given the estimated statistical power of the study design.

2.1.2 Vegetation frequency: subplots

The area between any two adjacent transects formed the boundary of 10 × 20-m subplots that were used to estimate within-plot frequency of perennial plant species, annual and perennial non-native plants, and all lifeforms. The occurrence of any species/lifeform that was not measured on the adjacent line-point intercept transect was recorded to determine a within-plot frequency based on number of subplots occupied relative to the total number of subplots (i.e., 5). Figure 2-1 shows the relationship between each subplot and its corresponding adjacent transect.

2.1.3 Soil aggregate stability

Surface soil aggregate stability was measured using a modified wet aggregate stability method (Herrick et al. 2005a). Within each plot, soil samples were attempted at 18 predetermined points along the line-point intercept transects. The dominant vegetation canopy cover and substrate cover at each point were determined. A uniformly sized (2–3 mm thick and 6-8 mm on each side) soil sample was collected at each predetermined point. 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 (See Table 2-2; Herrick et al. 2005a).

2.1.4 Biological soil crust cover and frequency: Point-quadrats

In addition to line-point intercept measurements, biological soil crust cover was measured using 0.25-m^2 quadrats. Three quadrats were measured per transect using the point-quadrat method (similar in concept to line-point intercept), with 16 intercept measurements per quadrat, resulting in 18 quadrats and 288 measurements per plot. At each intercept, biological soil crusts were recorded as light cyanobacteria, dark cyanobacteria, bryophytes (moss and liverworts), and lichens by growth form (crustose, gelatinous, foliose, fruticose, and squamulose). The observer then visually surveyed the quadrat for any morphological group or lichen growth form that was present. Soil crust frequency by lichen growth form and morphological group was determined by the number

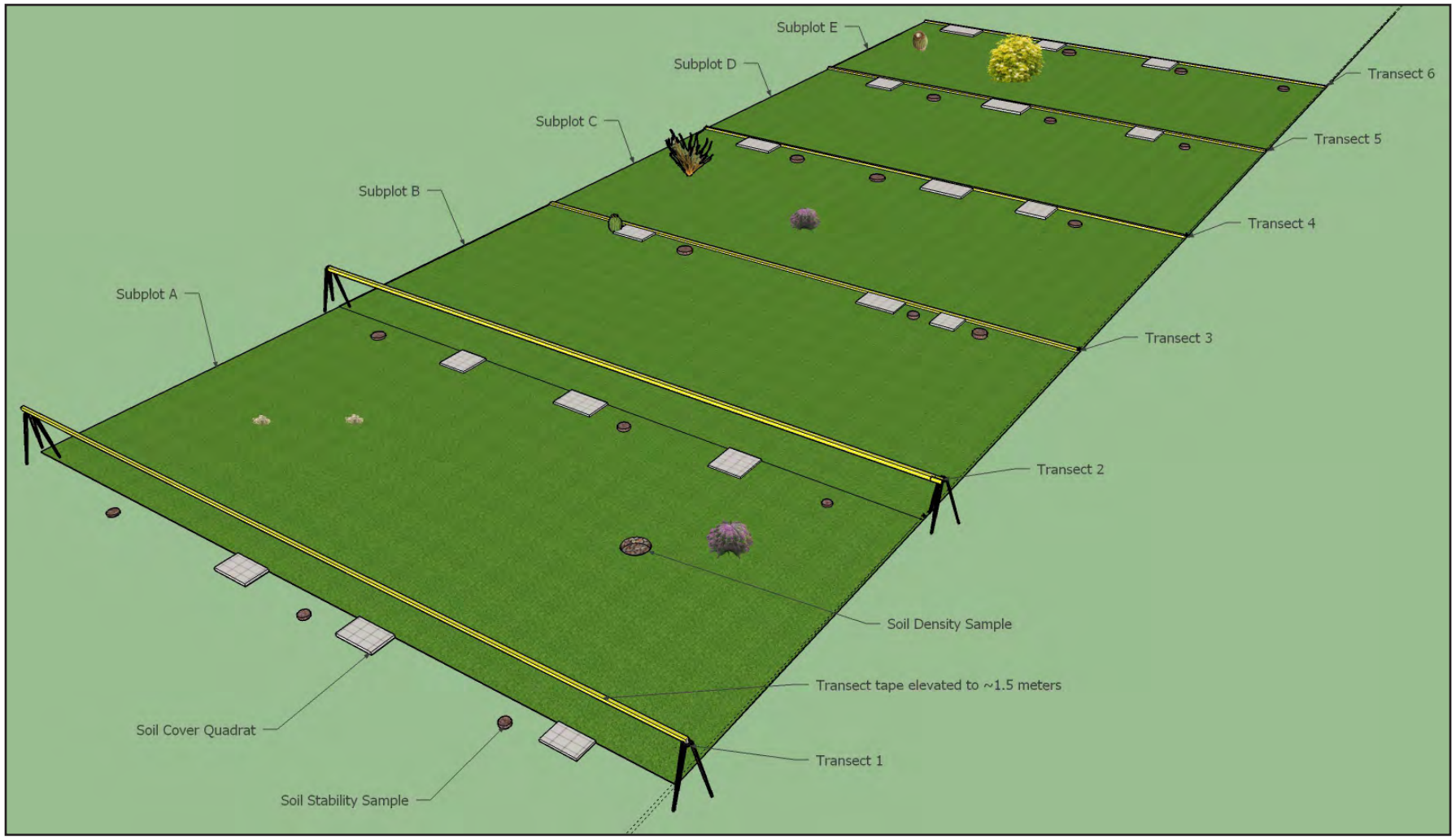


Figure 2-1. Terrestrial vegetation and soils monitoring plot design. See Hubbard and others (2012) for additional details on design and data collection.

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

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

*Adapted from Herrick and others (2005a)

of quadrats occupied relative to the total number of quadrats (i.e., 18). The Sonoran Desert Network terrestrial vegetation and soils monitoring protocol (Hubbard et al. 2012, SOP #6) provides a detailed description of the point-quadrat methodology. The initial round of sampling at Leslie Canyon NWR will help the Sonoran and Chihuahuan Deserts Zone to determine differences between the line-point intercept and point-quadrat methodologies.

2.1.5 Soil and site characterization

Proximate soil and landform factors are known to influence vegetation and dynamic soil function parameters at local scales (McAuliffe 1999). To characterize the soil and landscape attributes of each plot, a suite of topoedaphic variables were collected through site diagrams, repeat photo points, and collection of a soil core. Landform and slope position, type, and inclination (%) were recorded at each plot. Erosion features were described by estimating broad areal percentage classes of areas affected by tunneling, sheets, rills, gullies, pedestals, terracettes, and burrowing. Permanent photo points were established at each plot corner to characterize general site physiognomy and as an aid to interpreting quantitative trend data in successive sampling periods. In addition, general site descriptions (including observed disturbances such as fire) were collected for each plot.

The soil core was collected at a predetermined random location within the first subplot, with alternate random locations sampled if the first location was not suitable. The soil core collection followed the compliant cavity method (Blake and Hartge 1986) and cores were approximately 10-cm deep. These soil samples were returned to a lab where they wereprocessed to determine bulk density, rock fragment content, soil texture, total organic content, EC (electrical conductivity) and pH.

2.2 Sampling design

2.2.1 Overview

All plots are sampled in fall of the same year, and then revisited at five-year intervals. If a major disturbance (e.g., an extended drought, extreme frost, significant soil erosion event, major fire) occurs in the intervening years, we may collect additional plot data to characterize and account for the potential effects of these important stochastic events.

Stratification (see Section 3.2.3, Hubbard et al. 2012) was employed to reduce spatial variability and increase sampling efficiency. Terrestrial vegetation and soils plots were allocated to strata based on elevation and soil rock-fragment classes. We use surface soil coarse rock fragment content as an additional stratification variable, as this parameter is a reasonable proxy for soil development (Hubbard et al. 2012). Plots were proportionately allocated to two strata:

- "Non-Rocky, Mid-Mountain:" 4,501-6,000 ft. (~1,370-1,830 m), <35% surface soil rock fragments (stratum 401)
- "Rocky, Mid-Mountain:" 4,501-6000 ft. (~1,370-1,830 m), 35-90% surface soil rock fragments (stratum 402)

Therefore, inference from the plots at Leslie Canyon NWR is to all terrestrial areas of the park by soil and elevation strata, excluding the areas discussed in 2.2.3.

Table 2-3. Allocation of permanent terrestrial vegetation and soils monitoring plots by strata, Leslie Canyon NWR.

Stratum	Elevation	% Rock Fragments	Total Area (acres)	Percentage of Total		# plots per strata
				Refuge area	Frame area	
0*	n/a	n/a	594.30	21%	0%	0
401	4500-6000′	<35%	615.6	22%	28%	6
402	4500-6000′	35-90%	1560.12	56%	72%	14
Totals	--	--	**2175.7**	**79%**	**100%**	**20**

* Strata with <5% of refuge area (combined in this category called "Stratum 0") were excluded.

We allocated 20 permanent monitoring plots in a spatially balanced arrangement within Leslie Canyon NWR and sampled in 2014. Sample sizes were 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). Table 2-3 shows the allocation of permanent monitoring plots by strata.

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 Create Spatially Balanced Points tool (Geostatistical Analyst) in ArcGIS 10. 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 and the Generalized Random Tessellation Stratified (GRTS) approach (Stevens and Olsen 2004), are increasingly being applied to ecosystem monitoring (e.g., Environmental Protection Agency Ecological Monitoring and Assessment Program) because they provide the advantages of a probabilistic design (Stehman 1999) and they ensure spatial balance regardless of overall sample size. RRQRR designs facilitate adding or removing sites in a spatially balanced manner if statistical power, financial considerations, or additional monitoring objectives warrant adjusting the sample size. This scaling ability is an important advantage, as (1) the number of plots per refuge cannot be adequately estimated *a priori* (see Section 3.4.2, Hubbard et al. 2012) and (2) future changes in technology, objectives, and budgets may necessitate increasing or decreasing sample sizes.

2.2.3 Sampling frame

The sampling frame for Leslie Canyon NWR includes all terrestrial areas within refuge boundaries, except for the following (Figure 2-2):

- Slopes of ≥ 45° (for crew safety)
- Roads and buildings (including a 100-m buffer)
- Trails, washes, streams, and the refuge boundary (including 50-m buffer)
- High elevation strata types that constituted <5% of the areas of the Refuge

The total area excluded under these criteria was approximately 241 hectares (595 acres), or 21% of the Refuge area.

2.2.4 Management assessment points as the link between science and management

To achieve the USFWS core mission of resource protection, resource management and monitoring must be explicitly linked (Bingham et al. 2007). We advocate the use of management assessment points as a bridge between science and management. Management assessment points are,

> ". . . pre-selected points along a continuum of resource-indicator values where scientists and managers have agreed to stop and assess the status or trend of a resource relative to program goals, natural variation, or potential concerns" (Bennetts et al. 2007).

Management assessment points aid interpretation of ecological information within a management context. They do not define strict management or ecological thresholds, inevitably result in management actions, or reflect any legal or regulatory standard; they are only intended to serve as a potential early warning system

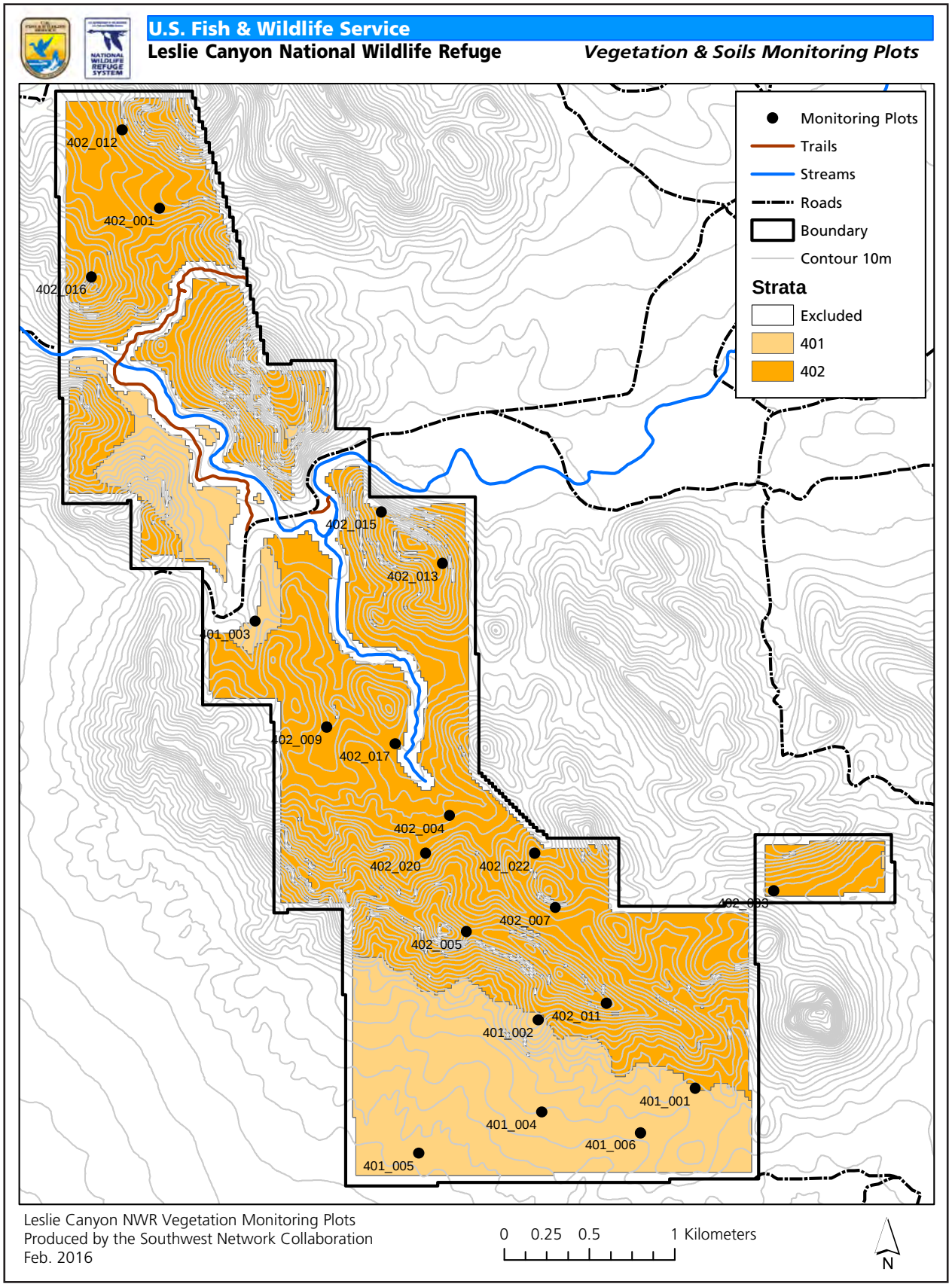


Figure 2-2. Sampling frame and allocation of monitoring plots for terrestrial vegetation and soils monitoring, Leslie Canyon NWR.

Table 2-4. Proposed management assessment points for terrestrial vegetation and soils monitoring at Leslie Canyon NWR.

Issue	Management Assessment Point	Strata	Information Source
Erosion Hazard	Exposed bare ground (with no overhead vegetation) is >20% cover	All	Value is based on professional judgment of authors; modified from Las Cienegas National Conservation Area Management Plan (2003; as cited in Gori and Schussman 2005)
	Surface soil aggregate stability (with no overhead vegetation) is <Class 3	All	Value is based on professional judgment of authors
	Mature Biological Soil Crusts occupy <2% cover of available habitat	All	Value is based on Bowker and Belnap (2008)
Plant Community Resilience	Foliar cover of dead perennial plants is >10% (field)	All	Value is based on professional judgment of authors
	Foliar cover of dead perennial plants is >5% (subcanopy)	All	Value is based on professional judgment of authors
	"Annual plant cover: total plant cover is >1:2 (0.50) (field)"	All	Value is based on professional judgment of authors
	<25% (field) foliar cover of perennial grasses	402-B	Value is based on professional judgment of authors
	Native taxonomic diversity decrease >10% over time	All	Value is based on professional judgment of authors
	Native within-plot species richness decrease of >10% over time	All	Value is based on professional judgment of authors
Exotic Plant Presence	The detection of a new exotic species (annual or perennial) on any plot	All	Value is based on professional judgment of authors
	Increase in Extent of existing exotic species within a stratum	All	Value is based on professional judgment of authors
Exotic Plant Abundance	5% change in cover of ERALEH within a plot	All	Value is based on professional judgment of authors
	Exotic plant cover: total plant cover is >1:20 (0.05) (field)	All	Value is based on professional judgment of authors
	Total cover of all exotic plants is >5% (field)	All	Value is based on professional judgment of authors
Fire Hazard	Leaf litter and woody debris > 75%	All	Value is based on professional judgment of authors

allowing scientists and managers to pause, review the available information in detail, and consider options. Bennetts and others (2007) have provided a detailed explanation of this concept and its application to monitoring and management of protected areas.

Although no management assessment points have been formally established for Leslie Canyon NWR, we propose some assessment points here, based on the ecological literature and our knowledge of these ecosystems and refuge management goals. We intend for these assessment points to (1) initiate a discussion of potential indicators and assessment points and (2) provide a useful framework for evaluating terrestrial vegetation and soils data in a broader ecological and managerial context. Proposed assessment points are summarized in Table 2-4 and discussed in Chapters 3 and 4.

2.2.5 Statistical power to distinguish status from management assessment points

Estimating our statistical power to distinguish current conditions - status- from management assessment points (2.2.4) is important for both protocol design (especially determining adequate sample sizes) and data interpretation. Adequate sample size (number of plots) is estimated by (Herrick et al. 2005b):

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

Where:

S = Standard deviation of the sample

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

$Z_ß$ = Z-coefficient for missed-change (Type II) error (we set at 10%)

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

Bonham (1989), Elzinga 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%)

$Z_ß$ = Z-coefficient for missed-change (Type II) error (we set at 10%)

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

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

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

Where:

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

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

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

2.2.7 Evaluation of strata

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

To evaluate the efficiency and pertinence of our preselected elevation strata, we contrasted the similarity of the vegetation communities on each stratum using permutational multivariate analysis of variance on vegetation similarity matrices (PERMANOVA+), non-metric multidimensional scaling (MDS), and SIMPER, a permutation procedure that reveals which species contribute the most to any between- and within-group dissimilarities. These non-parametric multivariate community analysis techniques make few assumptions about the data, yielding a simple yet powerful analysis tool (Clarke and Warwick 2001). Based on the results of the strata evaluation, we may combine some strata or modify sample sizes for a given stratum.

2.2.8 Diversity of perennial plants

Biodiversity is a primary focus of ecological research, and maintaining native biodiversity is a central tenet of natural resource conservation (Keddy 2007). Diversity indices can provide an indicator of the ecological "well-being" of an ecosystem, and are well-established measures in ecology - see Izsák and Papp (2000) and Warwick and Clarke (1995) for one of many published overviews of traditional indices, their assumptions, and their limitations.

There are three major limitations for utilizing traditional diversity indices in an ecological monitoring context: (1) sampling effort has a large influence on diversity measures, restricting valid comparisons to sites with consistent methods and effort; (2) phylogenetic diversity (phylogeny is the evolutionary history of a group of organisms, as explained in a family tree) is not reflected in the measure - two species in the same genera are as "diverse" as two species from different orders; (3) and there are no statistical approaches for testing departure from expected diversity and potential effects of human perturbation (Warwick and Clarke 1995).

We address perennial plant diversity using two approaches:

- Average Within-Plot Species Richness (S_{plot})

- Taxonomic Distinctness Index (Δ^+)

The within-plot species richness (S_{plot}) is an index of diversity rather than a 'true' species richness since it is dependent on sample effort. The taxonomic distinctness index is a measure of diversity that gives weight to the different levels of taxonomic hierarchy represented in the sample (i.e., the taxonomic breadth of a sample; Warwick and Clarke 1995). Examining both of these indices allows for a broader examination of biodiversity within and between strata.

3. Results

3.1 Design considerations

3.1.1 Evaluation of strata

PERMANOVA+ results suggested that vegetation differed between sites with non-rocky ("401," <35% surface soil rock fragments) versus rocky ("402," 35-90% surface soils rock fragments) surface soils (Pseudo F = 2.47, P (Perm) = 0.02). Non-metric multidimensional scaling (MDS; Figure 3-1) and cluster analysis is congruent with the PERMANOVA+ results, as rocky and non-rocky sites are generally partitioned, although rocky sites contained two groupings that are not explained by our *a. priori* soil rock fragment stratification.

Based on the PERMANOVA+ and MDS results, we retained the original stratification design but further investigated the source of the two clusters within the rocky strata. In addition, three of the sites fell outside of (401_003) or on the periphery of (402_007 & 402_017) their respective groups on the MDS suggesting these sites occurred along a gradient, having vegetation similarities in common with another group, rivaling that of their own group. The stratum 401 site was maintained within its initial group as the tabular and spatial data reviews did not show sufficient evidence to warrant such a change to our sampling scheme. SIMPER analysis was then used to determine which species were most responsible for the within-group similarities and between-group differences. Based on these evaluations the data were analyzed within three groups (Figure 3-2) hereafter referred to as stratum 401, stratum 402 substratum A (402-A) and stratum 402 substratum B (402-B). Refer to the discussion (Chapter 4) for more details. Figure 3-3 shows all monitoring plots by strata and substrata.

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

Our design generally exceeded our expectations for statistical power to detect trends in plant lifeforms and common perennial species (detect a 10% absolute change in foliar cover with 90% power and 10% chance of a false change error). Our data indicate that we will be able to detect a 5% change (absolute foliar cover) for most detected perennial species and lifeforms (Table 3-1, 3-7, 3-12). The only species that failed to meet this criteria was the non-native Lehmann lovegrass (*Eragrostis lehmanniana*) which had an estimated change detection of 15% in the field and subcanopy of substratum 402-B (Table 3-12) due to high variability across plots.

While not a primary objective of this monitoring, when the cover data for all lifeform classes (ferns, annual forbs, perennial forbs, annual grass, perennial grass, subshrub, shrub, succulent, tree, vine, snag) were

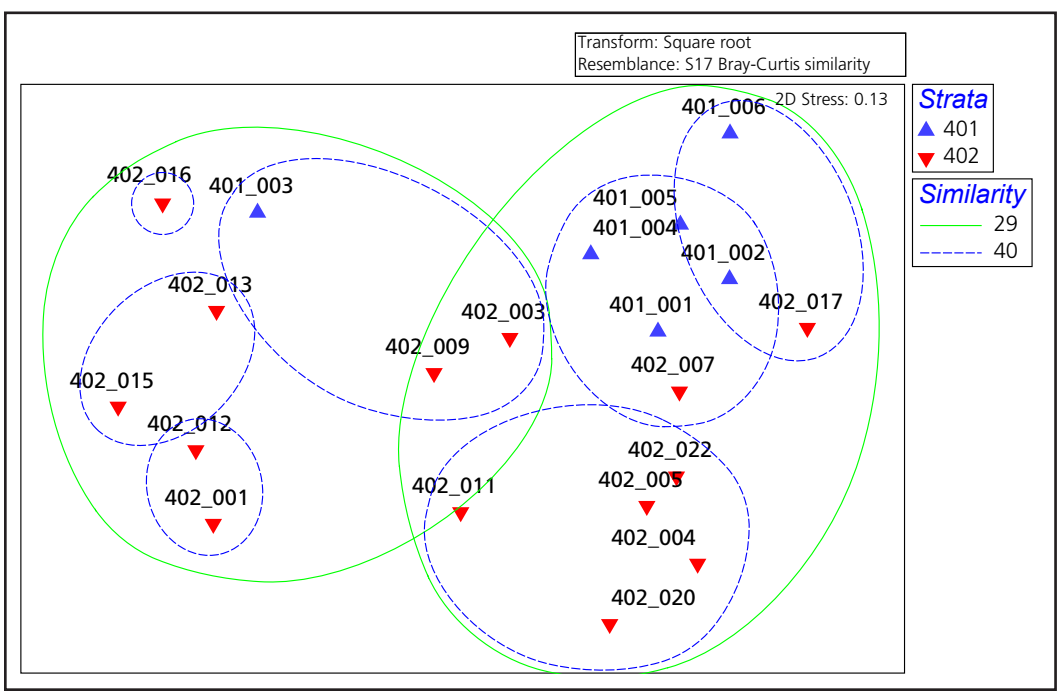


Figure 3-1. Non-metric multidimensional scaling (MDS) indicates similarity of vegetation communities by soil strata. MDS suggests two vegetation groupings within the 402 stratum. The distance between any two points increases as their composition and structure differ.

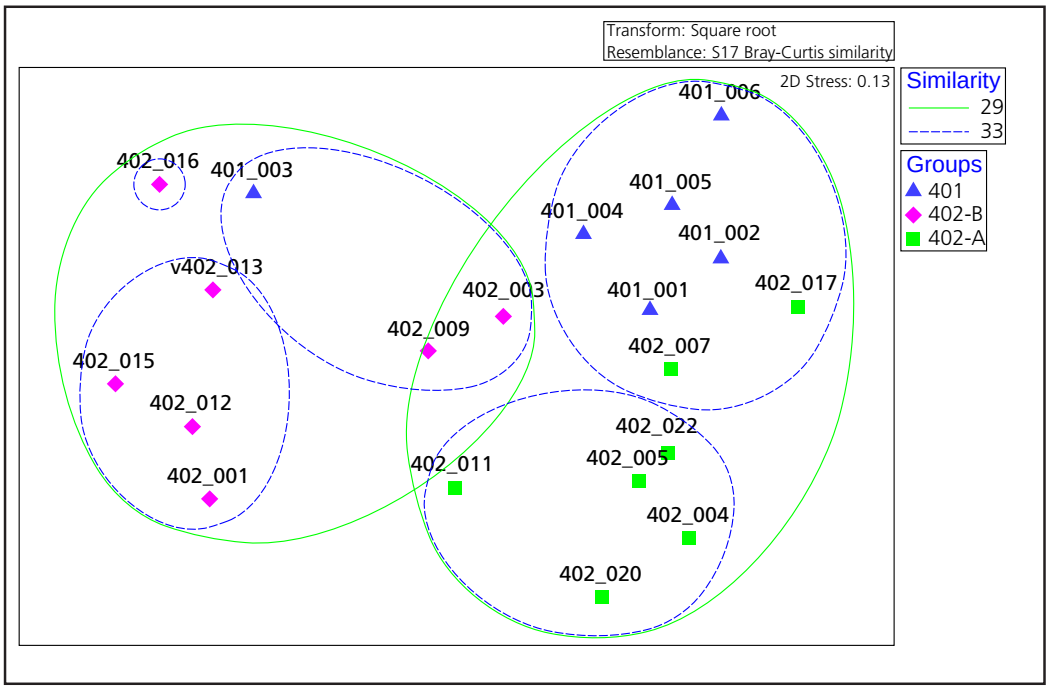


Figure 3-2. Non-metric multidimensional scaling (MDS) of vegetation similarity at Leslie Canyon NWR suggests three broad vegetation types within the two *a. priori* soil strata. The distance between any two points increases as their composition and structure differ.

combined, the minimum detectable change (MDC) of 10% was exceeded within several vegetation height classes. Refer to the vegetation cover summary tables for each stratum or substratum for more details.

3.1.3 Diversity of perennial plants

The 402-A substratum had the highest within-plot species richness (S_{plot}; 51.4 ± 3.2 mean ± SE), followed by the 402-B substratum (43.3 ± 4.2) and then the 401 stratum (37.2 ± 2.9). Analysis of variance (ANOVA) of S_{plot} for the three groups indicated that elevation and soil strata did significantly affect the number of perennial plant species (F = 4.05, P = 0.036). Pairwise t-tests (assuming unequal variances) indicated that the effect was due to a significantly higher species richness in the 402-A substratum compared to the 401 stratum (P = 0.0007). A significant difference between within-plot species richness did not exist between the 401 stratum and the 402-B stratum or between the two 402 substrata.

There was a significant difference (F = 4.80, P = 0.0222) in perennial plant taxonomic distinctness (Δ^+; 401 = 93.8 ± 0.6; 402-A = 92.9 ± 0.3; 402-B = 94.7 ± 0.4) between the three groups (Warwick and Clarke 1995). Pairwise t-tests (assuming unequal variances) indicated that the effect was due to a significant difference between the 402-A substratum and the 402-B substratum (P = 0.0038). Taxonomic distinctness was not significantly different between the 401 stratum and either of the 402 substrata.

We developed species accumulation curves for each of the strata or substrata to examine our ability to detect species richness with confidence given the number of sampling plots (Figures 3-4, 3-5, and 3-6). These graphs show the Sobs (actual species observed) and the UGE (analytical species accumulation curve as proposed by Ugland and others [2003]). The UGE is based on the idea that as sample effort/area increases, the cumulative species number increases until it reaches an asymptote. Slope decreased on each of our species accumulation curves, suggesting diminishing returns for detecting new species with increased sampling intensity.

3.2 Non-rocky, mid-mountain stratum (401)

Primarily restricted to the southern portion of the refuge, non-rocky (<35% surface soil rock fragments), mid-mountain (4,501-6,000 ft. elevation [1,370-1,830 m]) sites comprise about 22% of the terrestrial uplands of Leslie Canyon NWR. This stratum at Leslie Canyon NWR occupies the lower end of the mid-mountain elevation range.

Non-rocky, mid-mountain sites are somewhat uncommon in this region, although they do occur at Guadalupe Mountains National Park, Fort Davis National Historic Site, Coronado National Memorial and

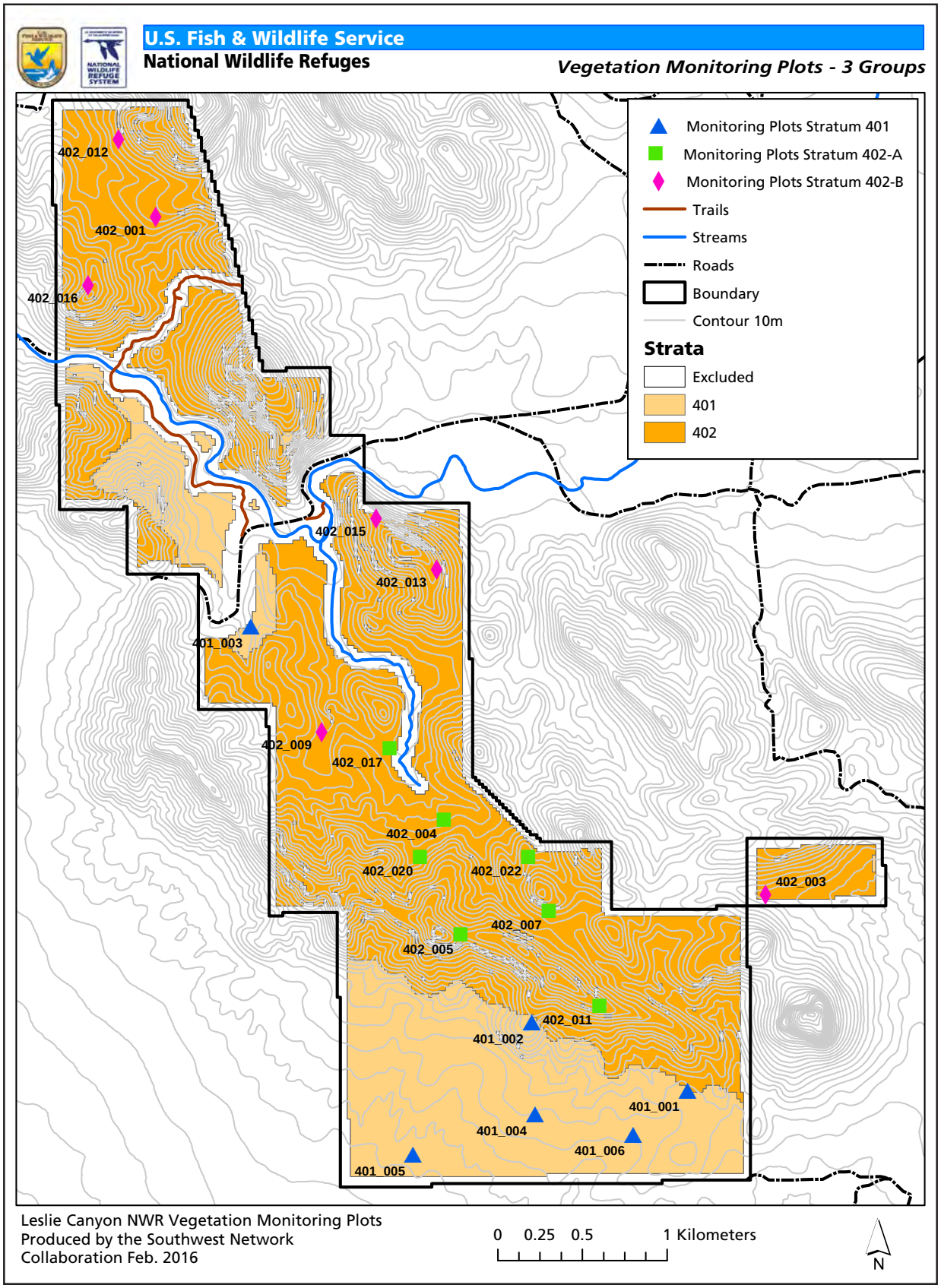


Figure 3-3. Locations of monitoring plots across the strata (401, 402-A, 402-B), Leslie Canyon National WIldlife Refuge, 2014.

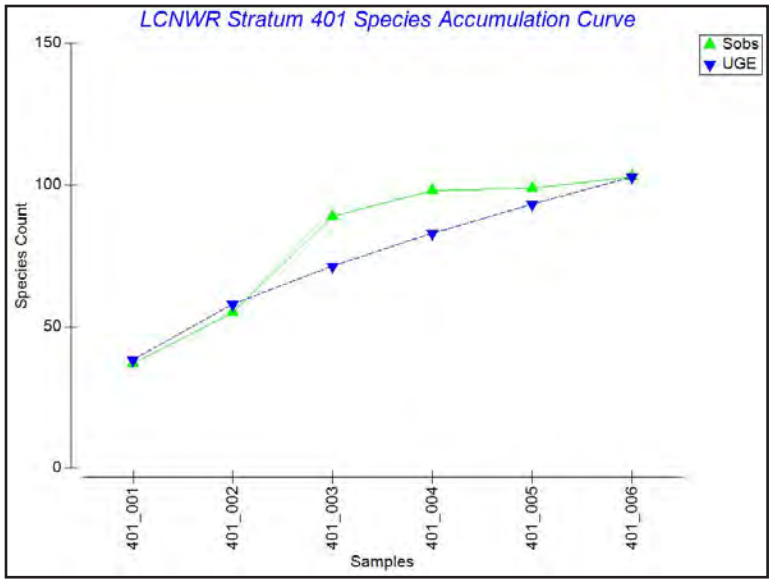


Figure 3-4. Species accumulation curves for non-rocky, mid-mountain stratum 401 suggest diminishing returns with increased sampling intensity. Sobs = the observed species richness. UGE = the modelled species richness.

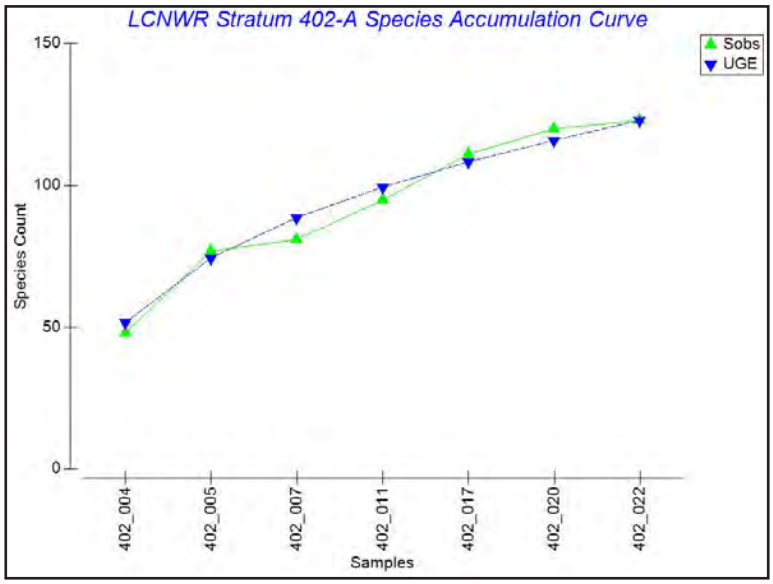


Figure 3-5. Species accumulation curves for rocky, mid-mountain substratum 402-A suggest diminishing returns with increased sampling intensity. Sobs = the observed species richness. UGE is the modelled species richness.

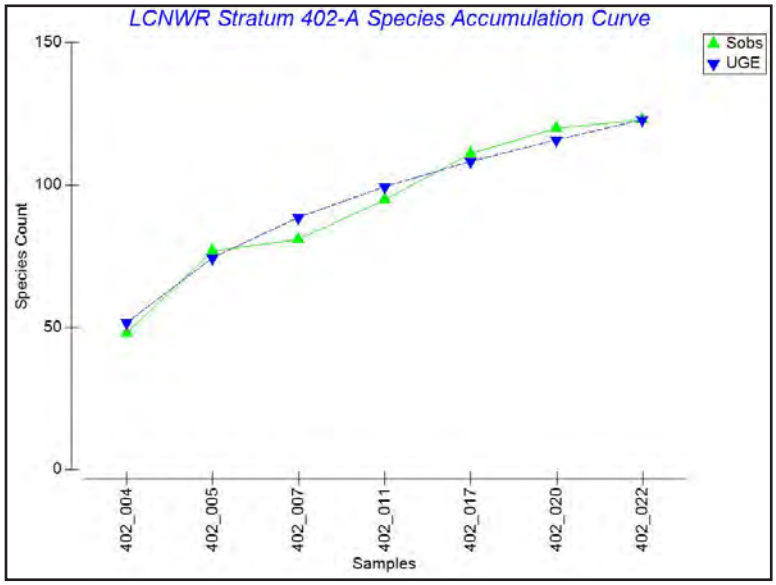


Figure 3-6. Species accumulation curves for rocky, mid-mountain substratum 402-B suggest diminishing returns with increased sampling intensity. Sobs = the observed species richness. UGE = the modelled species richness.

Photo: Vegetation typical of the non-rocky, mid-mountain stratum (401) on Leslie Canyon NWR.

Chiricahua National Monument. We sampled six monitoring sites in this stratum at Leslie Canyon NWR in 2014 (Figure 3-3).

3.2.1 Vegetation formations, lifeforms, and perennial plant diversity

The mid-mountain, non-rocky sites were primarily mariola/creosote bush shrubland. In addition to the dominance of shrubs, grasses and subshrubs were consistently present across monitoring sites. All major lifeforms were encountered on non-rocky, mid-mountain sites, with considerably more total vegetation cover in the field layer (<0.5 m height) than in the subcanopy (0.5-2.0 m) layer. Canopy (>2.0 m) cover was extremely sparse, and was comprised entirely of large tree-like shrubs. Trees were surprisingly lacking in this stratum, with only one species, netleaf hackberry (*Celtis reticulata*), being recorded on one frequency subplot. Trees were not recorded on the line-point intercept transects (Figure 3-7). The greatest lifeform diversity was found in the field layer, with shrubs dominating the height class (Figure 3-7).

The average similarity within this strata was 38.9% (SIMPER). Within-plot species richness of perennial plants (S_{plot}) on non-rocky, mid-mountain sites was 37.2 ± 2.9. This is the lowest number of perennial species detected among the three strata. Taxonomic distinctness (Δ^+) was 93.8 ± 0.6 making this strata more taxonomically distinct than the 402-A substrata and less distinct than the 402-B substratum.

3.2.2 Cover and extent of perennial plant species

Non-rocky, mid-mountain monitoring sites were dominated by three shrubs, Mariola (*Parthenium incanum*), creosote bush (*Larrea tridentata*), and viscid acacia (*Vachellia vernicosa*), in the field and subcanopy layers and the subshrub, rough menodora (*Menodora scabra*), in the field layer (based on cover, extent, and SIMPER results; Table 3-1). Subdominant species included two grasses, Lehmann lovegrass and purple threeawn (*Aristida purpurea)*, and four shrubs, American tarwort (*Flourensia cernua)*, ocotillo (*Fouquieria splendens)*, whitethorn acacia (*Vachellia constricta)* and littleleaf sumac (*Rhus microphylla)*.

The dominant/subdominant species were widespread, occurring on at least five of the six monitoring sites. Other common species in the non-rocky, mid-mountain stratum were the subshrub, desert zinnia (*Zinnia acerosa*, 5 sites), the forb, hairyseed bahia (*Bahia absinthifolia*, 4 sites), the shrub, Wright's beebrush

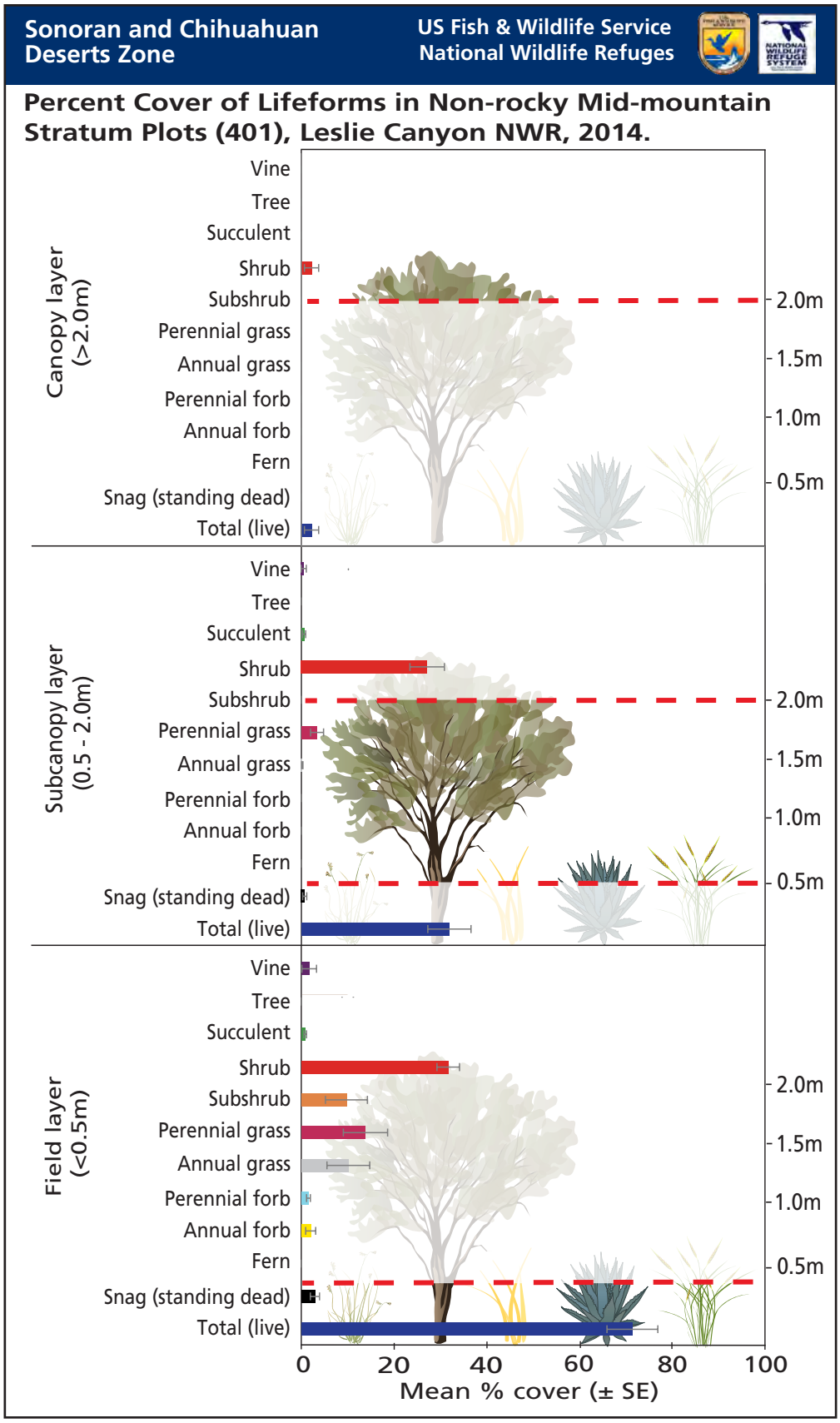


Figure 3-7. Lifeform cover in terrestrial vegetation monitoring plots on mid-mountain (4,501-6,000') sites with non-rocky soils (stratum 401) at Leslie Canyon NWR, 2014.

Table 3-1. Cover values (%) for perennial and non-native annual species (by lifeform) measured in the field (<0.5m stature), subcanopy (0.5-2.0m), and canopy (>2.0m) layers of mid-mountain (4,501-6,000'), non-rocky (401 stratum) terrestrial vegetation and soils plots at Leslie Canyon NWR, 2014. "AVG" = average on transects, "SE" = standard error, "MDC" = minimum detectable change (% cover), "Extent" is the number of plots in which the species was detected (out of 6) on transects or subplots, and "T1" = time one (first sampling year, 2014).

			Field (T1)			Subcanopy (T1)			Canopy (T1)			
Lifeform	**Scientific Name**	**Common Name**	**AVG**	**SE**	**MDC**	**AVG**	**SE**	**MDC**	**AVG**	**SE**	**MDC**	**Extent**
Vine	*Cissus trifoliata*	sorrelvine	0.1%	0.14%	5%	---	---	---	---	---	---	1
	Janusia gracilis	slender janusia	0.07%	0.07%	5%	---	---	---	---	---	---	1
Succulent	*Cylindropuntia spinosior*	walkingstick cactus	---	---	---	0.07%	0.07%	5%	---	---	---	3
	Opuntia engelmannii	cactus apple	0.21%	0.21%	5%	0.14%	0.14%	5%	---	---	---	2
	Opuntia sp.	pricklypear	0.21%	0.21%	5%	0.07%	0.07%	5%	---	---	---	1
	Yucca baccata	banana yucca	0.42%	0.28%	5%	0.35%	0.35%	5%	---	---	---	4
Shrub	*Aloysia wrightii*	Wright's beebrush	3.13%	2.79%	6%	2.71%	2.30%	5%	---	---	---	4
	Calliandra eriophylla	fairyduster	1.04%	0.73%	5%	---	---	---	---	---	---	4
	Condalia warnockii	Warnock's snakewood	0.28%	0.28%	5%	0.28%	0.28%	5%	---	---	---	2
	Eysenhardtia orthocarpa	Tahitian kidneywood	0.70%	0.70%	5%	0.90%	0.90%	5%	0.07%	0.07%	5%	1
	Flourensia cernua	American tarwort	2.85%	1.58%	5%	1.60%	0.69%	5%	---	---	---	5
	Fouquieria splendens	ocotillo	0.35%	0.17%	5%	1.67%	0.89%	5%	0.56%	0.48%	5%	6
	Larrea tridentata	creosote bush	2.50%	1.07%	5%	7.78%	3.06%	7%	---	---	---	5
	Mortonia scabrella	Rio Grande saddlebush	0.90%	0.68%	5%	0.70%	0.61%	5%	0.07%	0.07%	5%	3
	Parthenium incanum	mariola	11.74%	4.12%	9%	1.32%	0.44%	5%	---	---	---	6
	Rhus microphylla	littleleaf sumac	1.11%	0.66%	5%	1.39%	0.69%	5%	0.35%	0.35%	5%	5
	Vachellia constricta	whitethorn acacia	2.78%	2.03%	5%	3.75%	1.97%	5%	1.11%	1.11%	5%	3
	Vachellia vernicosa	viscid acacia	4.31%	1.42%	5%	5.07%	2.02%	5%	0.07%	0.07%	5%	4
Subshrub	*Ayenia filiformis*	Trans-Pecos ayenia	0.07%	0.07%	5%	---	---	---	---	---	---	1
	Dalea formosa	featherplume	0.14%	0.14%	5%	---	---	---	---	---	---	1
	Hibiscus denudatus	paleface	0.07%	0.07%	5%	---	---	---	---	---	---	3
	Menodora scabra	rough menodora	8.34%	4.33%	9%	---	---	---	---	---	---	5
	Polygala barbeyana	blue milkwort	0.14%	0.14%	5%	---	---	---	---	---	---	1
	Sphaeralcea laxa	caliche globemallow	0.07%	0.07%	5%	---	---	---	---	---	---	5
	Thymophylla pentachaeta	fiveneedle pricklyleaf	0.07%	0.07%	5%	---	---	---	---	---	---	2
	Tiquilia canescens	woody crinklemat	0.49%	0.27%	5%	---	---	---	---	---	---	5
	Zinnia acerosa	desert zinnia	0.35%	0.13%	5%	---	---	---	---	---	---	5

Table 3-1 (continued). Cover values (%) for perennial and non-native annual species (by lifeform) measured in the field (<0.5m stature), subcanopy (0.5-2.0m), and canopy (>2.0m) layers of mid-mountain (4,501-6,000'), non-rocky (401 stratum) terrestrial vegetation and soils plots at Leslie Canyon NWR, 2014. "AVG" = average on transects, "SE" = standard error, "MDC" = minimum detectable change (% cover), "Extent" is the number of plots in which the species was detected (out of 6) on transects or subplots, and "T1" = time one (first sampling year, 2014).

			Field (T1)			Subcanopy (T1)			Canopy (T1)			
Lifeform	**Scientific Name**	**Common Name**	**AVG**	**SE**	**MDC**	**AVG**	**SE**	**MDC**	**AVG**	**SE**	**MDC**	**Extent**
Grass	*Achnatherum eminens*	southwestern needlegrass	---	---	---	0.14%	0.14%	5%	---	---	---	3
	Aristida purpurea	purple threeawn	2.43%	1.31%	5%	0.55%	0.17%	5%	---	---	---	5
	Aristida ternipes	spidergrass	0.42%	0.42%	5%	---	---	---	---	---	---	1
	Bothriochloa barbinodis	cane bluestem	0.07%	0.07%	5%	---	---	---	---	---	---	1
	Bouteloua curtipendula	sideoats grama	0.49%	0.33%	5%	0.28%	0.17%	5%	---	---	---	5
	Bouteloua eriopoda	black grama	0.49%	0.25%	5%	---	---	---	---	---	---	5
	Bouteloua hirsuta	hairy grama	0.07%	0.07%	5%	---	---	---	---	---	---	1
	Dasyochloa pulchella	low woollygrass	0.28%	0.21%	5%	---	---	---	---	---	---	5
	Enneapogon desvauxii	nineawn pappusgrass	0.14%	0.09%	5%	---	---	---	---	---	---	3
	Eragrostis cilianensis*	**stinkgrass***	0.28%	0.14%	5%	0.14%	0.14%	5%	---	---	---	6
	Eragrostis intermedia	plains lovegrass	0.14%	0.14%	5%	0.14%	0.14%	5%	---	---	---	1
	Eragrostis lehmanniana*	**Lehmann lovegrass***	5.55%	4.58%	10%	1.74%	1.01%	5%	---	---	---	5
	Erioneuron avenaceum	shortleaf woollygrass	0.14%	0.14%	5%	---	---	---	---	---	---	3
	Leptochloa dubia	green sprangletop	0.21%	0.21%	5%	0.28%	0.28%	5%	---	---	---	1
	Muhlenbergia porteri	bush muhly	0.49%	0.27%	5%	---	---	---	---	---	---	4
	Panicum hallii	Hall's panicgrass	0.07%	0.07%	5%	---	---	---	---	---	---	4
	Scleropogon brevifolius	burrograss	0.07%	0.07%	5%	---	---	---	---	---	---	1
	Setaria leucopila	streambed bristlegrass	1.46%	1.01%	5%	0.28%	0.17%	5%	---	---	---	5
	Setaria macrostachya	large-spike bristlegrass	0.07%	0.07%	5%	---	---	---	---	---	---	1
	Sorghastrum nutans	Indiangrass	0.07%	0.07%	5%	---	---	---	---	---	---	1
	Tridens muticus	slim tridens	1.18%	0.65%	5%	---	---	---	---	---	---	4
Forb/Herb	*Abutilon parvulum*	dwarf Indian mallow	0.07%	0.07%	5%	---	---	---	---	---	---	1
	Acourtia nana	dwarf desertpeony	0.14%	0.14%	5%	---	---	---	---	---	---	1
	Acourtia wrightii	brownfoot	0.14%	0.14%	5%	---	---	---	---	---	---	1
	Artemisia ludoviciana	white sagebrush	0.07%	0.07%	5%	---	---	---	---	---	---	1
	Bahia absinthifolia	hairyseed bahia	0.49%	0.20%	5%	---	---	---	---	---	---	4
	Chamaesaracha sordida	hairy five eyes	0.63%	0.40%	5%	---	---	---	---	---	---	5

* Non-native plants (in bold).

Table 3-1 (continued). Cover values (%) for perennial and non-native annual species (by lifeform) measured in the field (<0.5m stature), subcanopy (0.5-2.0m), and canopy (>2.0m) layers of mid-mountain (4,501-6,000'), non-rocky (401 stratum) terrestrial vegetation and soils plots at Leslie Canyon NWR, 2014. "AVG" = average on transects, "SE" = standard error, "MDC" = minimum detectable change (% cover), "Extent" is the number of plots in which the species was detected (out of 6) on transects or subplots, and "T1" = time one (first sampling year, 2014).

			Field (T1)			Subcanopy (T1)			Canopy (T1)			
Lifeform	**Scientific Name**	**Common Name**	**AVG**	**SE**	**MDC**	**AVG**	**SE**	**MDC**	**AVG**	**SE**	**MDC**	**Extent**
Total Vine	---	---	1.67%	1.58%	5%	0.56%	0.56%	5%	---	---	---	---
Total Tree	---	---	---	---	---	---	---	---	---	---	---	---
Total Succulent	---	---	0.83%	0.28%	5%	0.63%	0.34%	5%	---	---	---	---
Total Shrub	---	---	31.67%	2.43%	6%	27.16%	3.72%	8%	2.23%	1.54%	5%	---
Total Subshrub	---	---	9.73%	4.51%	10%	---	---	---	---	---	---	---
Total Perennial Grass	---	---	13.82%	4.77%	10%	3.40%	1.40%	5%	---	---	---	---
Total Annual Grass	---	---	10.14%	4.60%	10%	0.21%	0.14%	5%	---	---	---	---
Total Perennial Forb	---	---	1.53%	0.40%	5%	---	---	---	---	---	---	---
Total Annual Forb	---	---	2.02%	1.09%	5%	---	---	---	---	---	---	---
Total Fern	---	---	---	---	---	---	---	---	---	---	---	---
Total Snag	---	---	2.92%	1.00%	5%	0.77%	0.44%	5%	---	---	---	---
Total Live	---	---	71.40%**	5.47%	12%**	31.94%	4.67%	10%	2.23%	1.54%	5%	---
Total Annuals	---	---	12.15%	4.83%	10%	0.21%	0.14%	5%	---	---	---	---
Total Exotics	---	---	5.83%	4.53%	10%	1.88%	0.98%	5%	---	---	---	---
Total Exotics: Total Live	---	---	7.20%**	5.48%	12%**	5.62%	2.02%	5%	---	---	---	---
Total Annuals: Total Live	---	---	16.19%**	5.70%	12%**	0.64%	0.46%	5%	---	---	---	---

**MDC >10% indicates the species or parameter failed to meet our statistical power criteria (highlighted).

(*Aloysia wrightii*, 4 sites) and the grass, sideoats grama (*Bouteloua curtipendula*, 5 sites; Table 3-1).

3.2.3 Frequency and extent of uncommon plant species

Fifty-three uncommon plant species were detected on the frequency subplots, but not on transects of the 401 stratum, further revealing the immense biodiversity of the area (Table 3-2). Nineteen species had a subplot frequency of 10% or more. Only two species - the non-native forb, spreading fanpetals (*Sida abutifolia)* and the subshrub, common sotol (*Dasylirion wheeleri*) - had average within-plot frequencies of 33% or more. Both of these were the most extensive uncommon plants across the non-rocky, mid-mountain stratum, detected on at least three of the six monitoring sites. Detected species unique to this stratum included two shrubs, longleaf jointfir (*Ephedra trifurca)* and water jacket (*Lycium andersonii*).

3.2.4 Cover and frequency of exotic species

Two non-native grasses, Lehmann lovegrass and stinkgrass (*Eragrostis cilianensis*), were detected on transects across the non-rocky, mid-mountain stratum. Lehmann lovegrass was the most common, occurring on the transects of four of the six plots sampled in stratum 401, but on five plots total when including the frequency subplots. Foliar cover was extremely variable, ranging from 0.8% in the field on plots 401_001 and 401_005 to 28.3% in the field on plot 401_003 (5.6% ± 4.6 mean ± SE in the field layer; Table 3-1). See Figure 3-8 for Lehmann lovegrass distribution.

One non-native forb, spreading fanpetals, was detected only in the frequency subplots of 3 plots. A total of 3 non-native species were detected across all plots in stratum 401 during the course of the sampling period (Table 3-3). Further discussion of exotic species at Leslie Canyon NWR can be found in Section 4.

3.2.5 Soil cover and biological soil crusts

Along the line-point intercept transects, soil cover (Table 3-4) was dominated by gravel (2-76 mm; 61.1% cover) and leaf litter and woody debris (15.3% cover). About 1.5% of the soil surface was bare soil without overhead vegetative cover – the category most susceptible to erosion – while about 4% was bare soil protected by overhead canopy. Biological soil crusts were present at low levels (2.5% cover), with light cyanobacteria as the dominant crust type. Rocks and bedrock comprised a cumulative 13.4% of soil cover. We met or exceeded our expectations for statistical power (to detect a 10% absolute change in foliar cover with 90% power and 10% chance of false change error) for all substrate types, except gravel and bedrock. Plot 401_003, an anomaly in the 401 stratum that is geographically and biologically more similar to the 402-B stratum, had an unusually high percent cover of bedrock (36.7%) and a very low percent

Table 3-2. Within-plot frequency (%), standard error (SE), and extent (out of 6 plots) of uncommon plant species (found only on subplots and not on transects) sampled on non-rocky, mid-mountain (401 stratum; 35-90% surface soil rock fragments, 4,501'-6,000') monitoring plots on Leslie Canyon NWR, 2014.

Lifeform	Scientific Name	Common Name	Within-plot freq	SE	Extent
Vine	*Ipomoea pubescens*	silky morning-glory	23%	16%	2
	Phaseolus angustissimus	slimleaf bean	10%	9%	1
	Funastrum crispum	wavyleaf twinevine	7%	6%	1
	Cucurbita digitata	fingerleaf gourd	3%	3%	1
	Galactia wrightii	Wright's milkpea	3%	3%	1
	Maurandya antirrhiniflora	roving sailor	3%	3%	1
Tree	*Celtis reticulata*	netleaf hackberry	3%	3%	1
Succulent	*Agave palmeri*	Palmer's century plant	17%	10%	2
	Echinocereus sp.	hedgehog cactus	13%	6%	3
	Mammillaria heyderi	little nipple cactus	13%	12%	1
	Opuntia phaeacantha	tulip pricklypear	10%	9%	1
	Mammillaria sp.	globe cactus	7%	6%	1

Table 3-2 (continued). Within-plot frequency (%), standard error (SE), and extent (out of 6 plots) of uncommon plant species (found only on subplots and not on transects) sampled on non-rocky, mid-mountain (401 stratum; 35-90% surface soil rock fragments, 4,501'-6,000') monitoring plots on Leslie Canyon NWR, 2014.

Lifeform	Scientific Name	Common Name	Within-plot freq	SE	Extent
Shrub	*Abutilon mollicomum*	Sonoran Indian mallow	13%	12%	1
	Ayenia microphylla	dense ayenia	13%	9%	2
	Lycium sp.	desert-thorn	7%	6%	1
	Ephedra trifurca	longleaf jointfir	3%	3%	1
	Lycium andersonii	water jacket	3%	3%	1
	Ziziphus obtusifolia	lotebush	3%	3%	1
Subshrub	*Dasylirion wheeleri*	common sotol	33%	14%	5
	Calliandra humilis	dwarf stickpea	13%	12%	1
	Croton pottsii	leatherweed	10%	6%	2
	Guitierrezia microcephala	threadleaf snakeweed	10%	9%	1
	Gymnosperma glutinosum	gumhead	3%	3%	1
	Nolina microcarpa	sacahuista	3%	3%	1
	Nolina texana	Texas sacahuista	3%	3%	1
Grass	*Cottea pappophoroides*	cotta grass	7%	4%	2
	Digitaria californica	Arizona cottontop	7%	6%	1
	Hilaria mutica	tobosagrass	7%	4%	2
	Muhlenbergia emersleyi	bullgrass	7%	4%	2
	Bouteloua gracilis	blue grama	3%	3%	1
	Heteropogon contortus	tanglehead	3%	3%	1
Forb	**Sida abutifolia***	**spreading fanpetals***	37%	16%	3
	Dalea pogonathera	bearded prairie clover	13%	12%	1
	Commelina dianthifolia	birdbill dayflower	10%	9%	1
	Dalea Wrightii	Wright's prairie clover	10%	9%	1
	Nicotiana obtusifolia	desert tobacco	7%	6%	1
	Penstemon sp.	beardtongue	7%	6%	1
	Physaria fendleri	Fendler's bladderpod	7%	6%	1
	Portulaca suffrutescens	shrubby purslane	7%	6%	1
	Boerhavia coccinea	scarlet spiderling	3%	3%	1
	Elytraria imbricata	purple scalystem	3%	3%	1
	Hedeoma drummondii	Drummond's false pennyroyal	3%	3%	1
	Hybanthus verticillatus	babyslippers	3%	3%	1
	Phemeranthus aurantiacus	orange fameflower	3%	3%	1
	Talinum paniculatum	jewels of Opar	3%	3%	1
	Verbena neomexicana	hillside vervain	3%	3%	1
	Viguiera dentata	toothleaf goldeneye	3%	3%	1
Fern	*Astrolepis cochisensis*	Cochise scaly cloakfern	23%	15%	3
	Cheilanthes lindheimeri	fairyswords	10%	9%	1
	Pellaea truncata	spiny cliffbrake	10%	9%	1
	Astrolepis sinuata	wavy scaly cloakfern	7%	6%	1
	Bommeria hispida	copper fern	7%	6%	1
	Astrolepis integerrima	hybrid cloakfern	3%	3%	1

* Non-native species (in bold).

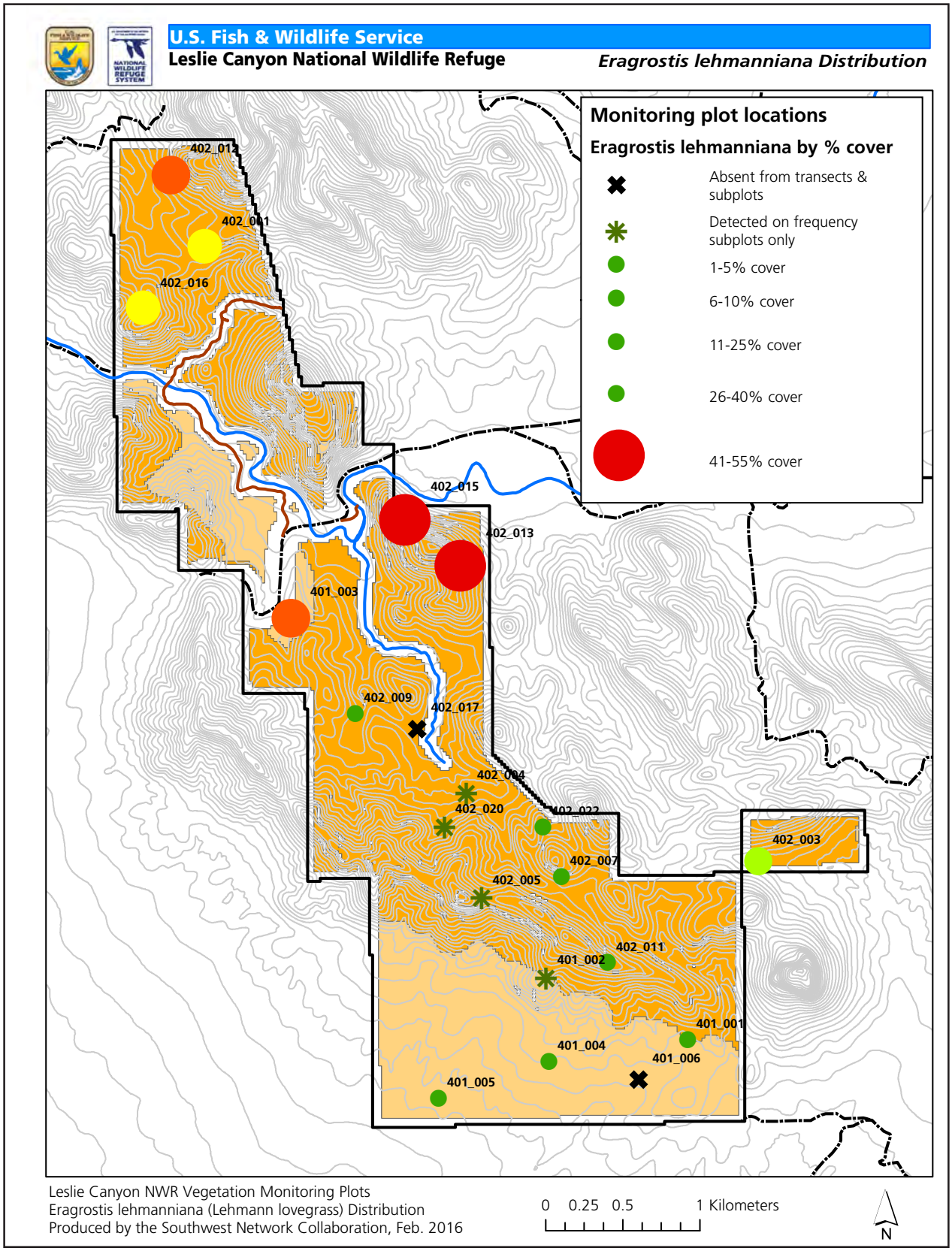


Figure 3-8. Distribution and cover of the non-native grass, Lehmann lovegrass (*Eragrostis lehmanniana*) at Leslie Canyon NWR, 2014.

Table 3-3. Presence/absence of non-native plants detected on vegetation monitoring plots, Leslie Canyon National Wildlife Refuge, 2014.

Strata/ Substrata	Plot	Species1	Species2	Total Species
401	401_001	*Eragrostis lehmanniana*	*Sida abutifolia*	2
	401_002	*Eragrostis cilianensis*	*Sida abutifolia*	2
	401_003	*Eragrostis lehmanniana*	n/a	1
	401_004	*Eragrostis cilianensis*	*Eragrostis lehmanniana*	2
	401_005	*Eragrostis lehmanniana*	n/a	1
	401_006	*Eragrostis cilianensis*	*Sida abutifolia*	2
402-A	402_004	*Sida abutifolia*	n/a	1
	402_005	n/a	n/a	0
	402_007	*Eragrostis lehmanniana*	n/a	1
	402_011	*Eragrostis lehmanniana*	n/a	1
	402_017	*n/a*	*n/a*	0
	402_020	*n/a*	*n/a*	0
	402_022	*Eragrostis lehmanniana*	*n/a*	1
402-B	402_001	*Eragrostis lehmanniana*	*Melinis repens*	2
	402_003	*Eragrostis cilianensis*	*Eragrostis lehmanniana*	2
	402_009	*Eragrostis lehmanniana*	*n/a*	1
	402_012	*Eragrostis lehmanniana*	*Sida abutifolia*	2
	402_013	*Eragrostis lehmanniana*	n/a	1
	402_015	*Eragrostis lehmanniana*	*Macroptilium gibbosifolium*	2
	402_016	*Eragrostis lehmanniana*	n/a	1

cover of gravel (7.1%) compared to all other plots in this group. These anomalies result in a MDC within those substrate types of 13% and 24% respectively.

Within the point-quadrats, mature biological soil crusts (dark cyanobacteria, lichens and bryophytes) occupied 2.4% ± 1.1 of the available habitat. Squamulose and gelatinous lichen growth forms were observed.

3.2.6 Soil stability

Surface soil aggregate stability was "moderately stable" (3.9 ± 0.2; see Table 2-2 for stability categories) across the stratum. Plot 401_003 was completely obstructed by rock and/or vegetation, thus preventing aggregate stability samples from being collected. Samples collected under vegetation canopies (n=68) had a mean stability rating of 4.0 ± 0.005 (moderately stable), whereas those without overhead canopy cover (n= 18) were more variable, ranging from unstable (2.5 ± 1.0 on plot 401_001) to very stable (6.0 ± 0.0; one sample (n=1) on plot 401_004) with a mean rating of 4.2 ± 0.6 (moderately stable).

3.2.7 Site and soil characterization

Surface soil cores (~10cm deep) were collected on four of the six plots, while obstructions prevented collection on the remaining two. Surface soils on stratum 401 plots were clay loam or sandy clay loam with an average rock fragment of 46%. Rock fragment content (fraction of soil sample >2 mm in diameter by mass) ranged from 37% to 66%. Organic content averaged 2.0% across the samples, with a range of 1.3% to 3.8%. Bulk density ranged from 1.0 to 2.6 g/cm^3. Plot 401_001 had a high bulk density (2.6 g/cm^3). Oven dry bulk densities greater than 2 g/cm^3 typically indicate compaction that could restrict root growth and movement of water and nutrients (Muckel 2004). Soils were somewhat alkaline with an average pH of 8.0. Plot-specific information is provided in Table 3-5.

Plots 401_005 and 401_006 had some degree (<5%) of burrowing. Several of the plots were crisscrossed with rills, with these being more extensive (6-25%) on plot 401_002 (see Appendix A) and Table 3-5 for details).

Table 3-4. Soil substrate cover (% by category) for non-rocky, mid-mountain (401 stratum; <35% surface soil rock fragments, 4,501'-6,000') monitoring plots on Leslie Canyon NWR, 2014. "AVG" = average, "SE" = standard error, "MDC" = minimum detectable change.

Soil cover category (Listed in order of highest to lowest erosion hazard)	AVG	SE	MDC
Bare soil (<2 mm) - no overhead cover	1.46%	0.41%	5%
Bare soil (<2 mm) - under vegetation	4.03%	1.14%	5%
Total bare soil	5.49%	1.46%	5%
Light Cyano - no overhead cover	0.42%	0.21%	5%
Light Cyano - under vegetation	1.74%	0.86%	5%
Total light cyanobacteria	2.15%	1.00%	5%
Leaf litter - needles, leaves, and cones (fine fuels)	13.26%	3.70%	8%
Woody debris <0.062 cm in diameter (1-hour fuel)	1.67%	0.70%	5%
Woody debris 0.62-2.54 cm in diameter (10-hour fuel)	0.21%	0.09%	5%
Woody debris 2.54-7.62 cm in diameter (100-hour fuel)	0.07%	0.07%	5%
Woody debris >7.62 cm in diameter (1000-hour fuel)	0.07%	0.07%	5%
Total leaf litter and woody debris	15.28%	3.52%	5%
Dark Cyano	0.35%	0.17%	5%
Gravel: 2-76 mm	61.11%*	11.43%	24%*
Lichen	0.00%	0.00%	5%
Moss	0.00%	0.00%	5%
Rock: > 76 mm	7.01%	3.38%	7%
Plant Base	2.22%	0.43%	5%
Bedrock	6.39%*	6.06%	13%*

*MDC >10% indicates the category failed to meet our statistical power criteria (highlighted).

3.2.8 Management assessment points

Our results for non-rocky, mid-mountain sites in the context of management assessment points (Section 2) indicate one primary issue for management consideration (Table 3-6). Lehmann lovegrass was detected on five of the six monitoring sites within stratum 401 (Table 3-1). With Lehmann lovegrass as the major contributor, exotic species had a total cover in the field of 5.8% ± 4.5 and represented 7.2% ± 5.5 of the total vegetation cover recorded on transects. While an increase in the cover and extent of Lehmann lovegrass cannot be measured until future sampling occurs, the ubiquitous presence is a cause for concern as it brings increased fuel loads and fierce competition for limited resources to the areas it occupies (Cox and Ruyle 1986, Anable et al. 1992). Further species discussion in context of refuge management can be found in Section 4.

Mature biological soil crust cover, surface soil aggregate stability and exposed bare soil measurements were within the acceptable ranges of their assessment points, indicating currently stable soils on non-rocky, mid-mountain sites (Table 3-6).

All indicators for plant community resilience, exotic plant presence and fire hazard, were below their corresponding assessment points or could not be assessed until a future sampling allows for assessment of trends (Table 3-6).

Table 3-5. 2014 soil and site characterization for non-rocky, mid-mountain (401 stratum) monitoring sites (Elev. 4,501-6,000'), at Leslie Canyon NWR.

Character	Parameter	Plot 401_001	Plot 401_002	Plot 401_003	Plot 401_004	Plot 401_005	Plot 401_006
Slope	Average plot slope (%)	6	30	37	12	12	5
	Slope position	Footslope	Backslope	Backslope	Footslope	Toeslope	Footslope
Aspect	Degrees	240	138	296	145	176	209
	Description	SW	SE	NW	SE	S	SW
Soil Lab Results	% Sand	47	---	---	52	43	52
	% Silt	25	---	---	27	30	26
	% Clay	27	---	---	20	27	21
	Soil Texture	Sandy Clay Loam	---	---	Sandy Clay Loam	Clay Loam	Sandy Clay Loam
	Rock Fragments (%)[a]	66	---	---	37	38	42
	Oven Dry Soil Bulk Density (g/cm^3)[b]	2.6	---	---	1.0	1.0	1.2
	Total Organic Content (%)	2.0	---	---	3.8	1.9	1.3
	Electrical Conductivity	180	---	---	217	205	148
	pH	7.9	---	---	8.0	7.9	8.0
	Reserve Acidity	0.2	---	---	0.3	0.4	0.4
Erosion Features	Tunneling	none	none	none	none	none	none
	Sheet	none	none	none	none	none	none
	Rill	none	26-50%	none	<5%	<5%	none
	Gully	none	none	none	none	none	none
	Pedestals	none	none	none	none	none	none
	Terracettes	none	none	none	none	none	none
	Burrowing	none	none	none	none	<5%	<5%
Landform	Description	Bajada	Drainage, Hill	Hill	Hill	Lower Alluvial Fan, Flood Plain	Bajada

[a] Rock Fragments (%) = fraction of soil >2mm in diameter by mass

[b] Oven Dry Soil Bulk Density excludes the weight and volume of rock fragments in sample. Rock fragment density assumed to be 2.65 g/cm^3

[c] Sample Bulk Density includes all rock fragments in sample

Table 3-6. Vegetation and soils data for non-rocky, mid-mountain (401 stratum) monitoring sites in the context of management assessment points, Leslie Canyon National Wildlife Refuge.

Issue	Management Assessment Point	Mean ± SE	Point met?	Recommendation
Erosion Hazard	Exposed bare ground (with no overhead vegetation) is >20% cover	1.46% ± 0.41	no	Continue monitoring
	Surface soil aggregate stability (with no overhead vegetation) is <Class 3	4.23 ± 0.60	no	Continue monitoring
	Mature Biological Soil Crusts occupy <2% cover of available habitat	2.4% ± 1.1	no	Continue monitoring
Plant Community Resilience	Foliar cover of dead perennial plants is >10% (field)	2.92% ± 1.00	no	Continue monitoring
	Foliar cover of dead perennial plants is >5% (subcanopy)	0.77% ± 0.44	no	Continue monitoring
	Annual plant cover: total plant cover is >1:2 (0.50) (field)	16.19% ± 5.70	no	Continue monitoring
	Native taxonomic diversity decrease >10% over time	n/a	[a]baseline; n/a	Continue monitoring
	Native within-plot species richness decrease of >10% over time	n/a	[a]baseline; n/a	Continue monitoring
Exotic plant presence	The detection of a new exotic species (annual or perennial) on any plot	n/a	[a]baseline;n/a	Continue monitoring
	Increase in Extent of existing exotic species within a stratum	n/a	[a]baseline; n/a	Continue monitoring
Exotic plant abundance	5% change in cover of ERALEH within a plot	n/a	[a]baseline; n/a	Continue monitoring
	Exotic plant cover: total plant cover is >1:20 (0.05) (field)[b]	7.20% ± 5.48[b]	YES	Meet and consider
	Total cover of all exotic plants is >5% (field)[c]	5.83% ± 4.53[c]	YES	Warning to managers
Fire Hazard	Leaf litter and woody debris > 75%	15.28% ± 3.52	no	Continue monitoring

[a]2014 represents the first year of long-term Terrestrial Vegetation and Soils Monitoring, Assessments of relevant MAPs will be completed after future sampling efforts.

[b]Meet and discuss. Parameter exceeds assessment point (in red).

[c]Warning to management. Parameter approaches or is at assessment point (in yellow).

Photo: Looking north into the rocky, mid-mountain substratum 402-A.

3.3 Rocky, mid-mountain stratum (substratum 402-A)

Comprising about 56% of the terrestrial uplands of Leslie Canyon NWR, rocky (35-90% surface soil rock fragments), mid-mountain (4,501-6,000 ft. elevation [1,370-1,830 m]) sites are found in the central and northern portion of the refuge, including the areas adjacent to Leslie Creek (Figure 3-3). This stratum, as defined by soils and elevation, encompasses substrata 402-A and 402-B of our sample. We sampled 14 rocky, mid-mountain monitoring sites at Leslie Canyon NWR in 2014 (7 in each substratum; Figure 3-3).

This stratum is found extensively in mountain ranges and "sky islands" of the American Southwest—including Big Bend, Carlsbad Caverns, Guadalupe Mountains, and Saguaro national parks, Chiricahua and Gila Cliff Dwellings national monuments, Coronado National Memorial, and Fort Bowie National Historic Site. We sampled 14 rocky, mid-mountain monitoring sites at Leslie Canyon NWR in 2014 (Figure 3-3).

Permanova and SIMPER analysis of the data revealed that the rocky, mid-mountain stratum supported two distinct vegetation communities (78.5% avg. dissimilarity). Further analysis of soils and landscape characterization did not result in a decisive factor upon which stratum 402 could be post-stratified. Due to the clear distinction between the vegetation communities, they will be discussed throughout the remainder of the report as separate groups within stratum 402 or "substratum" as mentioned in Section 3.1. Future sampling and analysis may or may not reveal a reliable factor which could be used for long-term post-stratification.

3.3.1 Vegetation formations, lifeforms, and perennial plant diversity

The mid-mountain, rocky sites in substratum 402-A are characterized as mariola/Rio Grande saddlebush/slim tridens shrub savanna. This substratum was dominated by a diverse blend of shrubs and perennial grasses, and often accompanied by the forb, toothleaf goldeneye (*Viguiera dentata*).

All major lifeforms were encountered on rocky, mid-mountain substratum 402-A sites, with more total vegetation cover in field (<0.5 m height) than subcanopy (0.5-2.0 m) layers. Canopy (>2.0 m) cover was thinly scattered, and was comprised entirely of large tree-like shrubs. Similar to stratum 401, trees were lacking, with only velvet mesquite (*Prosopis velutina*) being recorded on one frequency subplot. Trees were

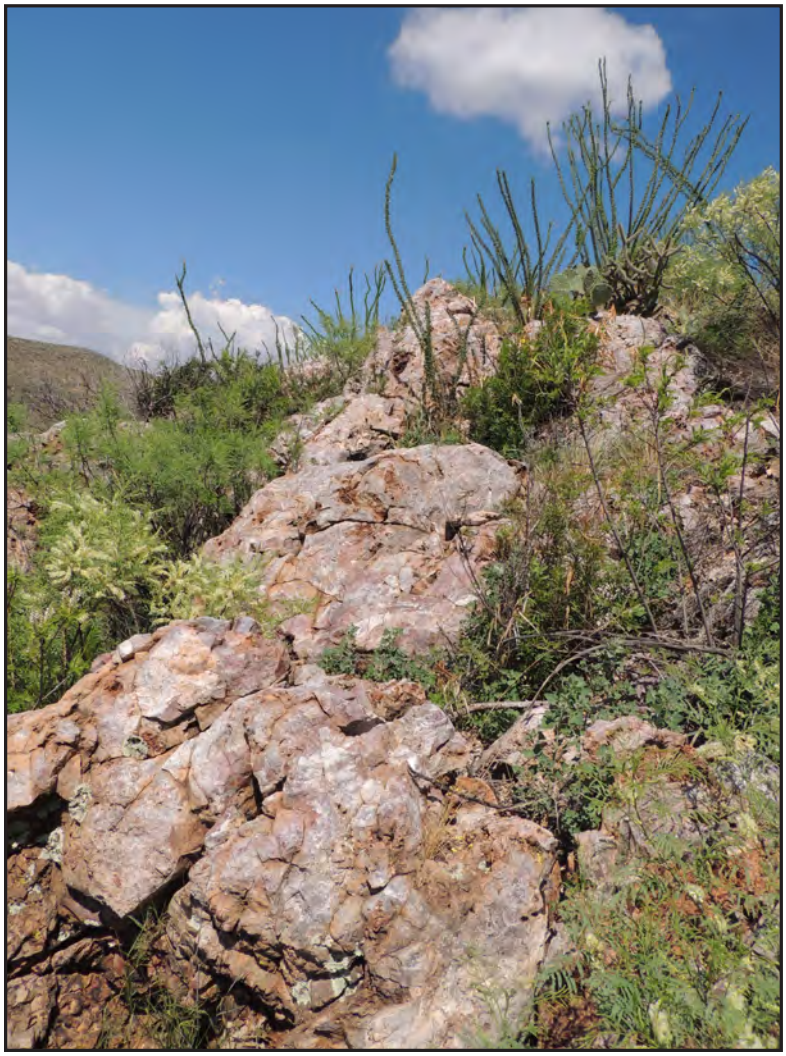
not recorded on the line-point intercept transects (Figure 3-9). The greatest lifeform diversity was found in the field layer, with shrubs narrowly dominating the height class (Figure 3-9).

The average similarity within this substrata was 44.0% (SIMPER). Within-plot species richness of perennial plants (S_{plot}) on rocky, mid-mountain sites was 51.4 ± 3.2, whereas taxonomic distinctness (Δ^+) was 92.9 ± 0.3.

3.3.2 Cover and extent of perennial plant species

Rocky, mid-mountain monitoring sites in substratum 402-A were dominated by two shrubs, mariola and Rio Grande saddlebush (*Mortonia scabrella*), and the grass, slim tridens (*Tridens muticus*) in the field and subcanopy layers (based on cover, extent, and SIMPER results; Table 3-7). Subdominant species included two grasses, southwestern needlegrass (*Achnatherum eminens*) and purple threeawn, the shrub, pungent oak (*Quercus pungens*), and the forb, toothleaf goldeneye. All of the dominant and subdominant species were widespread, occurring on at least six of the seven sites except pungent oak, a large and distinct tree-like shrub, which occurred on five sites.

Common species in this substratum are the grasses, black grama (*Bouteloua eriopoda*; 7 sites) and Hall's panicgrass (*Panicum halii*; 6 sites), the shrubs, ocotillo (6 sites), which dominated the sparse canopy, viscid acacia (4 sites), and whitethorn acacia (5 sites), and the subshrubs, Texas sacahuista (*Nolina texana*; 6 sites) and desert zinnia (7 sites). Of these dominant, subdominant, and common species, Rio Grande saddlebush, southwestern needlegrass, and Texas sacahuista were unique to this substratum in the 402 stratum, though present in stratum 401. Pungent oak was only recorded on substratum 402-A across the entirety of the refuge.



3.3.3 Frequency and extent of uncommon plant species

Sixty-three uncommon plant species were detected on the frequency subplots, but not on transects of 402-A (Table 3-8). Fourteen species, including the fern, fairyswords (*Cheilanthes lindheimeri*), had at least 10% subplot frequency. Four of these species had frequencies of 31% or higher and were detected on at least four of seven plots. Forty-five of the species (70%) were detected on only one plot within this substratum (Table 3-8).

3.3.4 Cover and frequency of exotic species

One non-native grass, Lehmann lovegrass, and one non-native forb, spreading fanpetals, were detected on plots in substratum 402-A (Table 3-3). Lehmann lovegrass had a relatively low foliar cover and occurred on only three of seven transects in this subset. However, it was detected on 6 of the 7

Photo: Characteristic pockets of diversity on the rocky outcrops across the 402-A substratum.

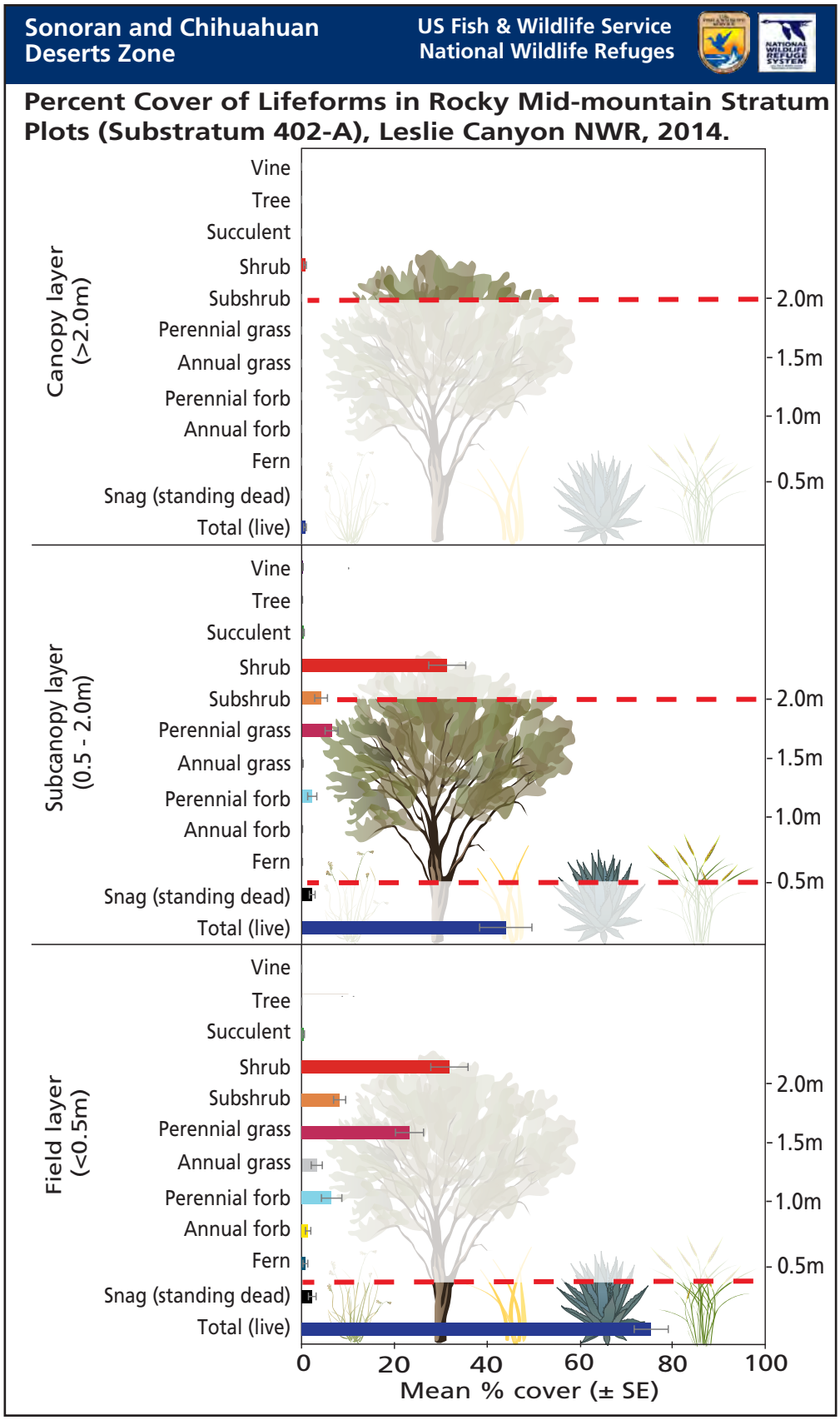


Figure 3-9. Lifeform cover in terrestrial vegetation monitoring plots on mid-mountain (4,501-6,000') sites with rocky soils (Substratum 402- A) at Leslie Canyon NWR, 2014.

Table 3-7. Cover values (%) for perennial and non-native annual species (by lifeform) measured in the field (<0.5m stature), subcanopy (0.5-2.0m), and canopy (>2.0m) layers of mid-mountain (4,501-6,000'), rocky (402-A substratum) terrestrial vegetation and soils plots at Leslie Canyon NWR, 2014. "AVG" = average on transects, "SE" = standard error, "MDC" = minimum detectable change (% cover), "Extent" is the number of plots in which the species was detected (out of 7) on transects or subplots, and "T1" = time one (first sampling year, 2014).

			Field (T1)			Subcanopy (T1)			Canopy (T1)			
Lifeform	**Scientific Name**	**Common Name**	**AVG**	**SE**	**MDC**	**AVG**	**SE**	**MDC**	**AVG**	**SE**	**MDC**	**Extent**
Vine	*Ipomoea pubescens*	silky morning-glory	---	---	---	0.06%	0.06%	5%	---	---	---	3
Succulent	*Opuntia engelmannii*	cactus apple	0.06%	0.06%	5%	---	---	---	---	---	---	1
	Yucca baccata	banana yucca	0.30%	0.18%	5%	0.18%	0.18%	5%	---	---	---	4
Shrub	*Aloysia wrightii*	Wright's beebrush	0.48%	0.32%	5%	0.65%	0.42%	5%	---	---	---	5
	Calliandra eriophylla	fairyduster	0.36%	0.23%	5%	---	---	---	---	---	---	3
	Cercocarpus montanus	alderleaf mountain mahogany	0.06%	0.06%	5%	0.24%	0.18%	5%	---	---	---	3
	Brickellia californicus	California brickellbush	0.06%	0.06%	5%	---	---	---	---	---	---	1
	Condalia correllii	Correll's snakewood	---	---	---	0.12%	0.12%	5%	---	---	---	2
	Ephedra sp.	jointfir	0.06%	0.06%	5%	0.12%	0.12%	5%	---	---	---	1
	Eysenhardtia orthocarpa	Tahitian kidneywood	0.12%	0.12%	5%	0.24%	0.24%	5%	---	---	---	1
	Fouquieria splendens	ocotillo	0.83%	0.35%	5%	2.14%	1.03%	5%	0.30%	0.15%	5%	6
	Mortonia scabrella	Rio Grande saddlebush	4.40%	1.28%	5%	6.73%	2.65%	6%	---	---	---	7
	Parthenium incanum	mariola	9.16%	1.82%	5%	3.81%	1.34%	5%	---	---	---	7
	Quercus pungens	pungent oak	5.60%	2.27%	5%	3.16%	1.07%	5%	0.12%	0.12%	5%	5
	Rhus microphylla	littleleaf sumac	0.95%	0.95%	5%	1.79%	1.79%	5%	---	---	---	5
	Rhus virens	evergreen sumac	0.59%	0.38%	5%	0.65%	0.42%	5%	---	---	---	4
	Vachellia constricta	whitethorn acacia	1.31%	0.98%	5%	2.98%	1.41%	5%	0.18%	0.18%	5%	5
	Vachellia vernicosa	viscid acacia	7.86%	4.37%	10%	8.57%	4.09%	9%	0.12%	0.12%	5%	4
Subshrub	*Ageratina wrightii*	Wright's snakeroot	0.12%	0.12%	5%	---	---	---	---	---	---	3
	Chaetopappa ericoides	rose heath	0.18%	0.18%	5%	---	---	---	---	---	---	2
	Dalea formosa	featherplume	0.36%	0.19%	5%	0.12%	0.12%	5%	---	---	---	7
	Dasylirion wheeleri	common sotol	1.07%	0.60%	5%	0.89%	0.47%	5%	---	---	---	5
	Gymnosperma glutinosum	gumhead	0.36%	0.23%	5%	0.06%	0.06%	5%	---	---	---	4
	Menodora scabra	rough menodora	1.55%	1.21%	5%	0.06%	0.06%	5%	---	---	---	4
	Nolina microcarpa	sacahuista	1.43%	1.43%	5%	1.07%	1.07%	5%	---	---	---	2
	Nolina texana	Texas sacahuista	1.78%	0.86%	5%	1.73%	0.96%	5%	---	---	---	6

Table 3-7 (continued). Cover values (%) for perennial and non-native annual species (by lifeform) measured in the field (<0.5m stature), subcanopy (0.5-2.0m), and canopy (>2.0m) layers of mid-mountain (4,501-6,000'), rocky (402-A substratum) terrestrial vegetation and soils plots at Leslie Canyon NWR, 2014. "AVG" = average on transects, "SE" = standard error, "MDC" = minimum detectable change (% cover), "Extent" is the number of plots in which the species was detected (out of 7) on transects or subplots, and "T1" = time one (first sampling year, 2014).

			Field (T1)			Subcanopy (T1)			Canopy (T1)			
Lifeform	**Scientific Name**	**Common Name**	**AVG**	**SE**	**MDC**	**AVG**	**SE**	**MDC**	**AVG**	**SE**	**MDC**	**Extent**
Subshrub, cont.	*Sphaeralcia laxa*	Caliche globemallow	0.06%	0.06%	5%	------	---	---	---	---	---	5
	Thymophylla pentachaeta	fiveneedle pricklyleaf	0.06%	0.06%	5%	---	---	---	---	---	---	1
	Tiquilia canescens	woody crinklemat	0.06%	0.06%	5%	---	---	---	---	---	---	3
	Zinnia acerosa	desert zinnia	1.13%	0.40%	5%	0.06%	0.06%	5%	---	---	---	7
Grass	*Achnatherum eminens*	southwestern needlegrass	2.92%	0.86%	5%	1.73%	0.63%	5%	---	---	---	7
	Aristida pansa	Wooton's threeawn	0.59%	0.31%	5%	0.06%	0.06%	5%	---	---	---	3
	Aristida purpurea	purple threeawn	3.69%	1.10%	5%	0.48%	0.19%	5%	---	---	---	7
	Aristida ternipes	spidergrass	0.83%	0.77%	5%	---	---	---	---	---	---	4
	Bouteloua curtipendula	sideoats grama	2.32%	0.84%	5%	1.13%	0.41%	5%	---	---	---	7
	Bouteloua eriopoda	black grama	0.89%	0.36%	5%	0.00%	0.00%	5%	---	---	---	7
	Bouteloua hirsuta	hairy grama	0.18%	0.08%	5%	0.06%	0.06%	5%	---	---	---	3
	Dasyochloa pulchella	low woollygrass	0.12%	0.12%	5%	---	---	---	---	---	---	7
	Enneapogon desvauxii	nineawn pappusgrass	0.12%	0.12%	5%	---	---	---	---	---	---	6
	Eragrostis lehmanniana*	***Lehmann lovegrass****	1.19%	0.59%	5%	0.30%	0.18%	5%	---	---	---	6
	Erioneuron avenaceum	shortleaf woollygrass	0.77%	0.28%	5%	---	---	---	---	---	---	6
	Hilaria mutica	tobosagrass	0.12%	0.08%	5%	---	---	---	---	---	---	2
	Leptochloa dubia	green sprangletop	0.36%	0.36%	5%	0.12%	0.12%	5%	---	---	---	3
	Lycurus setosus	bristly wolfstail	0.30%	0.15%	5%	0.12%	0.08%	5%	---	---	---	3
	Muhlenbergia emersleyi	bullgrass	0.12%	0.12%	5%	0.06%	0.06%	5%	---	---	---	3
	Muhlenbergia porteri	bush muhly	0.12%	0.08%	5%	---	---	---	---	---	---	4
	Muhlenbergia rigida	purple muhly	0.66%	0.52%	5%	0.30%	0.24%	5%	---	---	---	4
	Panicum hallii	Hall's panicgrass	0.89%	0.43%	5%	0.06%	0.06%	5%	---	---	---	6
	Setaria leucopila	streambed bristlegrass	0.12%	0.12%	5%	0.12%	0.08%	5%	---	---	---	4
	Sporobolus wrightii	big sacaton	0.24%	0.24%	5%	0.18%	0.18%	5%	---	---	---	1
	Tridens muticus	slim tridens	6.66%	2.14%	5%	1.55%	0.71%	5%	---	---	---	7
Forb	*Abutilon parvulum*	dwarf Indian mallow	0.06%	0.06%	5%	---	---	---	---	---	---	1
	Bahia absinthifolia	hairyseed bahia	0.24%	0.12%	5%	---	---	---	---	---	---	7
	Chamaesaracha sordida	hairy five eyes	0.65%	0.36%	5%	---	---	---	---	---	---	7

* Non-native plants (in bold).

Table 3-7 (continued). Cover values (%) for perennial and non-native annual species (by lifeform) measured in the field (<0.5m stature), subcanopy (0.5-2.0m), and canopy (>2.0m) layers of mid-mountain (4,501-6,000'), rocky (402-A substratum) terrestrial vegetation and soils plots at Leslie Canyon NWR, 2014. "AVG" = average on transects, "SE" = standard error, "MDC" = minimum detectable change (% cover), "Extent" is the number of plots in which the species was detected (out of 7) on transects or subplots, and "T1" = time one (first sampling year, 2014).

			Field (T1)			Subcanopy (T1)			Canopy (T1)			
Lifeform	**Scientific Name**	**Common Name**	**AVG**	**SE**	**MDC**	**AVG**	**SE**	**MDC**	**AVG**	**SE**	**MDC**	**Extent**
Forb, cont.	*Polygala alba*	white milkwort	0.06%	0.06%	5%	----	--	--	--	--	--	2
	Sida abutifolia*	***spreading fanpetals****	0.06%	0.06%	5%	----	----	----	----	----	----	3
	Solanum elaeagnifolium	silverleaf nightshade	0.06%	0.06%	5%	---	---	---	---	---	---	1
	Thelesperma longipes	longstalk greenthread	0.12%	0.12%	5%	---	---	---	---	---	---	2
	Verbesina rothrockii	Rothrock's crownbeard	0.12%	0.08%	5%	---	---	---	---	---	---	4
	Viguiera dentata	toothleaf goldeneye	5.06%	1.91%	5%	2.08%	0.97%	5%	---	---	5%	6
Fern	*Astrolepis cochisensis*	Cochise scaly cloakfern	0.60%	0.53%	5%	---	0.00%	5%	---	---	---	4
	Astrolepis integerrima	hybrid cloakfern	0.18%	0.18%	5%	---	---	---	---	---	---	5
Total Vine	---	---	---	---	---	0.06%	0.06%	5%	---	---	---	---
Total Tree	---	---	---	---	---	---	---	---	---	---	---	---
Total Succulent	---	---	0.36%	0.19%	5%	0.18%	0.18%	5%	---	---	---	---
Total Shrub	---	---	31.84%	4.02%	9%	31.19%	4.00%	9%	0.71%	0.27%	5%	---
Total Subshrub	---	---	8.15%	1.32%	5%	3.99%	1.37%	5%	---	---	---	---
Total Perennial Grass	---	---	23.21%	3.03%	7%	6.26%	1.38%	5%	---	---	---	---
Total Annual Grass	---	---	3.22%	1.19%	5%	0.06%	0.06%	5%	---	---	---	---
Total Perennial Forb	---	---	6.43%	2.20%	5%	2.08%	0.97%	5%	---	---	---	---
Total Annual Forb	---	---	1.37%	0.57%	5%	---	---	---	---	---	---	---
Total Fern	---	---	0.77%	0.53%	5%	---	---	---	---	---	---	---
Total Snag	---	---	2.26%	0.82%	5%	2.08%	0.62%	5%	---	---	---	---
Total Live	---	---	75.35%	3.68%	8%	43.82%**	5.65%	12%**	0.71%	0.27%	5%	---
Total Annuals	---	---	4.58%	1.52%	5%	0.06%	0.06%	5%	---	---	---	---
Total Exotics	---	---	1.25%	0.57%	5%	0.30%	0.18%	5%	---	---	---	---
Total Exotics: Total Live	---	---	1.81%	0.88%	5%	0.62%	0.31%	5%	---	---	---	---
Total Annuals: Total Live	---	---	6.22%	2.32%	5%	0.09%	0.09%	5%	---	---	---	---

* Non-native plants (in bold).

**MDC >10% indicates the species or parameter failed to meet our statistical power criteria (highlighted).

Table 3-8. Within-plot frequency (%), standard error (SE), and extent (out of 7 plots) for uncommon plant species (found only on subplots and not on transects) sampled on rocky, mid-mountain (402-A substratum; 35-90% surface soil rock fragments, 4,501-6,000') monitoring plots in Leslie Canyon NWR, 2014.

Lifeform	Scientific Name	Common Name	Within-plot freq	SE	Extent
Vine	*Maurandya antirrhiniflora*	roving sailor	3%	3%	1
	Rhynchosia senna	Texas snoutbean	3%	3%	1
Tree	*Prosopis velutina*	velvet mesquite	3%	3%	1
Succulent	*Opuntia phaeacantha*	tulip pricklypear	17%	9%	3
	Agave palmeri	Palmer's century plant	14%	4%	5
	Cylindropuntia spinosior	walkingstick cactus	11%	4%	4
	Echinocereus sp.	hedgehog cactus	3%	3%	1
	Mammillaria heyderi	little nipple cactus	3%	3%	1
Shrub	*Flourensia cernua*	American tarwort	6%	4%	2
	Larrea tridentata	creosote bush	6%	4%	2
	Condalia warnockii	Warnock's snakewood	3%	3%	1
	Krameria erecta	littleleaf ratany	3%	3%	1
	Krascheninnikovia lanata	winterfat	3%	3%	1
	Mimosa aculeaticarpa	catclaw mimosa	3%	3%	1
Subshrub	*Croton pottsii*	leatherweed	31%	14%	4
	Thamnosma texana	rue of the mountains	31%	11%	5
	Trichostema arizonicum	Arizona bluecurls	26%	9%	4
	Asclepias macrotis	longhood milkweed	3%	3%	1
	Ayenia filiformis	Trans-Pecos ayenia	3%	3%	1
	Brickellia lemmonii	Lemmon's brickellbush	3%	3%	1
	Calliandra humilis	dwarf stickpea	3%	3%	1
	Gutierrezia microcephala	threadleaf snakeweed	3%	3%	1
	Gutierrezia sarothrae	broom snakeweed	3%	3%	1
	Polygala barbeyana	blue milkwort	3%	3%	1
	Zinnia grandiflora	Rocky Mountain zinnia	3%	3%	1
Grass	*Aristida divaricata*	poverty threeawn	37%	12%	5
	Digitaria cognata	fall witchgrass	9%	9%	1
	Heteropogon contortus	tanglehead	9%	9%	1
	Bothriochloa barbinodis	cane bluestem	6%	4%	2
	Eragrostis intermedia	plains lovegrass	6%	6%	1
	Hesperostipa neomexicana	New Mexico feathergrass	6%	6%	1
	Sporobolus cryptandrus	sand dropseed	6%	4%	2
	Trachypogon spicatus	spiked crinkleawn	6%	6%	1
Forb	*Physaria fendleri*	Fendler's bladderpod	34%	16%	4
	Physaria purpurea	rose bladderpod	29%	14%	3
	Phyllanthus polygonoides	smartweed leaf-flower	20%	11%	4
	Dalea wrightii	Wright's prairie clover	17%	14%	2
	Senna bauhinioides	twinleaf senna	11%	11%	1
	Xanthisma spinulosum	lacy tansyaster	11%	11%	1
	Commelina erecta	whitemouth dayflower	9%	6%	2
	Dalea pogonathera	bearded prairie clover	9%	9%	1
	Hedeoma drummondii	Drummond's false pennyroyal	9%	6%	2

Table 3-8, continued. Within-plot frequency (%), standard error (SE), and extent (out of 7 plots) for uncommon plant species (found only on subplots and not on transects)sampled on rocky, mid-mountain (402-A substratum; 35-90% surface soil rock fragments, 4,501-6,000') monitoring plots in Leslie Canyon NWR, 2014.

Lifeform	Scientific Name	Common Name	Within-plot freq	SE	Extent
Forb, cont.	*Mirabilis comata*	hairy-tuft four o'clock	9%	6%	2
	Tetraclea coulteri	Coulter's wrinklefruit	9%	9%	1
	Echeandia flavescens	Torrey's craglily	6%	6%	1
	Elytraria imbricata	purple scalystem	6%	6%	1
	Froelichia arizonica	Arizona snakecotton	6%	6%	1
	Hedeoma nana	dwarf false pennyroyal	6%	6%	1
	Conoclinium greggii	palmleaf thoroughwort	3%	3%	1
	Dryopetalon runcinatum	rockmustard	3%	3%	1
	Erigeron divergens	spreading fleabane	3%	3%	1
	Jatropha macrorhiza	ragged nettlespurge	3%	3%	1
	Melampodium leucanthum	plains blackfoot	3%	3%	1
	Nicotiana obtusifolia	desert tobacco	3%	3%	1
	Penstemon sp.	beardtongue	3%	3%	1
	Polygala scoparioides	broom milkwort	3%	3%	1
	Verbena neomexicana	hillside vervain	3%	3%	1
Fern	*Cheilanthes lindheimeri*	fairyswords	23%	15%	2
	Argyrochosma limitanea	southwestern false cloak fern	9%	9%	1
	Astrolepis sinuata	wavy scaly cloakfern	3%	3%	1
	Cheilanthes sp.	lipfern	3%	3%	1
	Notholaena neglecta	Maxon's cloak fern	3%	3%	1
	Pellaea wrightiana	Wright's cliffbrake	3%	3%	1

plots when transects and frequency subplots were combined (Figure 3-8). Foliar cover was consistent on the three transects, with an average of 2.8% ± 0.004 SE in the field layer. Across all plots in substratum 402-A, total exotic cover in the field was more variable (1.3% ± 0.6; Table 3-7). Further discussion of exotic species at Leslie Canyon NWR can be found in Section 4.

3.3.5 Soil cover and biological soil crusts

As on non-rocky, mid-mountain sites, soil cover on the rocky sites of substratum 402-A was dominated by gravel (2-76 mm diameter; 49.2%) and fine fuels litter (22.7%; Table 3-9). Similarly, bare soil without overhead cover was also a comparable 1.1%, as was cover by rock and bedrock combined (13.4%). Biological soil crusts were uncommon along the line-point intercept transects on this rocky, mid-mountain substratum. We met or exceeded our expectations for statistical power (to detect a 10% absolute change in foliar cover with 90% power and 10% chance of false change error) for all substrate types except gravel, which has an MDC of 12%.

Within the point-quadrats, mature biological soil crusts (dark cyanobacteria, lichens and bryophytes) occupied 2.3% ± 0.9 of the available habitat. Squamulose and gelatinous lichen growth forms, moss and other undetermined bryophytes were observed.

3.3.6 Soil stability

Surface soil aggregate stability was "moderately stable" (3.6 ± 0.3; see Table 2-2 for stability categories) across the stratum. Samples collected under vegetation canopies (n = 92) had a mean stability rating of 3.7 ± 0.3 (moderately stable), whereas those without overhead canopy cover (n = 19) were more variable, ranging from unstable (1.0 ± 0.0 on plots 402_005 and 402_011; only 1 sample collected on these plots without vegetation cover (n=1)) to very stable (6.0 ± 0.0 on plot 402_004; n=2) with a mean rating of 2.9 ± 0.7 (somewhat unstable).

Table 3-9. Soil surface cover (% by category) for rocky, mid-mountain (402-A; 35%-95% surface soil rock fragments, 4500-6000') monitoring plots on Leslie Canyon NWR, 2014. "AVG" = average, "SE" = standard error, "MDC" = minimum detectable change. Highlighted values failed to meet our statistical power criteria.

Soil cover category (Listed in order of highest to lowest erosion hazard)	AVG	SE	MDC
Bare soil (<2 mm) - no overhead cover	1.13%	0.15%	5%
Bare soil (<2 mm) - under vegetation	6.19%	1.47%	5%
Total bare soil	7.32%	1.49%	5%
Light Cyano - no overhead cover	0.12%	0.12%	5%
Light Cyano - under vegetation	0.60%	0.43%	5%
Total light cyanobacteria	0.71%	0.54%	5%
Leaf litter - needles, leaves, and cones (fine fuels)	22.68%	3.33%	7%
Woody debris <0.062 cm in diameter (1-hour fuel)	1.79%	0.54%	5%
Woody debris 0.62-2.54 cm in diameter (10-hour fuel)	0.24%	0.08%	5%
Woody debris 2.54-7.62 cm in diameter (100-hour fuel)	0.12%	0.08%	5%
Woody debris >7.62 cm in diameter (1000-hour fuel)	0.00%	0.00%	5%
Total leaf litter and woody debris	24.82%	3.50%	5%
Dark Cyano	0.18%	0.18%	5%
Gravel: 2-76 mm	49.23%*	5.55%	12%*
Lichen	0.00%	0.00%	5%
Moss	0.06%	0.06%	5%
Plant Base	4.23%	0.66%	5%
Rock: >76 mm	7.02%	1.92%	5%
Bedrock	6.43%	3.73%	8%

*MDC >10% indicates the category failed to meet our statistical power criteria (highlighted).

3.3.7 Site and soil characterization

All surface soil samples collected on substratum 402-A were loam, sandy loam or sandy clay loam with the majority (5 of 7 plots) being sandy loam. Rock-fragment content (fraction of soil sample >2 mm in diameter by mass) ranged from 39% to 75%, with an average rock-fragment content of 55%. Organic content was an average of 3.0% across the samples, and ranged from 1.0% to 4.1%. Oven dry bulk density ranged from 0.8 to 5.2 g/cm^3. Plots 402_007 and 402_011 had high bulk densities (5.2 and 2.1 g/cm^3 respectively) which indicates compaction in the top 10 cm of soil which could restrict root growth and movement of water and nutrients. Soils were generally neutral with an average pH of 7.9 (an error on the processing of 402_007 prevented its use; n =6). Plot-specific information is provided in Table 3-10.

Signs of erosion were present on five of the seven plots in this stratum, with rills being the dominant type recorded. Plot 402_022 had more rills and gullies than the other plots, although gullies may have been misidentified (see Appendix A and Table 3-10 for details).

3.3.8 Management assessment points

Our results for rocky, mid-mountain substratum 402-A sites in the context of management assessment points (Section 2) indicate only one potential issue for management consideration (Table 3-11). The mean surface soil aggregate stability with no overhead vegetation (2.9% ± 0.7) fell just below the management assessment point threshold of being at or above a Category 3 (somewhat unstable; Table 2-2). While stability scores in this vegetation classification should be monitored for deterioration, it is typical for samples without vegetative cover to have lower stability compared to areas with vegetative cover due to less organic matter and surface roots (Herrick 2005b). Given the dense vegetative cover (see Table 3-7) in the stratum, the amount of soil surface without vegetative cover is relatively low.

Table 3-10. 2014 soil and site characterization for rocky, mid-mountain (402-A substratum) monitoring sites (Elev. 4,501-6,000'), at Leslie Canyon NWR.

Character	Parameter	Plot 402_004	Plot 402_005	Plot 402_007	Plot 402_011	Plot 402_017	Plot 402_020	Plot 402_022
Slope	Average plot slope (%)	10	48	41	16	8	42	43
	Slope position	Toeslope	Summit, Shoulder	Toeslope, Backslope	Shoulder, Summit, Backslope	Toeslope	Toeslope	Shoulder, Backslope
Aspect	Degrees	350	34	176	114[a]	26	318	286
	Description	N	NE	S	E-SE	NE	NW	W
Soil Lab Results	% Sand	72	75	64	66	51	71	42
	% Silt	15	12	25	20	26	18	38
	% Clay	12	13	10	14	22	10	20
	Soil Texture	Sandy loam	Sandy loam	Sandy loam	Sandy Loam	Sandy Clay Loam	Sandy loam	Loam
	Rock Fragments (%)[b]	39	52	75	63	53	49	56
	Oven Dry Soil Bulk Density (g/cm^3)[c]	1.4	0.8	5.2	2.1	1.4	1.3	0.9
	Total Organic Content (%)	2.0	3.0	1.0	3.4	2.3	2.8	4.1
	Electrical Conductivity	175	201	156	202	184	167	208
	pH	8.0	8.0	not avail.	7.7	7.9	8.0	7.8
	Reserve Acidity	0.5	0.4	not avail.	0.2	0.3	0.3	0.2
Erosion Features	Tunneling	none	none	none	none	none	none	none
	Sheet	none	none	6-25%	none	none	none	none
	Rill	none	<5%	<5%	none	<5%	none	6-25%
	Gully	<5%	none	none	none	none	none	6-25%
	Pedestals	none	none	none	none	none	none	none
	Terracettes	none	none	none	none	none	none	none
	Burrowing	none	none	none	none	none	none	none
Landform	Description	Bajada	Mountain	Hill	Hill, Outcrop, Mountain	Drainage, Hill	Hill	Drainage, Mountain

[a]Plot crosses a ridge so aspect is an average across the plots (one transect is south-facing, one transect is on the top of the ridge and the remaining transects are on north-facing slopes).

[b]Rock Fragments (%) = fraction of soil >2mm in diameter by mass

[c]Oven Dry Soil Bulk Density excludes the weight and volume of rock fragments in sample. Rock fragment density assumed to be 2.65 g/cm^3

Mature biological soil crust cover, and exposed bare soil measurements were within the acceptable ranges of their assessment points, indicating less current potential for erosion (Table 3-11).

All indicators for plant community resilience, exotic plant presence and abundance, and fire hazard were below their corresponding assessment points or could not be assessed until a future sampling allows for assessment of trends (Table 3-11).

Table 3-11. Vegetation and soils data for rocky, mid-mountain (402-A substratum) monitoring sites in the context of management assessment points, Leslie Canyon National Wildlife Refuge.

Issue	Management Assessment Point	Mean ± SE	Point met?	Recommendation
Erosion Hazard	Exposed bare ground (with no overhead vegetation) is >20% cover	1.13% ± 0.1	no	Continue monitoring
	Surface soil aggregate stability (with no overhead vegetation) is <Class 3[b]	2.94 ± 0.64[b]	YES	Warning to managers
	Mature Biological Soil Crusts occupy <2% cover of available habitat	2.3% ± 0.9	no	Continue monitoring
Plant Community Resilience	Foliar cover of dead perennial plants is >10% (field)	2.26% ± 0.82	no	Continue monitoring
	Foliar cover of dead perennial plants is >5% (subcanopy)	2.08% ± 0.62	no	Continue monitoring
	Annual plant cover: total plant cover is >1:2 (0.50) (field)	6.22% ± 2.32	no	Continue monitoring
	Native taxonomic diversity decrease >10% over time	n/a	baseline; n/a[a]	Continue monitoring
	Native within-plot species richness decrease of >10% over time	n/a	baseline; n/a[a]	Continue monitoring
Exotic plant presence	The detection of a new species (annual or perennial) on any plot	n/a	baseline; n/a[a]	Continue monitoring
	Increase in Extent of existing exotic species within a stratum	n/a	baseline; n/a[a]	Continue monitoring
Exotic plant abundance	5% change in cover of ERALEH within a plot	n/a	baseline; n/a[a]	Continue monitoring
	Exotic plant cover: total plant cover is >1:20 (0.05) (field)	1.80% ± 0.88	no	Continue monitoring
	Total cover of all exotic plants is >5% (field)	1.25% ± 0.57	no	Continue monitoring
Fire Hazard	Leaf litter and woody debris > 75%	24.8% ± 3.5	no	Continue monitoring

[a]2014 represents the first year of long-term Terrestrial Vegetation and Soils Monitoring, Assessments of relevant MAPs will be completed after future sampling efforts.

[b]Warning to management. Parameter approaches or is at assessment point (in yellow).

3.4 Rocky, mid-mountain stratum (substratum 402-B)

Comprising about 56% of the terrestrial uplands of Leslie Canyon NWR, rocky (35-90% surface soil rock fragments), mid-mountain (4,501-6,000 ft. elevation [1,370-1,830 m]) sites are found in the central and northern portion of the refuge, including the areas adjacent to Leslie Creek (Figure 2.2). This stratum, as defined by soils and elevation, encompasses both substrata 402-A and 402-B of our sample. This stratum is found extensively in mountain ranges and "sky islands" of the American Southwest—including Big Bend, Carlsbad Caverns, Guadalupe Mountains, and Saguaro national parks, Chiricahua and Gila Cliff Dwellings national monuments, Coronado National Memorial, and Fort Bowie National Historic Site. We sampled 14 rocky, mid-mountain monitoring sites at Leslie Canyon NWR in 2014 (7 in each substratum; Figure 3.3).

Permanova and SIMPER analysis of the data revealed that the rocky, mid-mountain stratum supported two distinct vegetation communities (78.5% avg. dissimilarity). Further analysis of soils and landscape characterization did not result in a decisive factor upon which stratum 402 could be post-stratified. Due to the clear distinction between the vegetation communities, they will be discussed throughout the remainder of the report as separate groups within stratum 402 or "substratum" as mentioned in section 3.1. Future sampling and analysis may or may not reveal a reliable factor which could be used for long-term post-stratification.

3.4.1 Vegetation formations, lifeforms, and perennial plant diversity

In contrast to the mid-mountain, rocky sites in substratum 402-A, substratum 402-B is characterized as a Lehmann lovegrass semi-desert grassland. This substratum was dominated by a blend of perennial grasses (22 species), and often accompanied by sparse shrubs.

All major lifeforms were encountered on rocky, mid-mountain sites (substratum 402-B), with more total vegetation cover in field (<0.5 m height) than subcanopy (0.5-2.0 m) layers. Canopy cover (>2.0 m) continues to be largely absent from the terrestrial landscape. Those species that were detected within this height class were all shrubs, though several tree species, velvet mesquite, netleaf hackberry and wingleaf soapberry (*Sapindus saponaria*), were detected infrequently in the field and subcanopy. (Figure 3-10).

The greatest lifeform diversity was found in the field layer, with perennial grasses dominating the height class (49.77% mean cover ± 7.73; Figure 3-10).

The average similarity within this strata was 33.8% (SIMPER). Within-plot species richness of perennial plants (S_{plot}) on rocky, mid-mountain sites subset B was 43.3 ± 4.2 (Figure 3-6), whereas taxonomic distinctness (Δ^+) was 94.7 ± 0.4.

Photo: The grasslands of rocky, mid-mountain substrata 402-B.

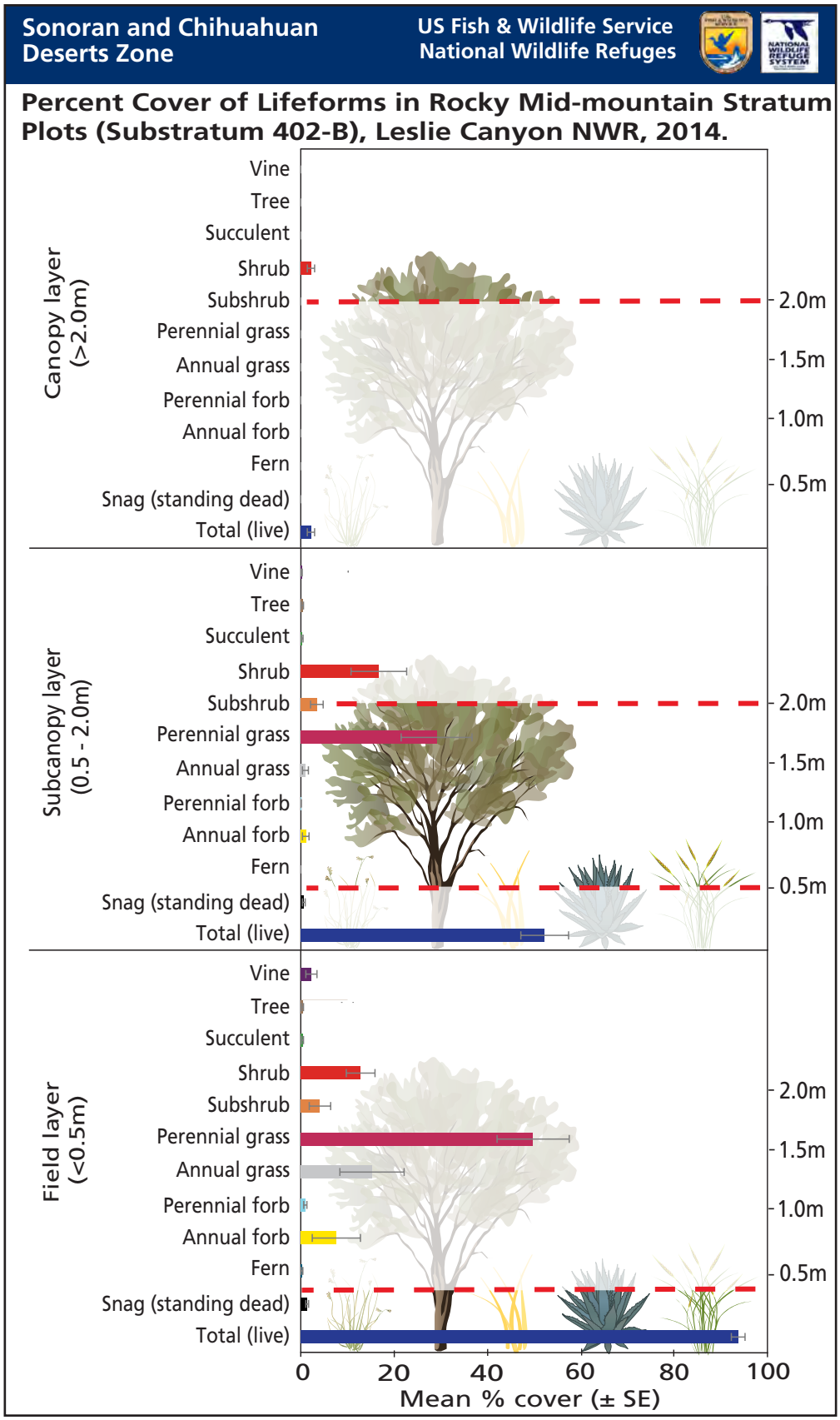


Figure 3-10. Lifeform cover in terrestrial vegetation monitoring plots on mid-mountain (4,501-6,000') sites with rocky soils (substratum 402-B) at Leslie Canyon NWR, 2014.

3.4.2 Cover and extent of perennial plant species

Rocky, mid-mountain monitoring sites in substratum 402-B were dominated by the non-native grass, Lehmann lovegrass (based on cover, extent, and SIMPER results; see Table 3-12 and Section 3.4.4 for mean cover data). The minimum detectable change (MDC) of 10% was exceeded for this grass (MDC = 15%; Table 12). Subdominant species in 402-B included the grass, sideoats grama, the subshrub, common sotol, and the shrub, ocotillo. All of the dominant and subdominant species were widespread, occurring on all seven sites. The grass, slender grama (*Bouteloua repens*), was a dominant species on two plots along with Lehmann lovegrass. Slender grama may have been more widespread prior to the Lehmann lovegrass invasion although it was only found in the 402-B substratum.

Common species in 402-B were the grasses, spidergrass (*Aristida ternipes*; 6 sites) and green sprangletop (*Leptochloa dubia*; 6 sites). Wright's beebrush (6 sites) was a common shrub, however cover was highly variable across plots. The sparse canopies (>2.0 m) of rocky, mid-mountain 402-B monitoring plots consisted of the shrubs, ocotillo, whitethorn acacia, viscid acacia and littleleaf sumac (Table 3-12).

3.4.3 Frequency and extent of uncommon plant species

The 402-B substratum contained seventy-eight uncommon plant species that were detected only on the frequency subplots (Table 3-13). Twenty-four of these species had at least 10% subplot frequency. The subshrub, caliche globemallow (*Sphaeralcea laxa*), was ubiquitous, occurring on all seven plots (100% extent) and had a within-plot frequency of (77% ± 13). Fifty-two of the species (66%) were detected on one plot each within this substratum (Table 3-13). Unique species detections in substratum 402-B include four species of *Evolvulus* (no other *Evolvulus* recorded in stratum 401 or substratum 402-A) and the shrubs, milfoil wattle (*Mariosousa millefolia*), spiny hackberry (*Celtis pallida*) and turpentine bush (*Ericameria laricifolia)*.

3.4.4 Cover and frequency of exotic species

Two non-native lovegrass species, Lehmann lovegrass, and stinkgrass, and one non-native forb, spreading fanpetals, were detected on transects in substratum 402-B. Lehmann lovegrass had a consistent presence, occurring on all of the seven plots sampled. The average foliar cover was 23.1% ± 7.0 in the field layer and 18.8% ± 6.8 in the subcanopy (Table 3-12, Figure 3-8). The other non-natives in substratum 402-B were limited to one plot, and had a low (<1%) foliar cover.

The non-native species, variableleaf bushbean (*Macroptilium gibbosifolium*) and rose Natal grass (*Melinis repens*) were each detected on one frequency subplot. A total of five non-native species were detected across all plots in substratum 402-B during the course of the sampling period (Table 3-3 exotics across all plots). Further discussion of exotic species at Leslie Canyon NWR can be found in Section 4.

3.4.5 Soil cover and biological soil crusts

Across the refuge soil substrate cover was dominated by gravel (2-76 mm diameter). The rocky sites of substratum 402-B were no exception with mean cover of 46.3%; Table 3-14). The plots of this substratum were far rockier than the other strata, with a 26.0% mean cover of rock (>76 mm diameter) and bedrock combined. Bare soil without overhead cover was slightly lower than in substratum 402-A (0.4%), as was cover by plant litter (17.9%). Biological soil crusts were once again uncommon along the transects of the 402-B rocky, mid-mountain sites. We met or exceeded our expectations for statistical power (to detect a 10% absolute change in foliar cover with 90% power and 10% chance of false change error) for all substrate types except gravel and rock, which have an MDC of 15% and 11% respectively (Table 3-14).

Within the point-quadrats, mature biological soil crusts (dark cyanobacteria, lichens and bryophytes) occupied 1.4% ± 0.6 of the available habitat. Gelatinous lichen growth forms, moss and other undetermined bryophytes were observed.

3.4.6 Soil stability

Surface soil aggregate stability was "moderately stable" (3.9 ± 0.6; see Table 2-2 for stability categories) across the stratum (n = 84). No samples could be collected on plot 402_016. Samples collected under vegetation canopies (n = 82; nearly all of the samples) had a mean stability rating of 3.9 ± 0.6 (moderately stable), whereas those without overhead canopy cover (n = 2) were variable, ranging from unstable (1.0 ± 0.0 on plot 402_013; n=1) to moderately stable (4.0 ± 0.0 on plot

Table 3-12. Cover values (%) for perennial and non-native annual species (by lifeform) measured in the field (<0.5m stature), subcanopy (0.5-2.0m), and canopy (>2.0m) layers of mid-mountain (4,501-6,000'), rocky (402-B substratum) terrestrial vegetation and soils plots at Leslie Canyon NWR, 2014. "AVG" = average on transects, "SE" = standard error, "MDC" = minimum detectable change (% cover), "Extent" is the number of plots in which the species was detected (out of 7) on transects or subplots, and "T1" = time one (first sampling year, 2014).

			Field (T1)			Subcanopy (T1)			Canopy (T1)			
Lifeform	**Scientific Name**	**Common Name**	**AVG**	**SE**	**MDC**	**AVG**	**SE**	**MDC**	**AVG**	**SE**	**MDC**	**Extent**
Vine	*Ipomoea pubescens*	silky morning-glory	0.42%	0.42%	5%	---	---	---	---	---	---	1
	Janusia gracilis	slender janusia	0.24%	0.15%	5%	---	---	---	---	---	---	2
	Rhynchosia senna	Texas snoutbean	0.06%	0.06%	5%	---	---	---	---	---	---	2
Tree	*Celtis reticulata*	netleaf hackberry	0.18%	0.18%	5%	0.18%	0.18%	5%	---	---	---	1
	Prosopis velutina	velvet mesquite	0.12%	0.12%	5%	0.18%	0.18%	5%	---	---	---	4
	Sapindus saponaria	wingleaf soapberry	0.06%	0.06%	5%	---	---	---	---	---	---	1
Succulent	*Agave palmeri*	Palmer's century plant	0.18%	0.18%	5%	0.06%	0.06%	5%	---	---	---	4
	Cylindropuntia spinosior	walkingstick cactus	0.12%	0.08%	5%	---	---	---	---	---	---	7
	Opuntia santa-rita	Santa Rita pricklypear	---	---	---	0.18%	0.18%	5%	---	---	---	1
Shrub	*Aloysia wrightii*	Wright's beebrush	2.20%	1.93%	5%	3.39%	2.76%	6%	---	---	---	6
	Calliandra eriophylla	fairyduster	3.33%	1.88%	5%	0.12%	0.12%	5%	---	---	---	3
	Ericameria laricifolia	turpentine bush	1.07%	1.07%	5%	1.01%	1.01%	5%	---	---	---	1
	Eysenhardtia orthocarpa	Tahitian kidneywood	0.65%	0.53%	5%	0.83%	0.77%	5%	---	---	---	4
	Fouquieria splendens	ocotillo	0.12%	0.12%	5%	3.57%	1.40%	5%	1.01%	0.42%	5%	7
	Krameria erecta	littleleaf ratany	0.12%	0.12%	5%	---	---	---	---	---	---	2
	Larrea tridentata	creosote bush	---	---	---	0.24%	0.24%	5%	---	---	---	1
	Mariosousa millefolia	milfoil wattle	0.06%	0.06%	5%	0.65%	0.48%	5%	---	---	---	2
	Mimosa aculeaticarpa	catclaw mimosa	0.12%	0.12%	5%	0.83%	0.83%	5%	---	---	---	1
	Parthenium incanum	mariola	4.11%	2.08%	5%	1.73%	1.00%	5%	---	---	---	5
	Rhus microphylla	littleleaf sumac	0.42%	0.27%	5%	0.83%	0.60%	5%	0.06%	0.06%	5%	5
	Vachellia constricta	whitethorn acacia	0.54%	0.37%	5%	3.27%	2.11%	5%	1.01%	0.67%	5%	4
	Vachellia vernicosa	viscid acacia	0.06%	0.06%	5%	0.24%	0.18%	5%	0.12%	0.12%	5%	3
Subshrub	*Calliandra humilis*	dwarf stickpea	0.24%	0.24%	5%	0.06%	0.06%	5%	---	---	---	3
	Croton pottsii	leatherweed	0.30%	0.18%	5%	---	---	---	---	---	---	5
	Dasylirion wheeleri	common sotol	3.10%	1.51%	5%	3.15%	1.14%	5%	---	---	---	7
	Gutierrezia microcephala	threadleaf snakeweed	0.06%	0.06%	5%	---	---	---	---	---	---	2
	Menodora scabra	rough menodora	0.06%	0.06%	5%	---	---	---	---	---	---	2
	Nolina microcarpa	sacahuista	0.36%	0.36%	5%	0.24%	0.24%	5%	---	---	---	1

Table 3-12, continued. Cover values (%) for perennial and non-native annual species (by lifeform) measured in the field (<0.5m stature), subcanopy (0.5-2.0m), and canopy (>2.0m) layers of mid-mountain (4,501-6,000'), rocky (402-B substratum) terrestrial vegetation and soils plots at Leslie Canyon NWR, 2014. "AVG" = average on transects, "SE" = standard error, "MDC" = minimum detectable change (% cover), "Extent" is the number of plots in which the species was detected (out of 7) on transects or subplots, and "T1" = time one (first sampling year, 2014).

			Field (T1)			Subcanopy (T1)			Canopy (T1)			
Lifeform	**Scientific Name**	**Common Name**	**AVG**	**SE**	**MDC**	**AVG**	**SE**	**MDC**	**AVG**	**SE**	**MDC**	**Extent**
Grass	*Aristida purpurea*	purple threeawn	0.30%	0.18%	5%	0.06%	0.06%	5%	---	---	---	4
	Aristida ternipes	spidergrass	2.32%	1.30%	5%	1.79%	0.91%	5%	---	---	---	6
	Bothriochloa barbinodis	cane bluestem	0.12%	0.08%	5%	0.30%	0.20%	5%	---	---	---	4
	Bouteloua curtipendula	sideoats grama	3.81%	1.57%	5%	4.17%	1.42%	5%	---	---	---	7
	Bouteloua eriopoda	black grama	0.18%	0.18%	5%	---	---	---	---	---	---	3
	Bouteloua repens	slender grama	9.52%**	6.88%	15%**	0.89%	0.58%	5%	---	---	---	2
	Digitaria californica	Arizona cottontop	0.06%	0.06%	5%	0.12%	0.12%	5%	---	---	---	3
	Elionurus barbiculmis	woolyspike balsamscale	0.06%	0.06%	5%	---	---	---	---	---	---	1
	Enneapogon desvauxii	nineawn pappusgrass	0.12%	0.12%	5%	---	---	---	---	---	---	1
	Eragrostis cilianensis*	**stinkgrass***	0.06%	0.06%	5%	0.12%	0.12%	5%	---	---	---	4
	Eragrostis intermedia	Plains lovegrass	---	---	---	0.06%	0.06%	5%	---	---	---	2
	Eragrostis lehmanniana*	**Lehmann lovegrass***	23.10%**	6.97%	15%**	18.75%**	6.81%	15%**	---	---	---	7
	Erioneuron avenaceum	shortleaf woollygrass	0.18%	0.18%	5%	0.06%	0.06%	5%	---	---	---	2
	Heteropogon contortus	tanglehead	0.60%	0.60%	5%	0.65%	0.53%	5%	---	---	---	3
	Leptochloa dubia	green sprangletop	1.73%	1.08%	5%	1.31%	0.45%	5%	---	---	---	6
	Muhlenbergia emersleyi	bullgrass	0.06%	0.06%	5%	0.06%	0.06%	5%	---	---	---	1
	Muhlenbergia porteri	bush muhly	0.54%	0.54%	5%	0.06%	0.06%	5%	---	---	---	2
	Panicum hallii	Hall's panicgrass	0.06%	0.06%	5%	---	---	---	---	---	---	1
	Setaria leucopila	streambed bristlegrass	0.36%	0.29%	5%	---	---	---	---	---	---	2
	Setaria macrostachya	large-spike bristlegrass	0.06%	0.06%	5%	---	---	---	---	---	---	1
	Trachypogon spicatus	spiked crinkleawn	0.06%	0.06%	5%	0.06%	0.06%	5%	---	---	---	1
	Tridens muticus	slim tridens	6.55%**	5.76%	12%**	0.77%	0.71%	5%	---	---	---	2
Forb	*Allionia incarnata*	trailing windmills	0.06%	0.06%	5%	---	---	---	---	---	---	1
	Artemisia ludoviciana	white sagebrush	0.18%	0.18%	5%	0.06%	0.06%	5%	---	---	---	2
	Boerhavia coccinea	scarlet spiderling	0.06%	0.06%	5%	---	---	---	---	---	---	2
	Commelina dianthifolia	birdbill dayflower	0.06%	0.06%	5%	---	---	---	---	---	---	5
	Phemeranthus aurantiacum	orange fameflower	0.06%	0.06%	5%	---	---	---	---	---	---	4

* Non-native plants (in bold).

**MDC >10% indicates the species or parameter failed to meet our statistical power criteria (highlighted).

Table 3-12, continued. Cover values (%) for perennial and non-native annual species (by lifeform) measured in the field (<0.5m stature), subcanopy (0.5-2.0m), and canopy (>2.0m) layers of mid-mountain (4,501-6,000'), rocky (402-B substratum) terrestrial vegetation and soils plots at Leslie Canyon NWR, 2014. "AVG" = average on transects, "SE" = standard error, "MDC" = minimum detectable change (% cover), "Extent" is the number of plots in which the species was detected (out of 7) on transects or subplots, and "T1" = time one (first sampling year, 2014).

			Field (T1)			Subcanopy (T1)			Canopy (T1)			
Lifeform	**Scientific Name**	**Common Name**	**AVG**	**SE**	**MDC**	**AVG**	**SE**	**MDC**	**AVG**	**SE**	**MDC**	**Extent**
Forb, cont.	***Sida abutifolia****	**spreading fanpetals***	0.06%	0.06%	5%	---	---	---	---	---	---	5
	Solanum elaeagnifolium	silverleaf nightshade	0.18%	0.12%	5%	---	---	---	---	---	---	4
	Tetraclea coulteri	Coulter's wrinklefruit	0.12%	0.12%	5%	---	---	---	---	---	---	1
	Tragia nepetifolia	catnip noseburn	0.06%	0.06%	5%	---	---	---	---	---	---	3
	Verbesina rothrockii	Rothrock's crownbeard	0.12%	0.08%	5%	---	---	---	---	---	---	3
Fern	*Astrolepis cochisensis*	Cochise scaly cloakfern	0.12%	0.08%	5%	---	---	---	---	---	---	4
	Astrolepis integerrima	hybrid cloakfern	0.12%	0.12%	5%	---	---	---	---	---	---	2
Total Vine	---	---	2.26%	1.21%	5%	0.18%	0.12%	5%	---	---	---	---
Total Tree	---	---	0.36%	0.19%	5%	0.36%	0.23%	5%	---	---	---	---
Total Succulent	---	---	0.36%	0.19%	5%	0.30%	0.18%	5%	---	---	---	---
Total Shrub	---	---	12.80%	3.06%	7%	16.73%**	5.96%	13%**	2.20%	0.78%	5%	---
Total Subshrub	---	---	4.11%	2.30%	5%	3.45%	1.34%	5%	---	---	---	---
Total Perennial Grass	---	---	49.77%**	7.73%	16%**	29.11%**	7.59%	16%**	---	---	---	---
Total Annual Grass	---	---	15.18%**	6.90%	15%**	1.01%	0.63%	5%	---	---	---	---
Total Perennial Forb	---	---	0.96%	0.34%	5%	0.06%	0.06%	5%	---	---	---	---
Total Annual Forb	---	---	7.62%**	5.16%	11%**	1.07%	0.71%	5%	---	---	---	---
Total Fern	---	---	0.24%	0.18%	5%	---	---	---	---	---	---	---
Total Snag	---	---	1.37%	0.28%	5%	0.66%	0.29%	5%	---	---	---	---
Total Live	---	---	93.65%	1.47%	5%	52.27%**	5.10%	11%**	2.20%	78.00%	5%	---
Total Annuals	---	---	22.80%**	7.02%	15%**	2.08%	0.83%	5%	---	---	---	---
Total Exotics	---	---	23.22%**	6.95%	15%**	18.87%**	6.77%	14%**	---	---	---	---
Total Exotics: Total Live	---	---	24.64%	7.26%	---	32.51%	9.56%	---	---	---	---	---
Total Annuals: Total Live	---	---	24.19%	7.31%	---	3.59%	1.41%	---	---	---	---	---

* Non-native plants (in bold).

**MDC >10% indicates the species or parameter failed to meet our statistical power criteria (highlighted).

Table 3-13. Within-plot frequency (%), standard error (SE), and extent (out of 7 plots) for uncommon plant species (found only on subplots and not on transects) sampled on rocky, mid-mountain (402-B substratum; 35-90% surface soil rock fragments, 4,501-6,000') monitoring plots in Leslie Canyon NWR, 2014.

Lifeform	Scientific Name	Common Name	Within-plot freq	SE	Extent
Vine	*Phaseolus angustissimus*	slimleaf bean	17%	12%	2
	Galactia wrightii	Wright's milkpea	9%	6%	2
	Phaseolus maculatus	spotted bean	9%	9%	1
	Apodanthera undulata	melon loco	3%	3%	1
	Funastrum crispum	wavyleaf twinevine	3%	3%	1
Succulent	*Echinocereus sp.*	hedgehog cactus	14%	7%	3
	Opuntia phaeacantha	tulip pricklypear	14%	14%	1
	Mammillaria heyderi	little nipple cactus	9%	6%	2
	Opuntia engelmannii	cactus apple	9%	6%	2
	Mammillaria sp.	globe cactus	6%	6%	1
	Mammillaria wrightii	Wright's nipple cactus	6%	6%	1
	Yucca baccata	banana yucca	6%	6%	1
	Echinocereus rigidissimus	rainbow hedgehog cactus	3%	3%	1
Shub	*Baccharis pteronioides*	yerba de pasmo	20%	14%	2
	Coleosanthus californicus	California brickellbush	11%	7%	2
	Trixis californica	American threefold	11%	9%	2
	Eriogonum wrightii	bastardsage	6%	6%	1
	Ziziphus obtusifolia	lotebush	6%	6%	1
	Baccharis brachyphylla	shortleaf baccharis	3%	3%	1
	Celtis ehrenbergiana	spiny hackberry	3%	3%	1
	Condalia correllii	Correll's snakewood	3%	3%	1
	Fendlera rupicola	cliff fendlerbush	3%	3%	1
	Hibiscus coulteri	desert rosemallow	3%	3%	1
	Morus microphylla	Texas mulberry	3%	3%	1
Subshrub	*Sphaeralcea laxa*	caliche globemallow	77%	13%	7
	Zinnia acerosa	desert zinnia	31%	14%	4
	Ayenia filiformis	Trans-Pecos ayenia	14%	7%	3
	Dalea formosa	featherplume	11%	7%	2
	Porophyllum gracile	slender poreleaf	9%	9%	1
	Aspicarpa hirtella	chaparral asphead	6%	6%	1
	Brickellia venosa	veiny brickellbush	6%	6%	1
	Thamnosma texana	rue of the mountains	6%	6%	1
	Abutilon abutiloides	shrubby Indian mallow	3%	3%	1
	Thymophylla pentachaeta	fiveneedle pricklyleaf	3%	3%	1
	Zinnia grandiflora	Rocky Mountain zinnia	3%	3%	1
Grass	*Muhlenbergia alopecuroides*	bristly wolfstail	11%	11%	1
	Dasyochloa pulchella	low woollygrass	9%	9%	1
	Digitaria pubiflora	Carolina crabgrass	9%	9%	1
	Bouteloua hirsuta	hairy grama	6%	6%	1
	Cyperus retroflexus	oneflower flatsedge	6%	6%	1
	Bouteloua gracilis	blue grama	3%	3%	1
	Cottea pappophoroides	cotta grass	3%	3%	1

Table 3-13, continued. Within-plot frequency (%), standard error (SE), and extent (out of 7 plots) for uncommon plant species (found only on subplots and not on transects) sampled on rocky, mid-mountain (402-B substratum; 35-90% surface soil rock fragments, 4,501-6,000') monitoring plots in Leslie Canyon NWR, 2014.

Lifeform	Scientific Name	Common Name	Within-plot freq	SE	Extent
Grass, cont.	*Digitaria cognata*	fall witchgrass	3.00%	3%	1
	Melinis repens*	**rose Natal grass***	3.00%	3%	1
Forb	*Dalea wrightii*	Wright's prairie clover	31.00%	14%	4
	Portulaca suffrutescens	shrubby purslane	26.00%	13%	3
	Viguiera dentata	toothleaf goldeneye	26.00%	13%	3
	Acourtia wrightii	brownfoot	23.00%	13%	3
	Bahia absinthifolia	hairyseed bahia	23.00%	9%	4
	Froelichia arizonica	Arizona snakecotton	20.00%	12%	3
	Chamaesaracha sordida	hairy five eyes	17.00%	14%	2
	Evolvulus alsinoides	slender dwarf morning-glory	17.00%	9%	3
	Glandularia sp.	mock vervain	17.00%	14%	2
	Verbena neomexicana	hillside vervain	11.00%	9%	2
	Dalea pogonathera	bearded prairie clover	9.00%	6%	2
	Evolvulus arizonicus	wild dwarf morning-glory	9.00%	9%	1
	Evolvulus nuttallianus	shaggy dwarf morning-glory	9.00%	6%	2
	Evolvulus sericeus	silver dwarf morning-glory	9.00%	9%	1
	Tephrosia tenella	red hoarypea	9.00%	9%	1
	Abutilon parvulum	dwarf Indian mallow	6.00%	6%	1
	Dalea nana	dwarf prairie clover	6.00%	4%	2
	Echeandia flavescens	Torrey's craglily	6.00%	6%	1
	Hesperidanthus linearifolius	slimleaf plainsmustard	6.00%	6%	1
	Berlandiera lyrata	lyreleaf greeneyes	3.00%	3%	1
	Commicarpus scandens	climbing wartclub	3.00%	3%	1
	Dalea albiflora	whiteflower prairie clover	3.00%	3%	1
	Dalea grayi	Gray's prairie clover	3.00%	3%	1
	Elytraria imbricata	purple scalystem	3.00%	3%	1
	Jatropha macrorhiza	ragged nettlespurge	3.00%	3%	1
	Lotus plebeius	New Mexico bird's-foot trefoil	3.00%	3%	1
	Macroptilium gibbosifolium*	**variableleaf bushbean***	3.00%	3%	1
	Stephanomeria pauciflora	brownplume wirelettuce	3.00%	3%	1
	Stephanomeria sp.	wirelettuce	3.00%	3%	1
Fern	*Cheilanthes lindheimeri*	fairyswords	37.00%	17%	4
	Bommeria hispida	copper fern	11.00%	11%	1
	Cheilanthes fendleri	Fendler's lipfern	3.00%	3%	1
	Cheilanthes wrightii	Wright's lipfern	3.00%	3%	1
	Pellaea wrightiana	Wright's cliffbrake	3.00%	3%	1

* Non-native species (in bold).

Table 3-14. Soil surface cover (% by category) for rocky, mid-mountain (402-B substratum; 35%-95% surface soil rock fragments, 4500-6000') monitoring plots on Leslie Canyon NWR, 2014. "AVG" = average, "SE" = standard error, "MDC" = minimum detectable change. Highlighted values failed to meet our statistical power criteria.

Soil cover category (Listed in order of highest to lowest erosion hazard)	AVG	SE	MDC
Bare soil (<2 mm) - no overhead cover	0.36%	0.25%	5%
Bare soil (<2 mm) - under vegetation	3.45%	0.76%	5%
Total bare soil	3.81%	0.78%	5%
Light Cyano - no overhead cover	0.06%	0.06%	5%
Light Cyano - under vegetation	0.48%	0.41%	5%
Total light cyanobacteria	0.54%	0.47%	5%
Leaf litter - needles, leaves, and cones (fine fuels)	14.64%	2.66%	6%
Woody debris <0.062 cm in diameter (1-hour fuel)	2.20%	0.59%	5%
Woody debris 0.62-2.54 cm in diameter (10-hour fuel)	0.72%	0.30%	5%
Woody debris 2.54-7.62 cm in diameter (100-hour fuel)	0.06%	0.06%	5%
Woody debris >7.62 cm in diameter (1000-hour fuel)	0.24%	0.18%	5%
Total leaf litter and woody debris	17.86%	2.91%	5%
Dark Cyano	0.48%	0.41%	5%
Gravel: 2-76 mm	46.25%*	7.10%	15%*
Lichen	0.12%	0.08%	5%
Moss	0.24%	0.10%	5%
Plant Base	4.70%	0.64%	5%
Rock: >76 mm	21.25%*	5.24%	11%*
Bedrock	4.76%	2.22%	8%

*MDC >10% indicates the species failed to meet our statistical power criteria (highlighted).

402_003; n=1). The small sample size and wide variation among the samples collected without overhead canopy cover in this substratum render these results indefinitive.

3.4.7 Site and soil characterization

Surface soil samples could only be collected on three of the seven plots. All surface soil samples collected on stratum 402-B were loam or sandy clay loam with an average rock fragment of 53%. Rock-fragment content (fraction of soil sample >2 mm in diameter by mass) ranged from 48% to 61%. Organic content had an average of 3% across the samples, with a range of 2.0% to 3.5%. Bulk density ranged from 1.0 to 1.5 g/cm^3. Soils were generally neutral with an average pH of 7.2, however one plot had a pH of 5.8 while the other two plots were 7.8 and 8.0. Plot-specific information is provided in Table 3-15.

The majority of the plots did not contain any notable erosion features, though plot 402_003 did exhibit 6-25% cover of both rills and gullies. Gullies seem to be misidentified natural drainages when examining plot photos. These features were representative of natural drainage on the plot as it approached small tributaries of the nearby watershed (see Appendix A).

3.4.8 Management assessment points

Our results for rocky, mid-mountain substratum 402-B sites in the context of management assessment points (Section 2) indicate several issues for management consideration (Table 3-16). The mean surface soil aggregate stability rating with no overhead vegetation cover (2.5% ± 1.5) fell below the management assessment point threshold of being at or above a Category 3 ("Somewhat unstable"; Table 2-2) soils class. However, there were only two samples in this category due to few samples without overhead vegetation and many obstructions (rock or vegetation) that prevented sample collections. So we suggest caution and advise that more data be collected to determine if management action is required.

Table 3-15. 2014 soil and site characterization for rocky, mid-mountain (402-B substratum) monitoring sites (Elev. 4,501-6,000'), at Leslie Canyon NWR.

Character	Parameter	Plot 402_001	Plot 402_003	Plot 402_009	Plot 402_012	Plot 402_013	Plot 402_015	Plot 402_016
Slope	Average plot slope (%)	19	21	29	39	61	31	55
	Slope position	Shoulder	Toeslope, Footslope	Footslope	Backslope	Backslope, Shoulder	Shoulder, Backslope, Summit	Backslope
Aspect	Degrees	210	161	94	264	75	282	306
	Description	SW	S	E	W	E	W	NW
Soil Lab Results	% Sand	--	60	42	58	--	--	--
	% Silt	--	22	33	25	--	--	--
	% Clay	--	18	25	16	--	--	--
	Soil Texture	--	Sandy Loam	Loam	Sandy Loam	--	--	--
	Rock Fragments (%)[a]	--	48	49	61	--	--	--
	Oven Dry Soil Bulk Density (g/cm^3)[b]	--	1.4	1.5	1.0	--	--	--
	Total Organic Content (%)	--	2.1	3.5	2.0	--	--	--
	Electrical Conductivity	--	185	192	41	--	--	--
	pH	--	7.8	8.0	5.8	--	--	--
	Reserve Acidity	--	0.3	0.4	0.8	--	--	--
Erosion Features	Tunneling	none	none	none	none	none	none	none
	Sheet	none	none	none	none	none	none	none
	Rill	none	6-25%	none	none	none	none	none
	Gully	none	6-25%	none	none	none	none	none
	Pedestals	none	none	none	none	none	none	none
	Terracettes	none	none	none	none	none	none	none
	Burrowing	none	none	<5%	none	none	none	none
Landform	Description	Hill	Arroyo, Drainage, Hill	Hill	Hill	Mountain	Hill, Mountain	Mountain

[a]Rock Fragments (%) = fraction of soil >2mm in diameter by mass

[b]Oven Dry Soil Bulk Density excludes the weight and volume of rock fragments in sample. Rock fragment density assumed to be 2.65 g/cm^3

The biological soil crust cover fell below the management assessment point threshold, occupying only 1.4% ± 0.6 of the available habitat (i.e. areas not currently occupied with rock, vegetation or embedded litter). While stability scores and biological soil crust cover in this vegetation classification should be monitored for deterioration, it is typical for soils in areas with dense vegetative and/or rock cover (such as substratum 402-B; Table 3-16) to have lower cover of biological soil crusts and therefore to rely less on biological soil crusts to maintain stability and more on the structural integrity of the geology and the vegetation community. Likewise it is typical for samples without vegetative cover to have lower soil stability compared to areas with vegetative cover due to less organic matter and surface roots. Given the dense vegetative cover in the stratum, the amount of soil surface without vegetative cover is relatively low.

Exposed bare soil (lacking overhead vegetation) measurements were within the acceptable ranges of their assessment points, further indicating less potential for erosion than on less heavily vegetated sites (Table 3-16).

Exotic plant abundance exceeded two of the three thresholds set as management assessment points. Lehmann lovegrass was detected on all seven (100%) of the monitoring sites within substratum 402-B. The

Table 3-16. Vegetation and soils data for rocky, mid-mountain (402-B substratum) monitoring sites in the context of management assessment points, Leslie Canyon National Wildlife Refuge.

Issue	Management Assessment Point	Mean ± SE	Point met?	Recommendation
Erosion Hazard	Exposed bare ground (with no overhead vegetation) is >20% cover	0.36% ± 0.2	no	Continue monitoring
	Surface soil aggregate stability (with no overhead vegetation) is <Class 3[b]	2.5 ± 1.5[b]	YES	Warning to managers
	Mature Biological Soil Crusts occupy <2% cover of available habitat[c]	1.4% ± 0.6[c]	YES	Warning to managers
Plant Community Resilience	Foliar cover of dead perennial plants is >10% (field)	1.37% ± 0.3	no	Continue monitoring
	Foliar cover of dead perennial plants is >5% (subcanopy)	0.66% ± 0.3	no	Continue monitoring
	Annual plant cover: total plant cover is >1:2 (0.50) (field)	24.19% ± 7.31	no	Continue monitoring
	<25% (field) foliar cover of perennial grasses	49.77% ± 7.73	no	Continue monitoring
	Native taxonomic diversity decrease >10% over time	n/a	baseline; n/a[a]	Continue monitoring
	Native within-plot species richness decrease of >10% over time	n/a	baseline; n/a[a]	Continue monitoring
Exotic plant presence	The detection of a new species (annual or perennial) on any plot	n/a	baseline; n/a[a]	Continue monitoring
	Increase in Extent of existing exotic species within a stratum	n/a	baseline; n/a[a]	Continue monitoring
Exotic plant abundance	5% change in cover of ERALEH within a plot	n/a	baseline; n/a[a]	Continue monitoring
	Exotic plant cover: total plant cover is >1:20 (0.05) (field)[c]	24.64% ± 7.26[c]	YES	Meet and discuss
	Total cover of all exotic plants is >5% (field)[c]	23.22% ± 6.95[c]	YES	Meet and discuss
Fire Hazard	Leaf litter and woody debris > 75%	17.9% ± 2.9	no	Continue monitoring

[a]2014 represents the first year of long-term Terrestrial Vegetation and Soils Monitoring, Assessments of relevant MAPs will be completed after future sampling efforts.

[b]Meet and discuss. Parameter exceeds assessment point (in red).

[c]Warning to management. Parameter approaches or is at assessment point (in yellow).

average foliar cover was 23.1% ± 7.0 in the field layer (Table 3-12, Figure 3-9). With Lehmann lovegrass as the major contributor, exotic species had a total cover in the field of 23.2% ± 7.0 and represented 24.6% ± 7.3 of the total vegetation cover recorded on transects. While an increase in the cover and extent of Lehmann lovegrass cannot be measured until future sampling occurs, the dominant presence is a cause for concern as it brings increased fuel loads and fierce competition for limited resources to the areas it occupies (Cox and Ruyle 1986, Anable et al. 1992). In an area currently characterized by a high diversity of perennial grasses (with several species occurring in low quantity; Table 3-12 and Table 3-13), the impact of further invasion by Lehmann lovegrass could be felt as a loss of several species which are in direct competition with this invader. Further species discussion in context of refuge management can be found in Section 4.

All indicators for plant community resilience, exotic plant presence, and fire hazard were below their corresponding assessment points or could not be assessed until a future sampling allows for assessment of trends (Table 3-16).

4. Discussion

4.1 Terrestrial vegetation communities at Leslie Canyon NWR

Terrestrial vegetation communities at Leslie Canyon NWR were comprised of three types based on surface soil rock content and exotic plant encroachment. Non-rocky (<35% surface soil rock fragments) locations were characterized by mariola/creosote bush shrublands (401 stratum; Figure 4-1) occupying about a quarter of the refuge. These sites were typically located along the toeslopes of this steep landscape. More than half of the refuge has rockier surface soils (35-90% rock fragments) - generally on upper slopes and ridges - and contained either mariola/Rio Grande saddlebush/slim tridens shrub savannas (402-A substratum; Figure 4-2) or Lehmann lovegrass dominated (an invasive, non-native

Figure 4-1. Example of the mariola/creosote bush shrublands (401 stratum) found on non-rocky (<35% surface soil rocks) locations within Leslie Canyon NWR, 2014 (USFWS)

Figure 4-2. Example of the mariola/Rio Grande saddlebush/slim tridens shrub savannas (402-A substratum) found on some rocky (35-90% surface soil rocks) locations within Leslie Canyon NWR, 2014. (USFWS)

bunchgrass) semi-desert grasslands (402-B substratum; Figure 4-3). Vegetation and soils data for the three strata/substrata in the context of management assessment points can be seen in Figures 4-4, 4-5, and 4-6. The former occurred along Leslie Canyon Road and extended to the north, whereas the latter was found throughout the central and southern portions of the refuge (Figure 4-7).

4.1.1 Non-rocky (401) vs. rocky sites (402)

As we have observed at many other units in the American Southwest (e.g., Hubbard et al. 2015), surface soil rock content had a strong effect in differentiating major vegetation communities at Leslie Canyon NWR. Greater surface rock content (>35%) on sites free of extensive Lehmann lovegrass (*Eragrostis lehmanniana*) colonization was correlated with the appearance of toothleaf goldeneye (*Viguiera dentata*) and scrub oak (*Quercus pungens*) - characteristic species on intact rocky sites that were absent on Lehmann lovegrass dominated locations (Figure 4-8). Greater rock content on intact sites was also correlated to sharp increases (five to sevenfold) in the shrub, Rio Grande saddlebush (*Mortonia scabrella*) and the native bunchgrass, slim tridens (*Tridens muticus*), and the shrub, viscid acacia (*Vachellia vernicosa*) nearly doubled, whereas the subshrub, rough menodora (*Menodora scabra*) sharply decreased (approximately fivefold; Figure 4-8). Creosote bush (*Larrea tridentata*) - a dominant species on non-rocky sites (401 stratum) - was not present on intact rocky sites (402-A substratum; Figure 4-8).

4.1.2 Intact, rocky (402-A) vs. invaded rocky (402-B) sites

Lehmann lovegrass - an invasive bunchgrass introduced from southern Africa - dominated many rocky sites (402-B substratum; Figure 4-9). This problematic grass exploded to comprise about one quarter of the total cover - by far the dominant species - on these sites relative to intact, rocky sites (approximately 1% cover; 402-A substratum).The native bunchgrass sideoats grama (*Bouteloua curtipendula*) and the shrub common sotol (*Dasylirion wheeleri*) had two to three times the cover on invaded, rocky sites compared to intact, rocky sites, though their overall cover is still relatively low (3-4%; Tables 3-7 and 3-12). The shrubs mariola (*Parthenium incanum*) and Rio Grande saddlebush - dominant species on intact, rocky sites sharply decreased on these invaded sites, and in the case of the latter, even disappeared in Lehmann lovegrass grasslands. Cover of the native bunchgrass slim tridens also ebbed on invaded sites (Tables 3-7 and 3-12).

The high degree of dissimilarity (78.5%) of vegetation composition and abundance between the two groups (402-A and 402-B) on rocky soils suggests a strong differentiation of vegetation based on factors beyond the soils information contained in the Cochise

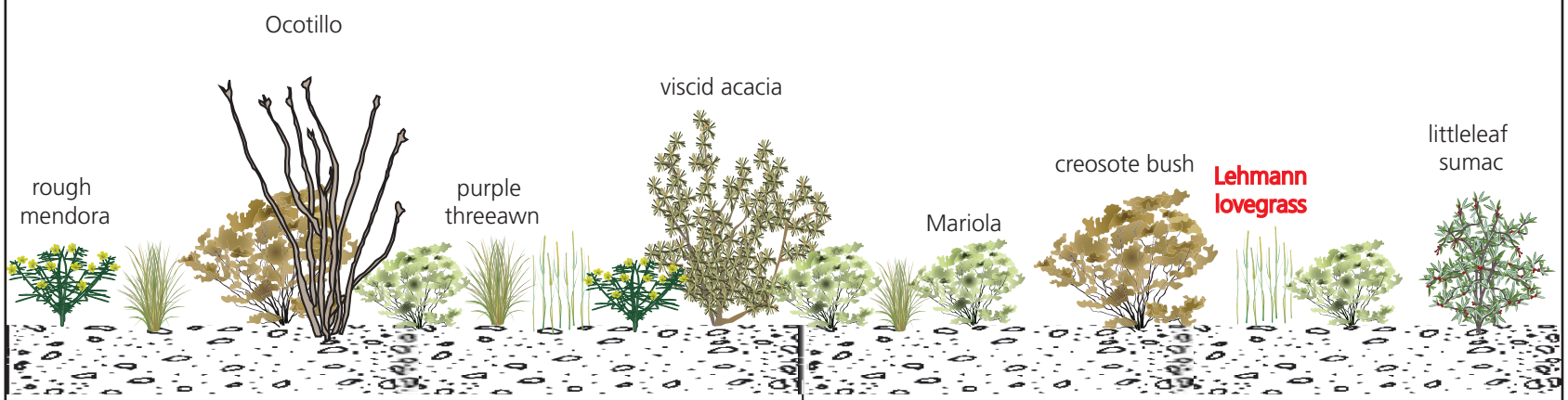
Figure 4-3. Example of the Lehmann lovegrass semi-desert grasslands (402-B substratum) found on some rocky (35-90% surface soil rocks) locations within Leslie canyon NWR, 2014. (USFWS)

Non-Rocky, Mid-Mountain (401)

Mariola/Creosote Bush Shrubland

Average similarity: 38.9%
Perennial species richness: 37.2 ± 2.9
Taxonomic distinctness: 93.8 ± 0.6

* Non- rocky soils (< 35% surface soil rock fragments)
* 22% of Leslie Canyon NWR
* Lowest number of perennial species detected among the three strata/substrata
* Taxonomic distinctness > 402-A and < 402-B



	Point	
Plant Community Resilience	>10%	Dead perennial cover (field): 2.9%±1.0
	>5%	Dead perennial cover (subcanopy): 0.8% ± 0.4
	>1:2	Annual: Total cover (field): 16.2%±5.7
Fire Hazard	>75%	Leaf litter and woody debris: 15.3% ±3.5

	Point	
Erosion Hazard	>20%	Exposed bare ground: 1.5%±0.4
	<class 3	Soil surface stability: 4.2±0.6
	<2%	Biological crust cover: 2.4%±1.1
Exotic Plant Abundance	1:2	Exotic: Total cover: 7.2%± 5.5
	>5%	Exotic total cover (field): 5.8%±4.5

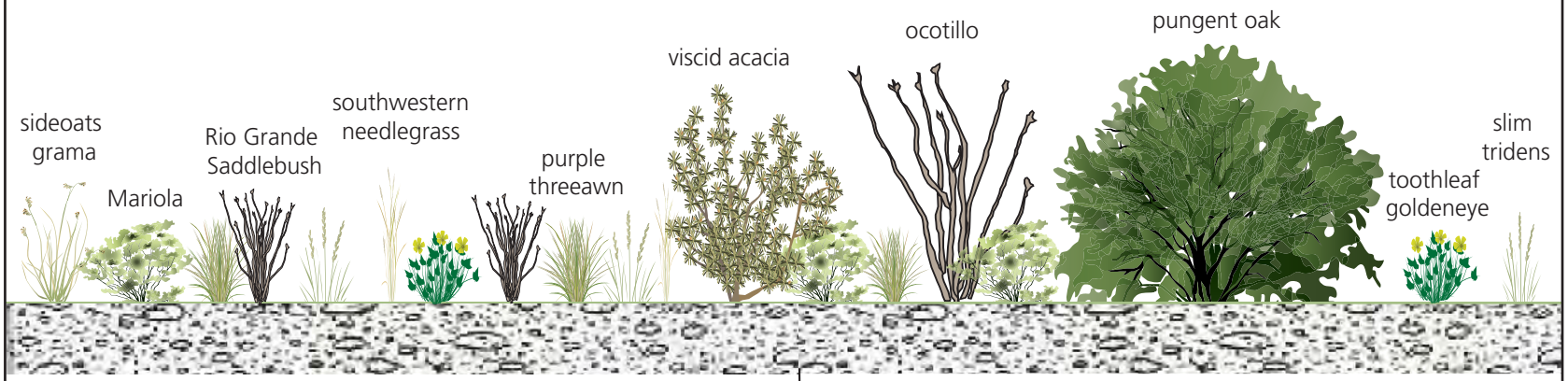
Figure 4-4. Vegetation and soils data for non-rocky, mid-mountain (401 stratum) monitoring sites in the context of management assessment points. Leslie Canyon NWR, 2014.

Rocky Mid-Mountain (402-A)

Mariola/Rio Grande Saddle-bush/Slim Tridens Shrub Savanna

Average similarity: 44.0%
Perennial species: 51.4 ± 3.2
Taxonomic Distinctness: 92.9 ± 0.3

* Rocky soils (35-90% surface soil rock fragments)
* 56% of Leslie Canyon NWR is represented by rocky, mid-mountain strata (includes 402-A and 402-B)
* Greatest number of perennial species detected among the three strata/substrata
* Lowest taxonomic distinctness among the three strata/substrata



	Point	
Plant Community Resilience	>10%	Dead perennial cover (field): 2.3%±0.8
	>5%	Dead perennial cover (subcanopy): 2.1% ± 0.6
	>1:2	Annual: Total cover (field): 6.2% ±2.3
Fire Hazard	>75%	Leaf litter and woody debris: 24.8%±3.5

	Point	
Erosion Hazard	>20%	Exposed bare ground: 1.1%±0.1
	<class 3	Soil surface stability: 2.9±0.7
	<2%	Biological crust cover: 2.3%±0.9
Exotic Plant Abundance	1:2	Exotic: Total cover: 1.8% ± 0.9
	>5%	Exotic total cover (field): 1.3%±0.6

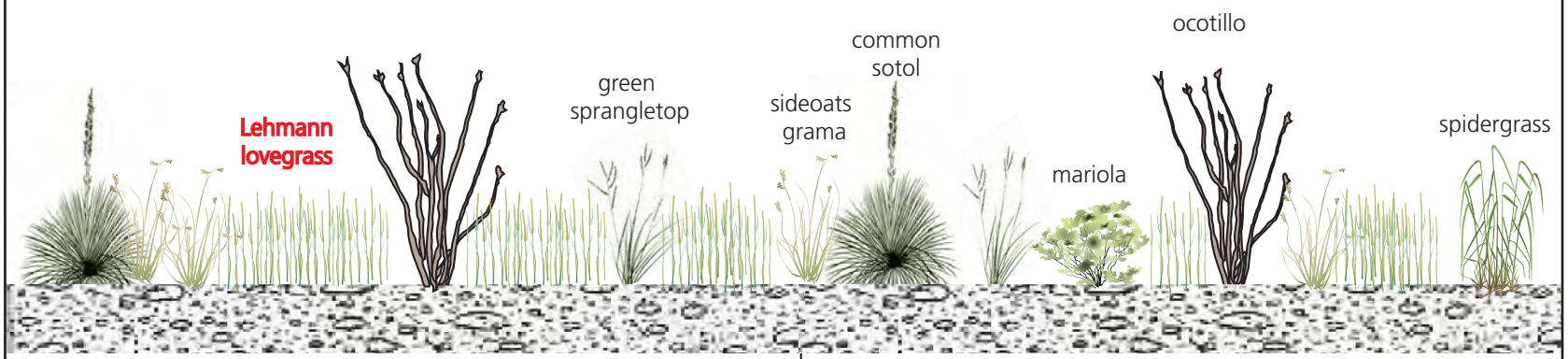
Figure 4-5. Vegetation and soils data for rocky, mid-mountain (402-A substratum) monitoring sites in the context of management assessment points, Leslie Canyon NWR, 2014.

Rocky Mid-Mountain (402-B)

Lehmann Lovegrass Semi-desert Grassland

Average similarity: 33.8%
Perennial species richness: 43.3 ± 4.2
Taxonomic distinctness: 94.7 ± 0.4

* Rocky soils (35-90% surface soil rock fragments)
* 56% of Leslie Canyon NWR is represented by rocky, mid-mountain strata (includes 402-A and 402-B)
* Total perennial species > 401 and < 402-A
* Highest taxonomic distinctness among the three strata/substrata



	Point	
Plant Community Resilience	>10%	Dead perennial cover (field): 1.4% ± 0.3
	>5%	Dead perennial cover (subcanopy): 0.7% ±0.3
	>1:2	Annual: Total cover (field): 24.2% ± 7.3
Fire Hazard	>75%	Leaf litter and woody debris: 17.9% ± 2.9

	Point	
Erosion Hazard	>20%	Exposed bare ground: 0.4% ± 0.2
	<class 3	Soil surface stability: 2.5 ± 1.5
	<2%	Biological crust cover: 1.4% ± 0.6
Exotic Plant Abundance	1:2	Exotic: Total cover: 24.7% ± 7.3
	>5%	Exotic total cover (field): 23.2% ± 7.0

Figure 4-6. Vegetation and soils data for rocky, mid-mountain (402-B substratum) monitoring sites in the context of management assessment points. Leslie Canyon NWR, 2014.

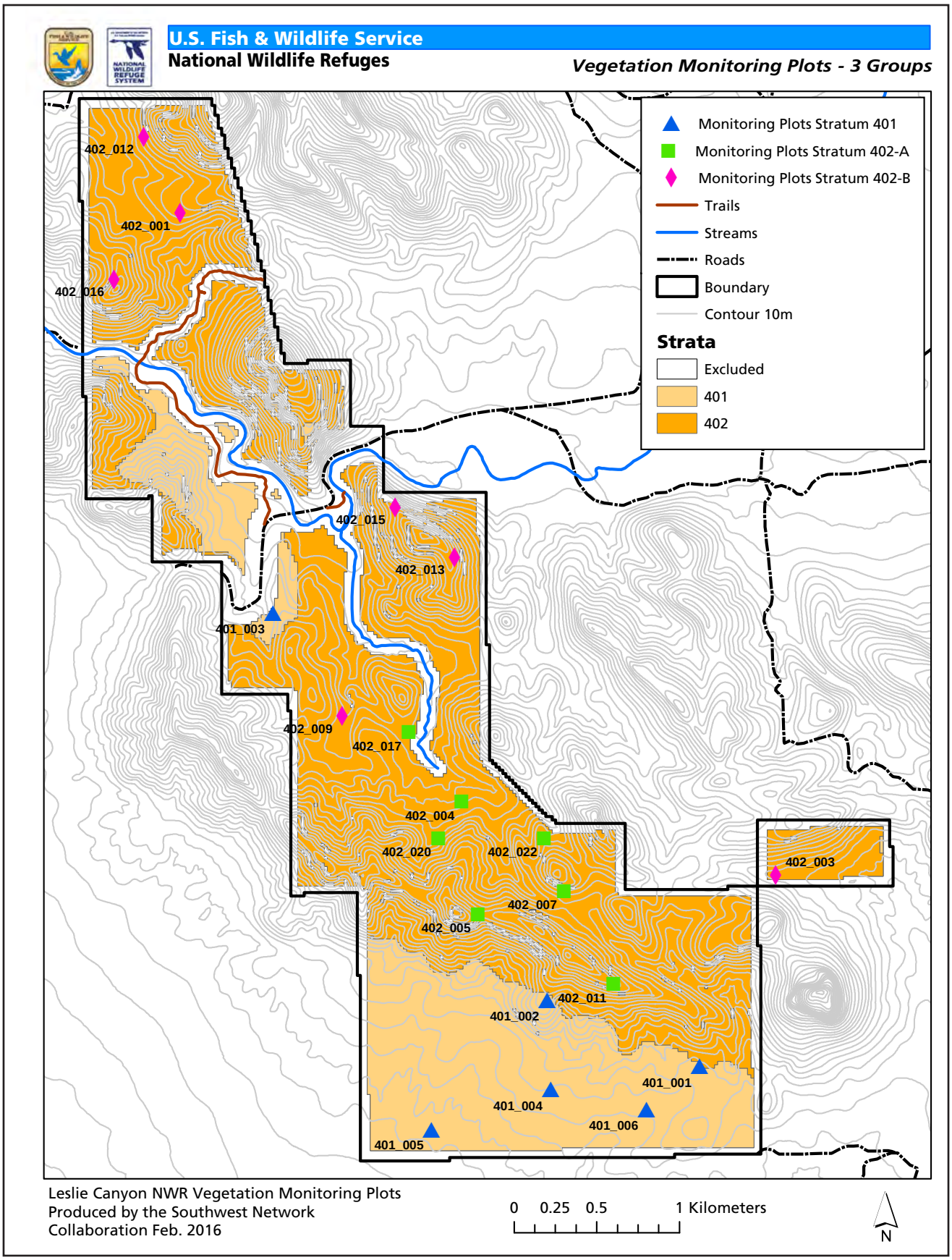


Figure 4-7. Locations of plots in each of the three vegetation types at Leslie Canyon NWR.

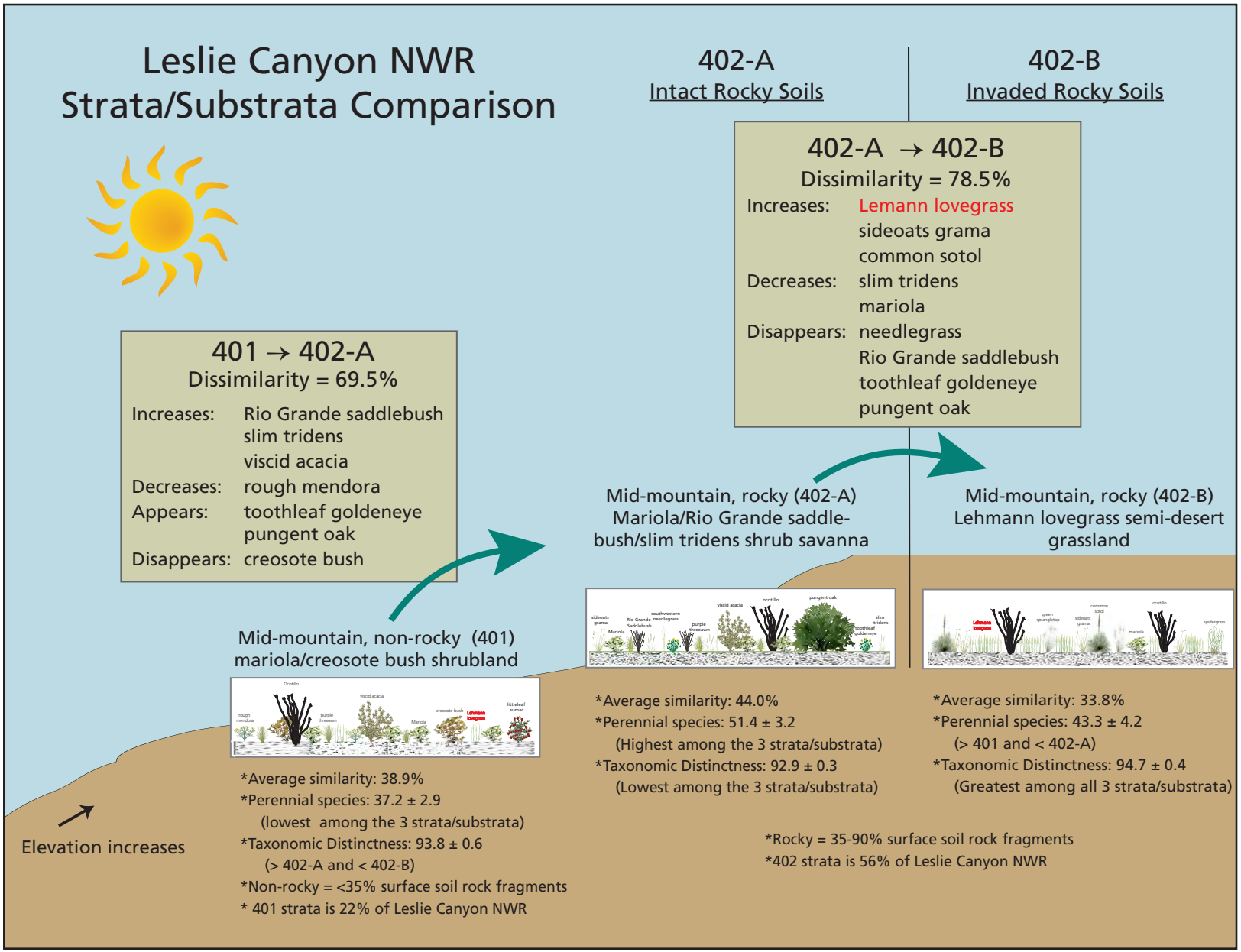


Figure 4-8. Summary of the three primary terrestrial vegetation types at Leslie Canyon NWR, 2014: non-rocky mariola/creosote bush shrubland (401); rocky mariola/Rio Grande saddlebush/slim tridens shrub savanna (402-A); rocky Lehmann lovegrass semi-desert grassland. Details are given in "Results."

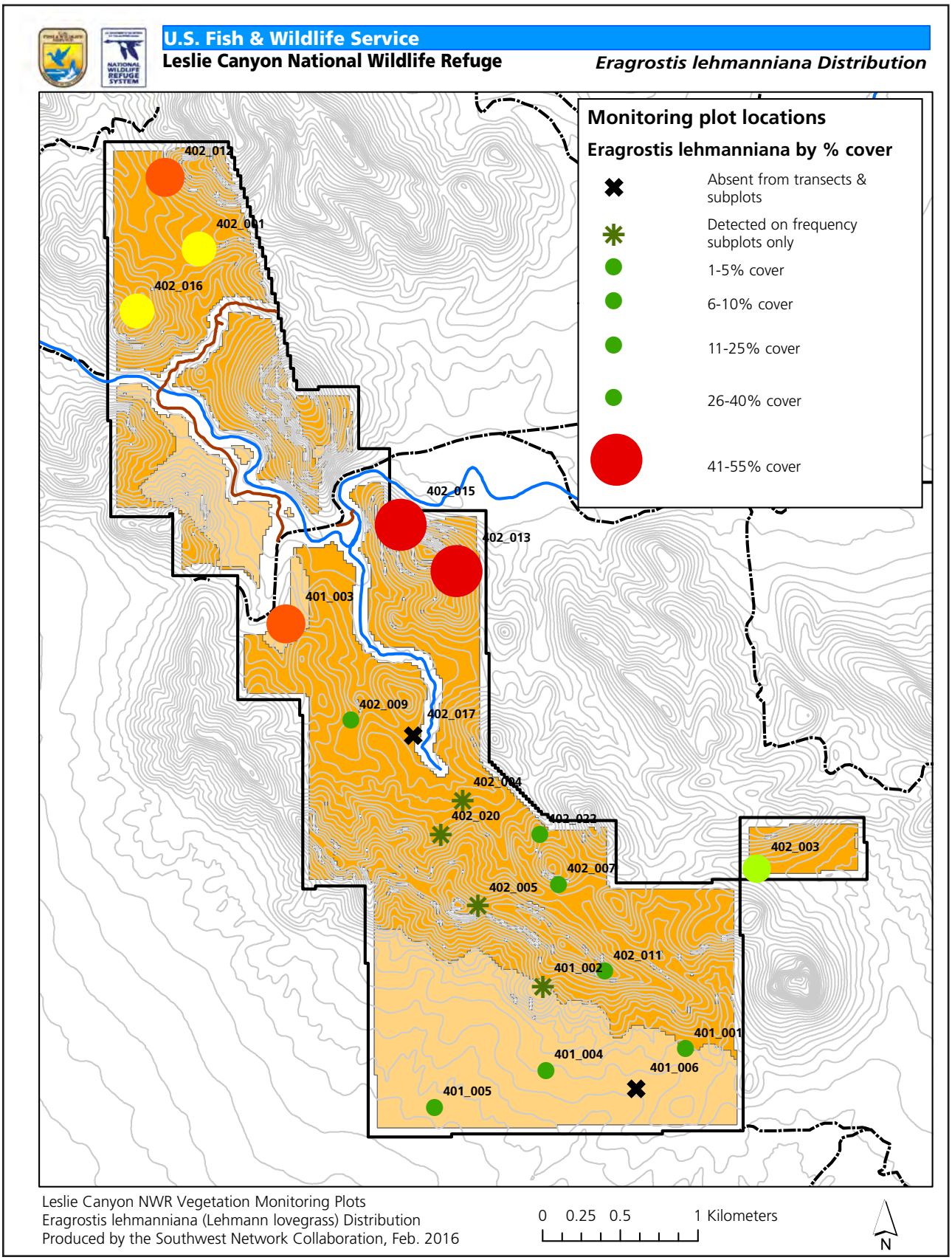


Figure 4-9. Distribution and cover of the non-native grass, Lehmann lovegrass (*Eragrostis lehmanniana*) at Leslie Canyon NWR, 2014.

County soil survey ("clipped" to the small extent of the refuge). What potential factors might be driving this sorting of vegetation on rocky sites? The occurrence and dominance of Lehmann lovegrass appears to play a key role - one that we will explore in the next section.

4.2 Lehmann lovegrass encroachment: soils, land use, or fire?

The most striking differences in terrestrial vegetation at Leslie Canyon NWR appear to be driven by the varying distribution and dominance of the non-native invasive bunchgrass Lehmann lovegrass on rocky sites (Figures 4-9 and 4-10). Northern reaches of the refuge have been extensively colonized, and broadly lack many native species that are dominant or characteristic of uncolonized sites (Figure 4-11). Management assessment points related to exotic plant absolute abundance and cover relative to total plant cover were consistently exceeded on these sites, and to a lesser extent, on non-rocky locations along the toeslopes (Figures 4-4 and 4-6). Lehmann lovegrass colonization can dramatically reduce native plant and animal diversity (Bock et al 1986), and control of this noxious weed is a major focus of vegetation management in the region (McGlone and Huenneke 2004).

Why were some sites much more likely to be colonized by Lehmann lovegrass and to lack key species from intact sites? The Cochise County soil survey - conducted at a broad scale and for different objectives than ecosystem management - does not indicate potential explanatory differences within the rocky mid-mountain types at Leslie Canyon NWR, nor do the results of our local soil core analyses for each plot.

Figure 4-10. Non-native species detected on monitoring plots at Leslie Canyon NWR, 2014. Clockwise from top left- Lehman lovegrass (*Eragrostis lehmanniana*), spreading fanpetals (*Sida abutifolia*), stinkgrass (*Eragrostis cilianensis*), rose Natal grass (*Melinis repens*), variable-leaf bushbean (*Macroptilium gibbosifolium*). (USFWS)

Figure 4-11. Common native perennial plants that were absent on Lehmann lovegrass-dominated sites at Leslie Canyon NWR, 2014. Clockwise from top left: southwestern needlegrass (*Achnatherum eminens*); Rio Grande saddlebush (*Mortonia scabrella*); toothleaf goldeneye (*Viguiera dentata)*; scrub oak (*Quercus pungens*). Slim tridens (*Tridens muticus*) and mariola (*Parthenium incanum*) were also greatly reduced in cover on invaded sites. (USFWS)

If soils are a factor in the Lehmann encroachment, we lack the data to assess the degree of susceptibility.

Lehmann lovegrass (Figure 4-12) tends to be favored over native grasses on sites with a history of intensive livestock grazing or mining (Cox and Ruyle 1986, Anable et al. 1992, McClaran and Anable 1992). Although the land use history of Leslie Canyon NWR is not well understood (Lacrecia Johnson, personal communication), southeastern Arizona sustained a period of overgrazing combined with drought that led to widespread range deterioration in the early 20th century (Bailey 1994). The northern reaches of the refuge may have been particularly subject to livestock

Figure 4-12. Lehmann lovegrass (*Eragrostis lehmanniana*) comprised about 25% cover on invaded sites - the most dominant plant species on these locations. (USFWS)

grazing, and the presence of an abandoned mine near the north boundary suggests additional land use impacts. Lehmann lovegrass was introduced and actively seeded in Arizona for forage production and erosion control starting in the 1930s. We suspect that information on land use history and vegetation condition for the lands that became Leslie Canyon NWR likely exist in local historical records, legal documents, and even the living memory of local ranchers and other residents. Even very anecdotal information might yield important clues as to the causes of Lehmann lovegrass encroachment and potential for spread that might inform and improve management of the refuge.

Although wildfire plays an important role in maintaining intact semi-desert grassland (McPherson 1995), increased fire intensity may yield a competitive advantage to Lehmann lovegrass, which is highly tolerant of wildfire, reestablishing vegetative canopies quickly after burning (Cable, 1965; Pase, 1971; Martin, 1983). Anable and others (1992) suggested a positive feedback loop with fire and encroachment wherein increased Lehmann lovegrass leaf litter production supported more frequent and intense wildfires to the detriment of less tolerant native species, resulting in increasing colonization. The shift in common plant lifeforms from shrubland and shrub savanna towards grassland with increasing Lehmann lovegrass at Leslie Canyon NWR appears to follow this pattern.

Does fire history help explain the current distribution of Lehmann lovegrass in the refuge? As with land use history, little is known of past fire frequency, extent, and intensity at Leslie Canyon NWR. However, Refuge Manager Bill Radke described a lightning fire on the slopes on the eastern portion of the refuge in 1998 that left a "scar that was visible for many years because it inspired wonderful grass growth, [and] so looked different from surrounding hillsides". This slope contains the two plots (402_013 and 015) with the highest Lehmann lovegrass cover in 2014. Developing a fire history to assess the role of fire in Lehmann lovegrass colonization could be combined with a land use history, and would provide insights into the current condition and future potential for spread of this problematic species. Without understanding the root causes of Lehmann lovegrass invasion at Leslie Canyon NWR, developing an effective control strategy will be unlikely.

4.3 Erosion potential: Implications for Leslie Creek

4.3.1 Watershed influences on Leslie Creek

The potential for enhanced soil erosion within the local watershed can have important consequences for both terrestrial vegetation and for the aquatic and riparian ecosystems along Leslie Creek - the management focus and mission of Leslie Canyon NWR. Ecosystem impacts of erosion in upland areas include reduced water holding capacity, disrupted nutrient cycles, and decreased soil organic matter and soil

depth in eroded soils (Pimentel and Kounang 1998).

Sediment and nutrient transport from uplands into Leslie Creek can dramatically increase turbidity and reduce dissolved oxygen, with contingent effects on stream flora, fauna, and hydrologic function (4-13). Suspended sediment intercepts sunlight, increasing shallow water temperatures while reducing light penetration to biota in the benthos. Fine sediment may also clog gills and shift stream substrate habitat drastically, placing many native vertebrates and invertebrates at risk, as illustrated by the groundbreaking work of Ellis (1936) and confirmed repeatedly by later work (see EPA 1992 for a review).

Nutrients - primarily nitrogen (N) and phosphorus (P) - transported to Leslie Creek in sediment can result in nutrient loading and eventual eutrophication of the aquatic ecosystem, with contingent effects on fish, amphibian, invertebrate, and algae communities (NRC 2000). Although nutrient loading is often more acute in watersheds containing agricultural, urban, wastewater treatment, and pastoral uses, even wildland watersheds can produce substantial pulses of N and P to aquatic systems (Preston et al. 2011), particularly after fire (Spencer et al. 2003).

Major erosion events in the watershed can also have direct consequences for hydrologic function in Leslie Canyon via changes in channel morphology and substrate (Rosgen 1996). Gully formation and changes in sediment volume, composition, and location can alter streamflow, aquatic habitat (run/riffle/pool), and depth (Brooks et al. 1991). The powerful influence of upland erosion on hydrologic function, chemistry, morphology, nutrients, and biological processes suggests that managing upland areas is critical to successful management of aquatic resources in Leslie Creek.

4.3.2 Understanding upland erosion potential at Leslie Canyon NWR

As described in Section 1.4.5, the potential for accelerated erosion on a site is a combination of static and dynamic factors (Herrick et al. 2005a). We focus on dynamic factors, such as amount and type of soil cover and soil aggregate stability, that may be influenced by management.

The total amount of soil cover is the single most-important dynamic factor affecting water erosion (Herrick et al. 2005a). Most soil loss occurs in "unprotected" areas; that is, bare soils without vegetative cover (Davenport et al. 1998). Rock, gravel, vegetation, biological soil crusts, and even plant debris (litter and duff) can "armor" the soil (Figure 4-14), slow the flow of water and permit increased infiltration of water into the soil profile (Belnap et al. 2007).

Our data indicate that soils at Leslie Canyon NWR are currently very well armored, with less than 2% of the soil surface consisting of exposed, bare-mineral soil (see Tables 3-4, 3-9, and 3-14). Vegetative cover - the first line of defense against raindrop impact (Figure 4-14) - was relatively high, and biological crust cover was also within our assessment point limits. Both raindrops penetrating the canopies and overland flow would also meet great resistance to soil erosion at the second line of defense, as the majority of soil cover consisted of highly resistant materials such as gravels and rocks - inorganic materials that are impervious to combustion during wildfire and unaffected by prolonged drought.

The third line of resistance to soil erosion is surface soil aggregate stability - an indicator of soil structure and potential for erosion. Surface soil aggregate stability across the refuge was "moderately stable", although a few sites were much less stable, likely due to inherent site soil characteristics (see Section 1.4.5 for details). However, stability on exposed soil – a subset of locations that were not protected by vegetation canopies - varied greatly by stratum, and presents some potential management concerns.

For exposed soils on the less-rocky mariola/creosote bush shrublands (401), soil aggregate stability was "moderately stable" - these sites are currently well protected from enhanced soil erosion. However, we were unable to confidently assess soil aggregate stability on exposed soils of rocky sites (402A, 402B), as relatively high rock content and vegetative cover greatly limited our sampling. Soil aggregate stability of the relatively few samples we were able to collect was low - ranging from "somewhat unstable" to "unstable."

As exposed bare soil is the weakest link in the soil "armor" mitigating erosion on a site (Herrick et al. 2005a, Figure 4-14), we recommend a targeted assessment of soil aggregate stability on rocky sites to provide an accurate assessment of erosion potential for these sites. Such an assessment is most critical for Lehmann lovegrass desert grasslands, where we expect increased fire occurrence and intensity relative

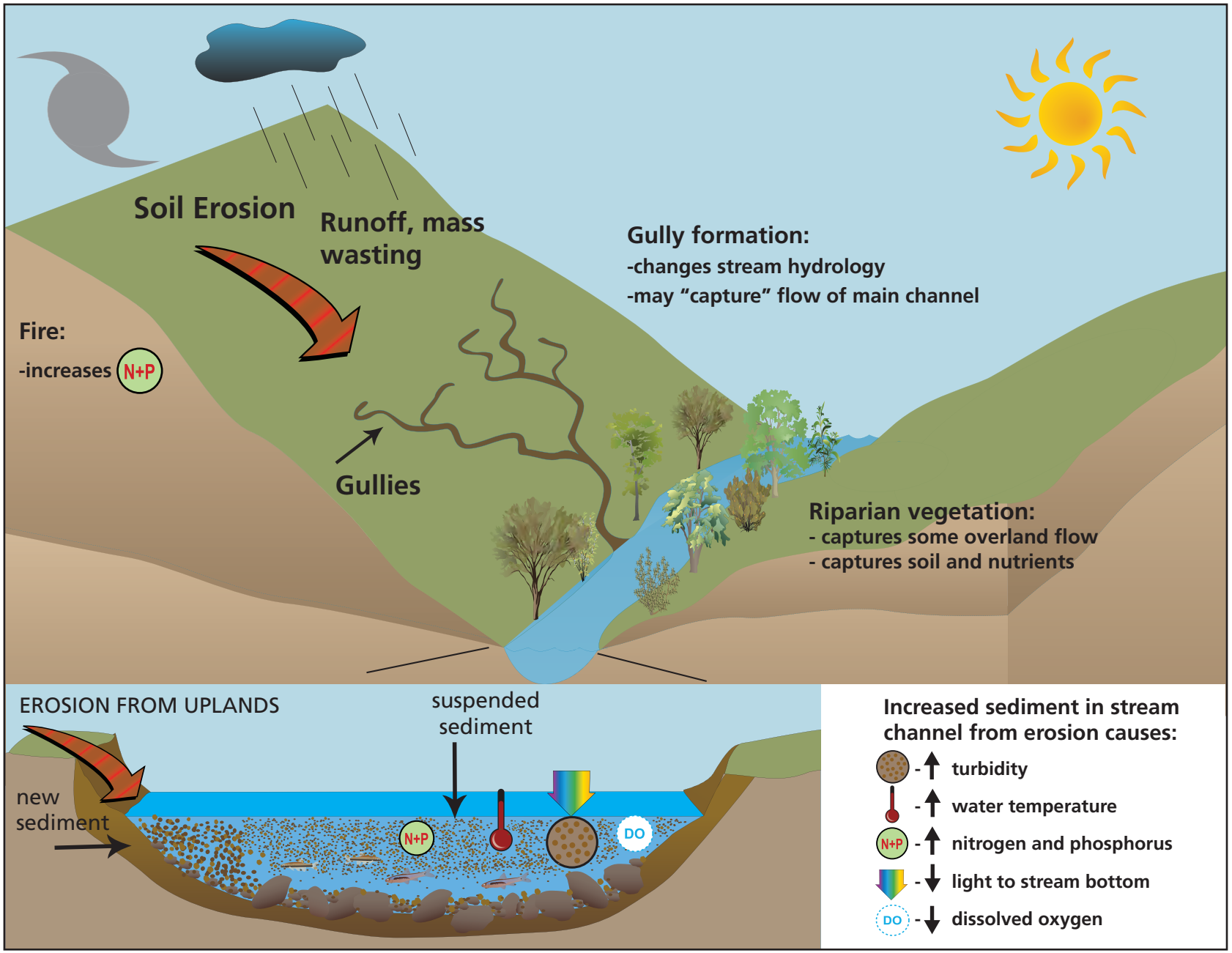


Figure 4-13. Diagram of the effects of soil erosion in uplands areas on riparian and stream systems.

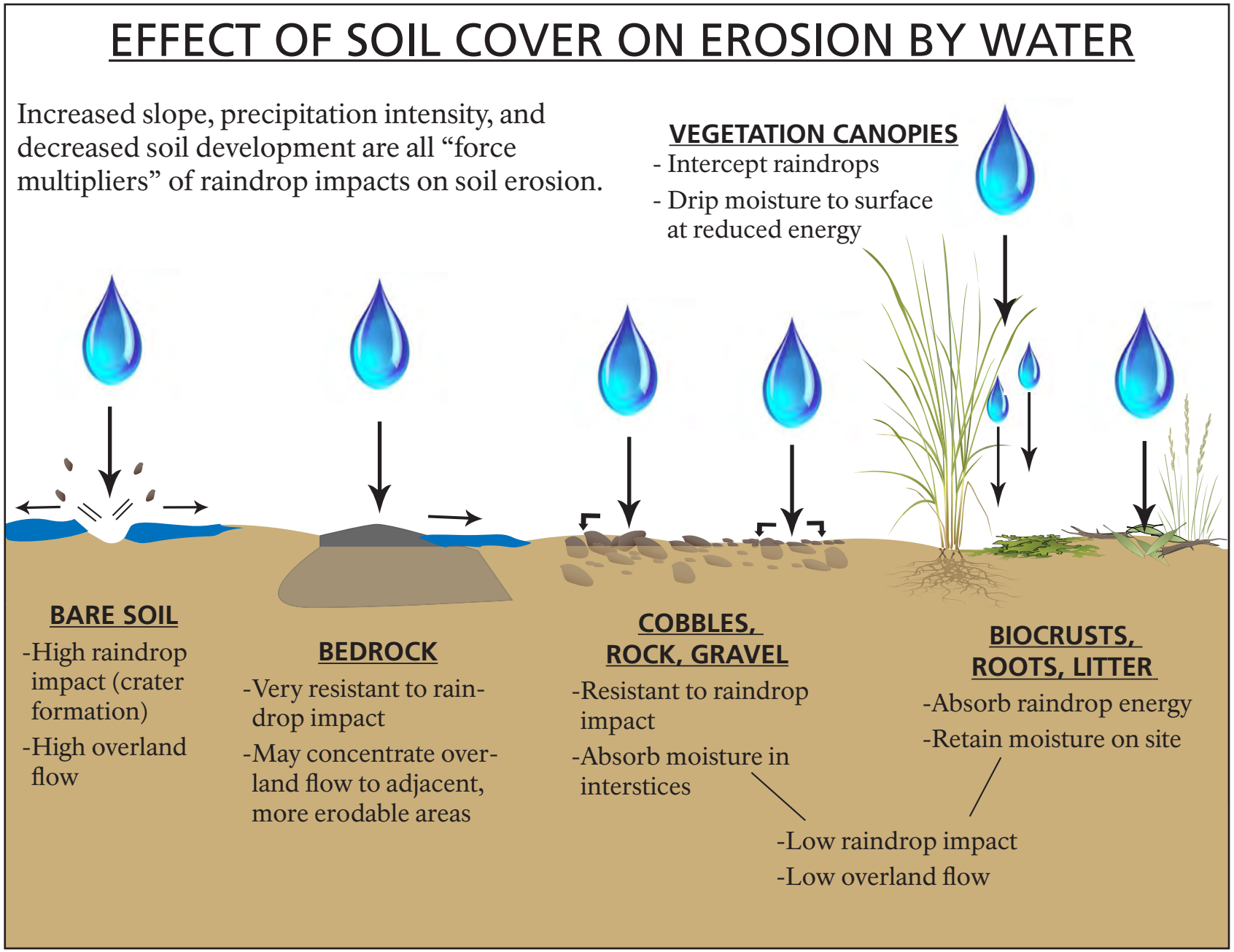


Figure 4-14. Effect of soil cover on erosion by water.

to uninvaded sites, exacerbating post-fire erosion (see section 4.2for a review). Erosion potential on these sites is a particular concern, and mitigating erosion impacts – especially in the proximate watershed areas around Leslie Creek - should be a focus for watershed management at Leslie Canyon NWR.

4.4 Diversity and flora

Although there was little difference in within-plot species richness or taxonomic distinctness for perennial plants between the three strata/substrata, we were surprised at the overall floristic diversity of Leslie Canyon NWR. We detected about 35% of the 509 known species (as determined by a companion flora effort occurring in concert with this sampling) in terrestrial vegetation plots - a surprising number given that we were not sampling riparian areas or identifying annual plants to species (exception: invasive non-native annual species). During the broader flora development, we collected 463 specimens in just 25 field days; 361 of these were newly documented species for the refuge. The rich plant diversity of the refuge is likely the product of the sharp elevation gradient, varied geology (including some key limestone outcrops that support many rare plants; Figure 4-15), and the biogeographic position near the "crossroads" of the Sonoran and Chihuahuan deserts and the Sierra Madre and Rocky Mountains. The sensitivity of this biodiverse flora to Lehmann lovegrass encroachment suggests the strong need for a sustained weed control effort at Leslie Canyon NWR.

Figure 4-15. Examples of the very rare species that occur at Leslie Canyon NWR. Clockwise from top left: Scaled cloak fern (*Notholaena aschenborniana*), Heartleaf morning-glory (*Ipomoea cardiophylla*), Tweedy's milkwort (*Polygala lindheimeri*) and poreleaf dogweed (*Adenophyllum porophyllum*). (USFWS)

4.5 Recommendations for additional research and monitoring

Based on our findings, we recommend five additional research and monitoring efforts:

Compile an administrative history of land use and disturbance at Leslie Canyon NWR

As compared with many protected lands in the American Southwest, Leslie Canyon NWR - established in 1988 - is relatively new. To best ascertain the legacy of past land uses and disturbances, we recommend the development of a short "administrative history" of Leslie Canyon NWR. By locating historic data, public records, area research, and interviewing local residents, a clearer picture of the past conditions and actions within the bounds of what is now the refuge could be compiled. In our experience, such historic data is invaluable to effective resource management, and may address some lingering questions posed by this report and other research projects at the refuge. Good examples of administrative histories include Pinto et al. (2000) and Russell (1992), for Fort Bowie National Historic Site and Montezuma Castle National Monument (respectively).

Repeat the terrestrial vegetation and soils monitoring effort in 2019

The 2014 effort described in this report provides a baseline of upland conditions, and also revealed a surprisingly high floristic biodiversity at Leslie Canyon NWR. Based on work throughout the region, we expect these vegetation communities and soil function parameters to interact strongly with climate change and disturbance factors in a dynamic fashion. To maximize the value of this effort and promote an "early warning" approach to mitigating potential resource issues at Leslie Canyon NWR, we recommend repeating this effort on 5-year intervals, with the second round of sampling to occur in 2019.

Continue the work began by the 2014 Flora Project effort

While the work carried out under the 2014 Flora Project and the 2014 terrestrial vegetation and soils monitoring effort at Leslie Canyon NWR made great leaps in documenting the floristic diversity of the refuge, there may be substantially more rare and sensitive species to be discovered. Botanist Frankie Coburn, who spearheaded the field effort in 2014, estimates that there are likely at least 50% more species, or another 200 - 300 species, still undocumented on the refuge (F. Coburn, personal communication). Data collected using the terrestrial vegetation and soils monitoring protocol are not meant to detect changes in rare species, and do not target native annuals or species found in riparian corridors. Given the surprisingly rich and diverse flora determined by the initial effort, a complementary approach such as the inventory work of the Flora Project is appropriate to capture baseline information, and to target specific species of interest (i.e. sensitive species, non-native species) for land managers.

Conduct a site-specific soil inventory coupled with erosion modelling

Local soil conditions provide the foundation for terrestrial ecosystems at Leslie Canyon NWR, yet they are poorly understood. The Cochise County survey is mapped at a scale that is inappropriate for the relatively small size of the refuge, and the county survey focuses on agricultural and engineering applications rather than the ecosystem management mandate of Leslie Canyon NWR. When coupled with an existing erosion model (e.g., Watershed Erosion Prediction Project, Rangeland Hydrology and Erosion Model), and the vegetation and dynamic soil function information collected in the current effort, a soil inventory could provide a very powerful tool for assessing potential ecosystem degradation of Leslie Creek and the surrounding watershed.

Consider a habitat monitoring approach to Leslie Creek

A habitat monitoring approach that integrates hydrology, channel morphology and riparian vegetation would provide an early warning indicator of potential change in Leslie Creek that would complement existing monitoring of focal fish species. Adoption of a cost-effective, existing "Integrated Streams" protocol (such as the ongoing effort at eight nearby national parks) or development of a site specific protocol would greatly enhance ecological knowledge on the condition of the aquatic and riparian species that are the focus of management at Leslie Canyon NWR.

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

Although Lehmann lovegrass encroachment is (depressingly) not uncommon in southeastern Arizona, with a few sites (such as at Coronado

National Memorial) containing near monocultures, the dominance of this invasive bunchgrass on rocky sites within the northern reaches of Leslie Canyon NWR is outside the range of natural variability for intact systems. By contrast, vegetation composition and total cover are well within natural limits on rock sites in the southern half of the refuge, and on most non-rocky sites throughout the refuge. Dynamic soil functional characteristics are likely well within the range of natural variability throughout Leslie Canyon NWR, though the lack of a soil survey limits our assessment.

5. Literature Cited

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

Anable, M.E., McClaran, M.P., Ruyle, G.B. 1992. Spread of introduced Lehmann lovegrass *Eragrostis lehmanniana* (Nees) in Southern Arizona, USA. Biological Conservation 6: 181-188.

Bailey, L. R. 1994. "We'll all wear silk hats": The Erie and Chiricahua cattle companies and rise of corporate ranching in the Sulphur Springs Valley of Arizona, 1883-1909. Tucson, Arizona: Western Lore Press.

Belnap, J. 2003a. The world at your feet: desert biological soil crusts. Frontiers in Ecology and the Environment 1:181-189.

Belnap, J. 2003b. Factors influencing nitrogen fixation and nitrogen release in biological soil crusts. Pages 241–261 *in* J. Belnap and O. L. Lange, eds., Biological soil crusts: Structure, function, and management. Ecological Studies Series 150, second edition. Berlin, Germany.

Belnap, J., B. Büdel, and O. L. Lange. 2003. Biological soil crusts: Characteristics and distribution. Pages 3–30 *in* J. Belnap and O. L. Lange, eds., Biological soil crusts: Structure, function, and management. Ecological Studies Series 150, second edition. Berlin, Germany.

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

Belnap, J., J. H. Kaltenecker, R. Rosentreter, J. Williams, S. Leonard, and D. Eldridge. 2001. Biological soil crusts: Ecology and management. BLM Technical Reference 1730-2. Bureau of Land Management, Denver, Colorado.

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

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

Blake, G. R., and K. H. Hartge. 1986. Excavation method. Pages 367–371 *in* Klute, E. A., ed., Methods of soil analysis, Part 1: Physical and mineralogical methods. Soils Science Society of America Book Series 5. American Society of Agronomy, Agronomy Monographs 9(1), Madison, Wisconsin.

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

Bock, C. E., Bock, J. H., Jepson, K. L., Ortega, J. C., 1986. Ecological effects of planting African lovegrasses in Arizona. National Geographic Research 2:456–463.

Broska, J. 2009. Water resources of the Leslie Canyon National Wildlife Refuge. US Fish & Wildlife Service, Albuquerque, New Mexico.

Brown, D. E., F. Reinchenbacher, and S. E. Franson. 1994. A classification system and map of the biotic communities of North America.

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

Cable, D. R. 1965. Damage to mesquite, Lehmann lovegrass, and black grama by a hot June fire. J. Range Manage. 18:326-329.

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

Cox, J., and G. B. Ruyle. 1986. Influence of climatic and edaphic factors on the distribution of *Eragrostis lehmanniana* (Nees) in Arizona, USA.

Journal of the Grassland Society of Southern Africa, 3(1):25-29.

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

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

Deeming, J. E., R. E. Burgan, and J. D. Cohen. 1977. The national fire danger rating system - 1978. General Technical Report INT-39. Intermountain Forest and Range Experiment Station. USDA, Forest Service, Ogden, Utah.

Eldridge, D. J., and R. Rosentreter. 1999. Morphological groups: A framework for monitoring microphytic crusts in arid landscapes. Journal of Arid Environments 41:11–25.

Ellis, M.M. 1936. Erosion silt as a factor in aquatic environments. Ecology 17:29-42.

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

Environmental Protection Agency (EPA). 1992. Sediment classification methods compendium. EPA-823-R-92-006.

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

Herrick, J. E., J. W. Van Zee, K. M. Havstad, L. M. Burkett, and W. G. Whitford. 2005b. Monitoring manual for grassland, shrubland, and savanna Ecosystems. Volume II: design, supplementary methods, and interpretation. Tucson, Arizona: University of Arizona Press.

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

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

Izsak, J., and L. Papp. 2000. A link between ecological diversity indices and measures of biodiversity. Ecol. Model 130:151 – 156.

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

Lange, O. L. 2003. Photosynthesis of soil-crust biota as dependent on environmental factors. Pages 271–240 *in* J. Belnap and O. L. Lange, eds., Biological soil crusts: Structure, function, and management. Ecological Studies Series 150, second edition. Berlin, Germany.

Martin, S. C. 1983. Responses of semi-arid grasses and shrubs to fall burning. J. Range Manage. 36:604-610.

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

McClaren, M. P. and M. E. Anable. 1992. Spread of introduced Lehmann lovegrass along a grazing intensity gradient. Journal of Applied Ecology 29:92–98.

McGlone, C. M., and L. F. Huenneke. 2004. The impact of a prescribed burn on introduced Lehmann lovegrass versus native vegetation in the northern Chihuahuan Desert. Journal of Arid Environments 57:297–310.

McPherson, G. R. 1995. The role of fire in the desert grasslands. Pages 131-151 *in* M. P. McClaran and R. R. Van Devender, eds. The desert grassland. Tucson: University of Arizona Press.

Muckel, G.B. ed. 2004. Understanding soil risks and hazards - Using soil survey to identify areas with risks and hazards to human life and property. United States Department of Agriculture, Natural Resources Conservation Service, National Soil Survey Center, Lincoln, Nebraska.

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

National Research Council (NRC). 2000. Clean coastal waters: Understanding and reducing the effects of nutrient pollution. Washington, D.C.: National Academy Press.

Pase, C. P. 1971. Effects of February burn on Lehmann lovegrass. J. Range Manage. 24:454-456.

Pimentel, D., and N. Kounang. 1998. Ecology of soil erosion. Ecosystems 1:416-426.

Pinto, R., I. Herring, and P. A. Kirk. 2000. Fort Bowie National Historic Site cultural landscapes inventory. Prepared for National Park Service Cultural Landscapes Program, Intermountain Region, Santa Fe, N.M.

Preston, S. D., R. B. Alexander, G. B. Schwarz, and C. G. Crawford. 2011. Factors affecting stream nutrient loads: A synthesis of regional SPARROW model results for the continental United States. Journal of the American Water Resources Association, Paper No. JAWRA-10-0178-P.

Radke, W. R. 2014. Annual Narrative San Bernardino and Leslie Canyon National Wildlife Refuges. US Fish & Wildlife Service, Douglas, Arizona.

Rosgen, D. L. 1996. Applied river morphology, 2nd edition. Printed Media Companies, Minneapolis, Minnesota: Printed Media Companies.

Russell, P. 1992. Montezuma Castle National Monument: An administrative history. NPS Southwest Cultural Resources Center, Professional Papers No. 46. National Park Service, Santa Fe, New Mexico. Available at http://www.nps.gov/archive/gicl/adhi/adhit.htm.

Shinneman, D. J., and W. L. Baker. 2009. Environmental and climatic variables as potential drivers of post-fire cover of cheatgrass (*Bromus tectorum*) in seeded and unseeded semi-arid ecosystems. International Journal of Wildland Fire. V: 18, 191-202.

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

Spencer, C. N., K. O. Gabel, and F. R. Hauer. 2003. Wildfire effects on stream food webs and nutrient dynamics in Glacier National Park, USA. Forest Ecology and Management 178:141–153.

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

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

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

The Nature Conservancy (TNC). 1999. Ecoregional conservation analysis of the Arizona - New Mexico mountains. The Nature Conservancy, Santa Fe, NM.

Ugland, K. I., G. S. Gray, and K. E. Ellingsen. 2003. The species accumulation curve and estimation of species richness. J. Anim. Ecol. 72:888-897.

U.S. Department of Agriculture (USDA) Natural Resource Conservation Service. 2002. Soil survey of Cochise County, Arizona: Douglas-Tombstone part. Phoenix, Arizona.

U. S. Fish & Wildlife Service (USFWS). 1994. Yaqui fishes recovery plan. U.S. Fish and Wildlife Service, Region 2, Albuquerque, New Mexico.

U.S. Fish & Wildlife Service (USFWS). 1995. San Bernardino and Leslie Canyon National Wildlife Refuges comprehensive management plan:

1995-2015. U.S. Fish & Wildlife Service, Region 2, Albuquerque, New Mexico.

U.S. Fish & Wildlife Service (USFWS). 2016. Plants of Leslie Canyon and San Bernardino National Wildlife Refuges. U.S. Fish and Wildlife Service, Region 2, Sonoran and Chihuahuan Deserts Zone, Tucson, Arizona.

Van Auken, O. W. 2000. Shrub invasions of North American semiarid grasslands. Annu. Rev. Ecol. Syst. 31:197-215.

Warwick, R. M., Clarke, K. R., 1995. New 'biodiversity' measures reveal a decrease in taxonomic distinctness with increasing stress. Mar. Ecol. Prog. Ser. 129:301–305.

Whittaker, R. H. 1975. Communities and ecosystems. New York: Macmillan.

Appendix A. Permanent Plot Photos

Figures begin on next page.

U.S. Fish & Wildlife Service

Leslie Canyon National Wildlife Refuge

2014 Photographs of Uplands Plot 401_001

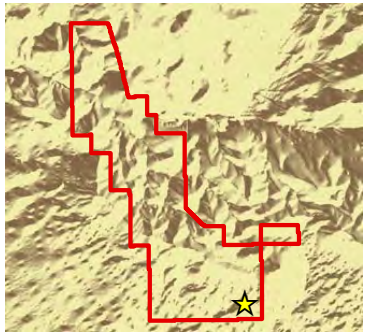
Photo Point 2 (0m,20m corner): 199 degrees

Photo Point 3 (50m,20m corner): 272 degrees

Photo Point 1 (0m,0m corner): 122 degrees

Photo Point 4 (50m,0m corner): 11 degrees

Plot Location



Refuge Boundary

Uplands Plot

N

Meters

0 1,900 3,800

Plot Layout

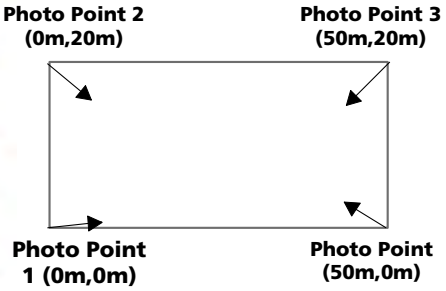


Photo points are located at each of the four plot corners. Meter marks (e.g., 0m,20m) represent the spatial location of the plot corner.
Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher resolution photos are available from SCDZ.

Produced by SCDZ
March 2016

U.S. Fish & Wildlife Service

Leslie Canyon National Wildlife Refuge

2014 Photographs of Uplands Plot 401_002

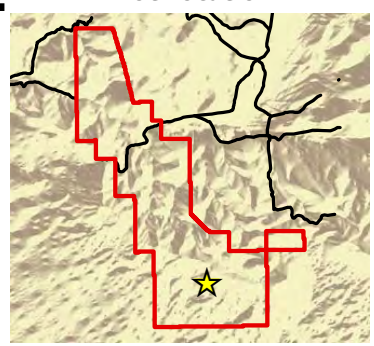
Photo Point 2 (0m,20m corner): 100 degrees

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

Photo Point 1 (0m,0m corner): 30 degrees

Photo Point 4 (50m,0m corner): 280 degrees

Plot Location



Uplands Plot

LCNWR Boundary

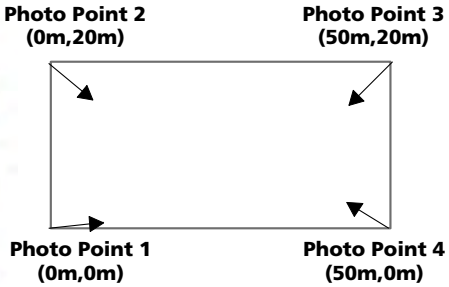
LCNWR Roads

N

Meters

0 2,000 4,000

Plot Layout



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March 2016

U.S. Fish & Wildlife Service

Leslie Canyon National Wildlife Refuge

2014 Photographs of Uplands Plot 401_003

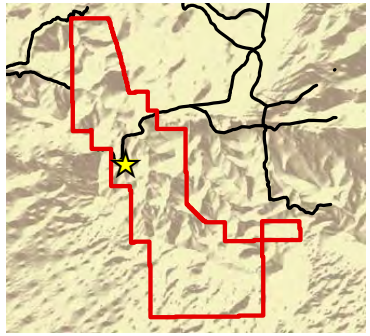
Photo Point 2 (0m,20m corner): 250 degrees

Photo Point 3 (50m,20m corner): 336 degrees

Photo Point 1 (0m,0m corner): 206 degrees

Photo Point 4 (50m,0m corner): 72 degrees

Plot Location



Uplands Plot

LCNWR Boundary

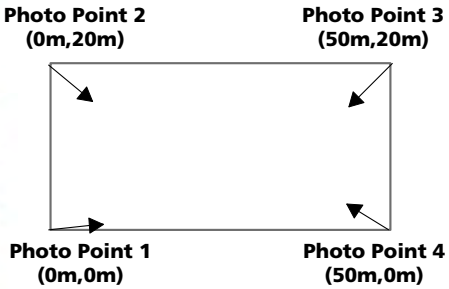
LCNWR Roads

N

Meters

0 2,000 4,000

Plot Layout



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U.S. Fish & Wildlife Service

Leslie Canyon National Wildlife Refuge

2014 Photographs of Uplands Plot 401_004

Photo Point 2 (0m,20m corner): 85 degrees

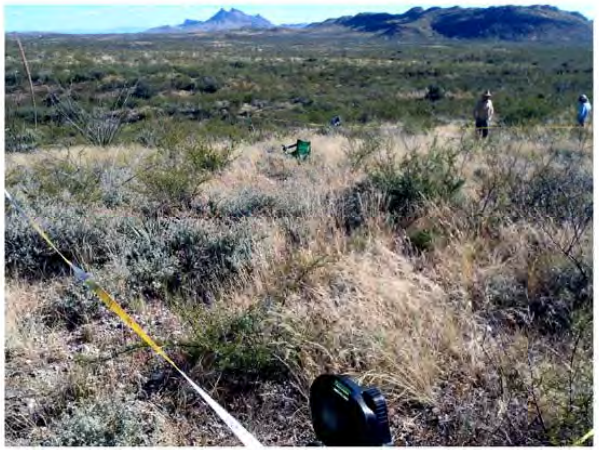
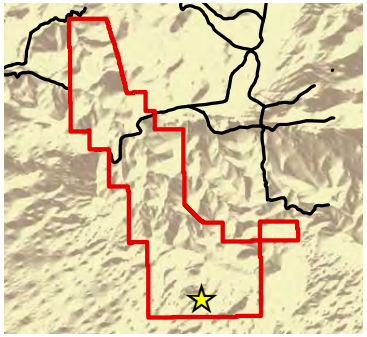


Photo Point 3 (50m,20m corner): 154 degrees

Photo Point 1 (0m,0m corner): 13 degrees

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

Plot Location



Uplands Plot

LCNWR Boundary

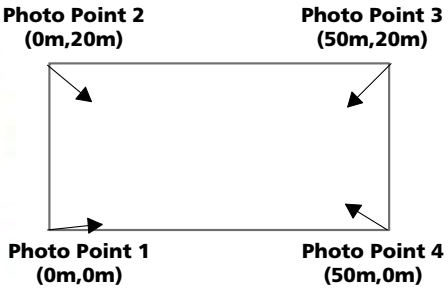
LCNWR Roads

N

Meters

0 2,000 4,000

Plot Layout



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Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher resolution photos are available from SCDZ.

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U.S. Fish & Wildlife Service

Leslie Canyon National Wildlife Refuge

2014 Photographs of Uplands Plot 401_005

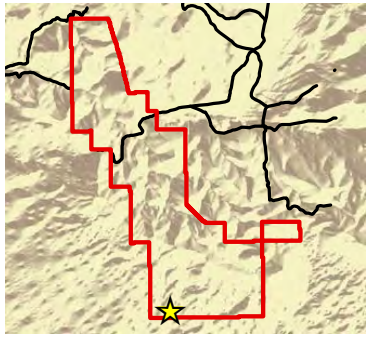
Photo Point 2 (0m,20m corner): 136 degrees

Photo Point 3 (50m,20m corner): 228 degrees

Photo Point 1 (0m,0m corner): 22 degrees

Photo Point 4 (50m,0m corner): 316 degrees

Plot Location



Uplands Plot

LCNWR Boundary

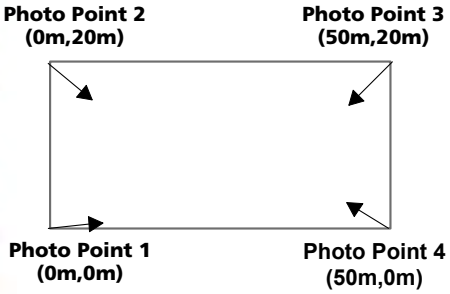
LCNWR Roads

N

Meters

0 2,000 4,000

Plot Layout



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Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher resolution photos are available from SCDZ.

Produced by SCDZ
March 2016

U.S. Fish & Wildlife Service

Leslie Canyon National Wildlife Refuge

2014 Photographs of Uplands Plot 401_006

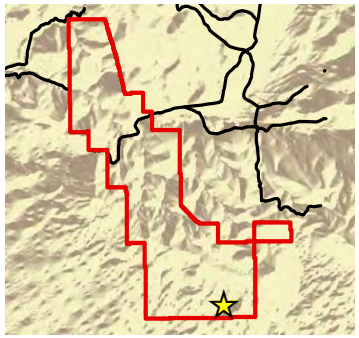
Photo Point 2 (0m,20m corner): 170 degrees

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

Photo Point 1 (0m,0m corner): 110 degrees

Photo Point 4 (50m,0m corner): 350 degrees

Plot Location



Uplands Plot

LCNWR Boundary

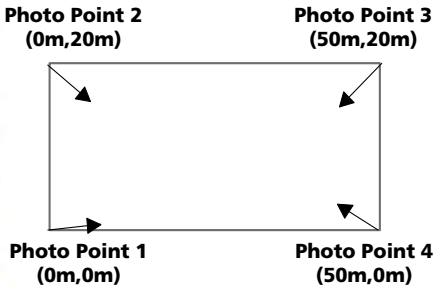
LCNWR Roads

N

Meters

0 2,000 4,000

Plot Layout



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Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher resolution photos are available from SCDZ.

Produced by SCDZ
March 2016

U.S. Fish & Wildlife Service

Leslie Canyon National Wildlife Refuge

2014 Photographs of Uplands Plot 402_001

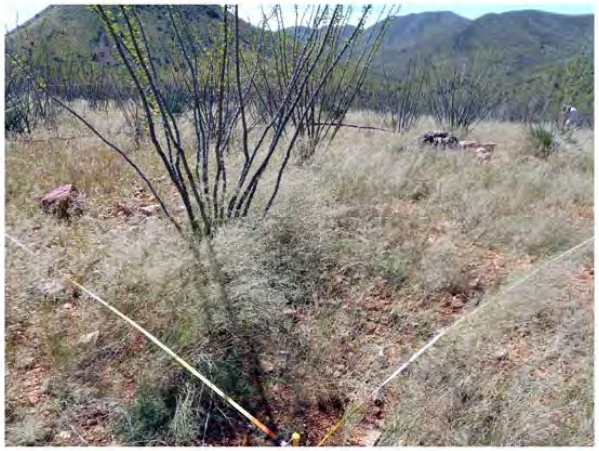


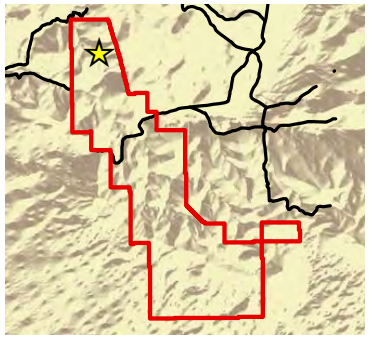
Photo Point 2 (0m,20m corner): 163 degrees

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

Photo Point 1 (0m,0m corner): 114 degrees

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

Plot Location



Uplands Plot

LCNWR Boundary

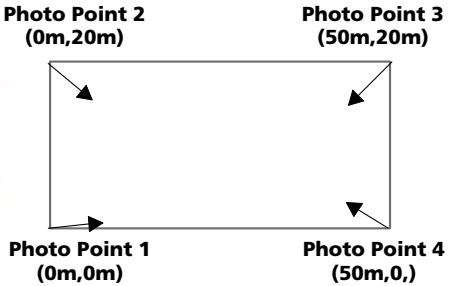
LCNWR Roads

N

Meters

0 2,000 4,000

Plot Layout



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Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher resolution photos are available from SCDZ.

Produced by SCDZ
March 2016

U.S. Fish & Wildlife Service

Leslie Canyon National Wildlife Refuge

2014 Photographs of Uplands Plot 402_003

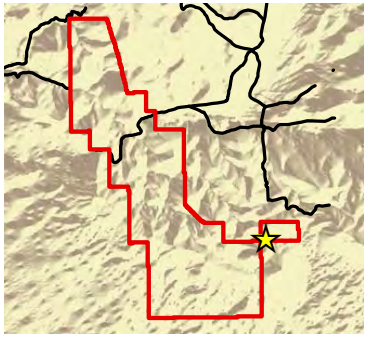
Photo Point 2 (0m,20m corner): 120 degrees

Photo Point 3 (50m,20m corner): 220 degrees

Photo Point 1 (0m,0m corner): 30 degrees

Photo Point 4 (50m,0m corner): 290 degrees

Plot Location



Uplands Plot

LCNWR Boundary

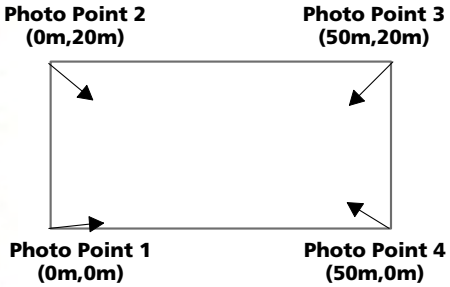
LCNWR Roads

N

Meters

0 2,000 4,000

Plot Layout



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Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher resolution photos are available from SCDZ.

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March 2016

U.S. Fish & Wildlife Service
Leslie Canyon National Wildlife Refuge

2014 Photographs of Uplands Plot 402_004

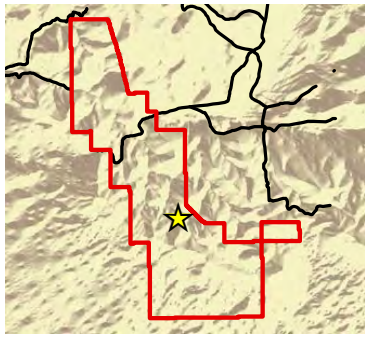
Photo Point 2 (0m,20m corner): 274 degrees

Photo Point 3 (50m,20m corner): 358 degrees

Photo Point 1 (0m,0m corner): 204 degrees

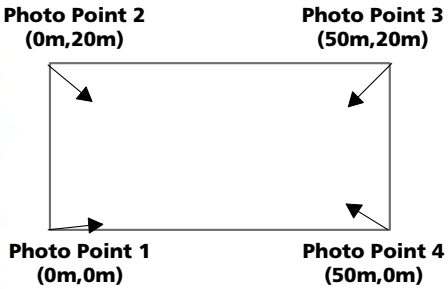
Photo Point 4 (50m,0m corner): 78 degrees

Plot Location



Uplands Plot
LCNWR Boundary
LCNWR Roads
N
Meters
0 2,000 4,000

Plot Layout



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Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher resolution photos are available from SCDZ.

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March 2016

U.S. Fish & Wildlife Service

Leslie Canyon National Wildlife Refuge

2014 Photographs of Uplands Plot 402_005

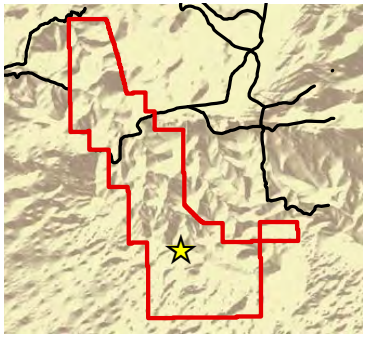
Photo Point 2 (0m,20m corner): 357 degrees

Photo Point 3 (50m,20m corner): 70 degrees

Photo Point 1 (0m,0m corner): 297 degrees

Photo Point 4 (50m,0m corner): 177 degrees

Plot Location



Uplands Plot

LCNWR Boundary

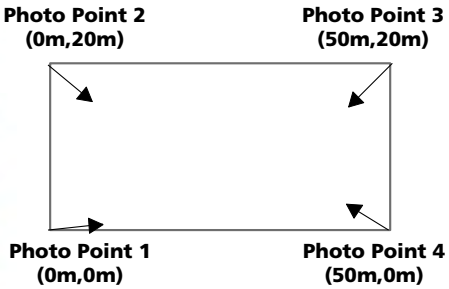
LCNWR Roads

N

Meters

0 2,000 4,000

Plot Layout



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Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher resolution photos are available from SCDZ.

Produced by SCDZ
March 2016

U.S. Fish & Wildlife Service

Leslie Canyon National Wildlife Refuge

2014 Photographs of Uplands Plot 402_007

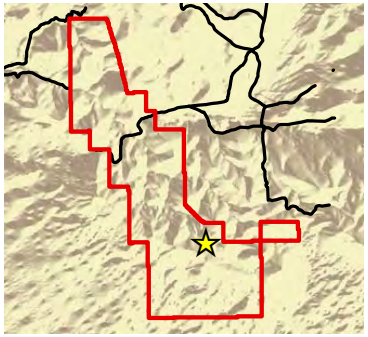
Photo Point 2 (0m,20m corner): 124 degrees

Photo Point 3 (50m,20m corner): 230 degrees

Photo Point 1 (0m,0m corner): 50 degrees

Photo Point 4 (50m,0m corner): 300 degrees

Plot Location



Uplands Plot

LCNWR Boundary

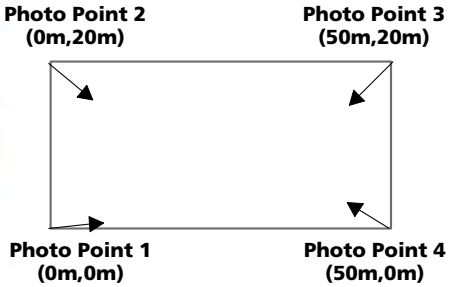
LCNWR Roads

N

Meters

0 2,000 4,000

Plot Layout



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Produced by SCDZ
March 2016

U.S. Fish & Wildlife Service

Leslie Canyon National Wildlife Refuge

2014 Photographs of Uplands Plot 402_009

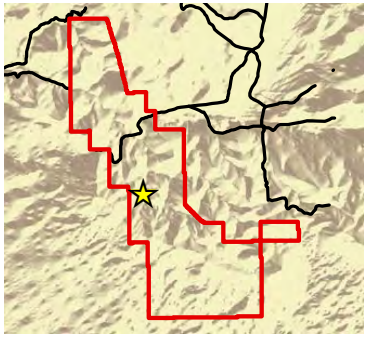
Photo Point 2 (0m,20m corner): 50 degrees

Photo Point 3 (50m,20m corner): 128 degrees

Photo Point 1 (0m,0m corner): 348 degrees

Photo Point 4 (50m,0m corner): 241 degrees

Plot Location



Uplands Plot

LCNWR Boundary

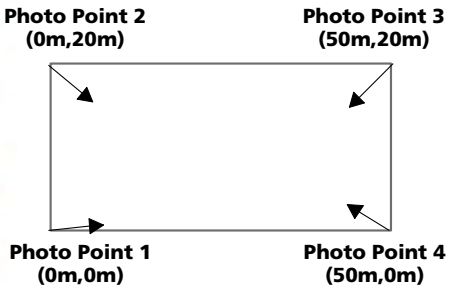
LCNWR Roads

N

Meters

0 2,000 4,000

Plot Layout



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Bearings, in degrees, reflect the direction of the photo into the plot.
Exact photo locations and higher resolution photos are available from SCDZ.

Produced by SCDZ
March 2016

U.S. Fish & Wildlife Service

Leslie Canyon National Wildlife Refuge

2014 Photographs of Uplands Plot 402_011

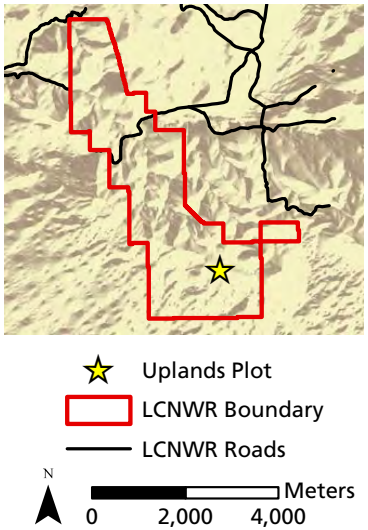
Photo Point 2 (0m,20m corner): 60 degrees

Photo Point 3 (50m,20m corner): 170 degrees

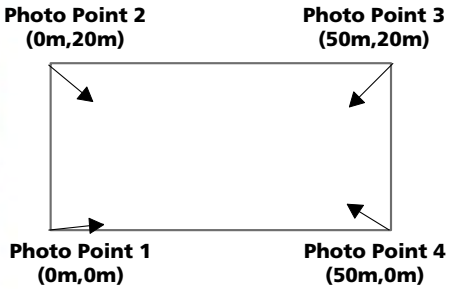
Photo Point 1 (0m,0m corner): 20 degrees

Photo Point 4 (50m,0m corner): 250 degrees

Plot Location



Plot Layout



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Produced by SCDZ
March 2016

U.S. Fish & Wildlife Service

Leslie Canyon National Wildlife Refuge

2014 Photographs of Uplands Plot 402_012

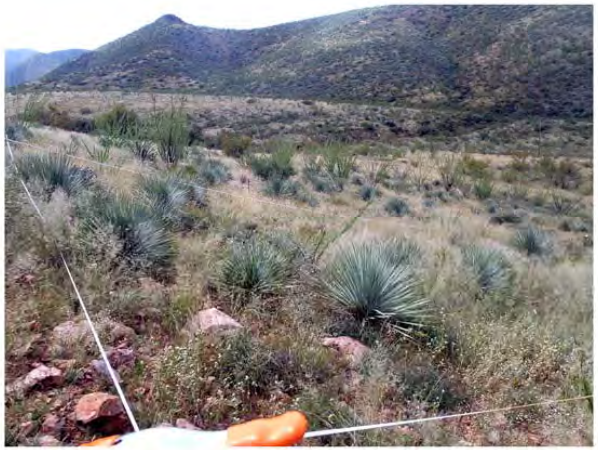


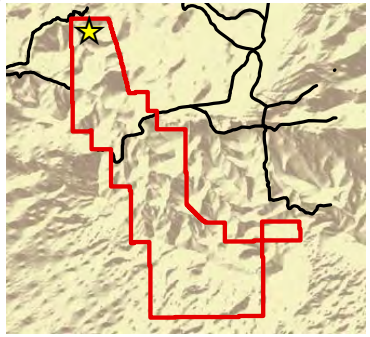
Photo Point 2 (0m,20m corner): 212 degrees

Photo Point 3 (50m,20m corner): 298 degrees

Photo Point 1 (0m,0m corner): 164 degrees

Photo Point 4 (50m,0m corner): 54 degrees

Plot Location



Uplands Plot

LCNWR Boundary

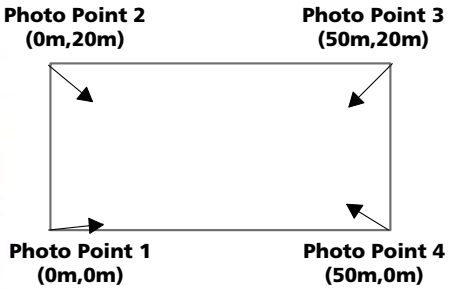
LCNWR Roads

N

Meters

0 2,000 4,000

Plot Layout



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Produced by SCDZ
March 2016

U.S. Fish & Wildlife Service

Leslie Canyon National Wildlife Refuge

2014 Photographs of Uplands Plot 402_013

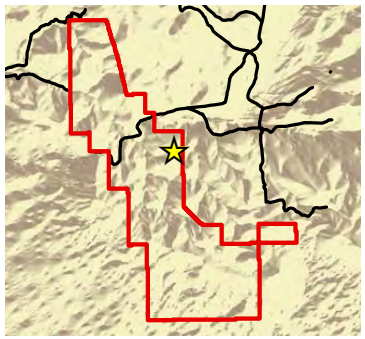
Photo Point 2 (0m,20m corner): 40 degrees

Photo Point 3 (50m,20m corner): 130 degrees

Photo Point 1 (0m,0m corner): 340 degrees

Photo Point 4 (50m,0m corner): 220 degrees

Plot Location

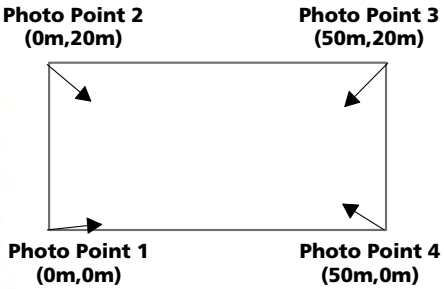


Uplands Plot
LCNWR Boundary
LCNWR Roads

N

Meters
0 2,000 4,000

Plot Layout



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Produced by SCDZ
March 2016

U.S. Fish & Wildlife Service

Leslie Canyon National Wildlife Refuge

2014 Photographs of Uplands Plot 402_015

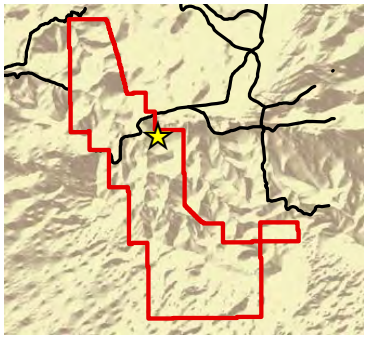
Photo Point 2 (0m,20m corner): 250 degrees

Photo Point 3 (50m,20m corner): 339 degrees

Photo Point 1 (0m,0m corner): 182 degrees

Photo Point 4 (50m,0m corner): 70 degrees

Plot Location



Uplands Plot

LCNWR Boundary

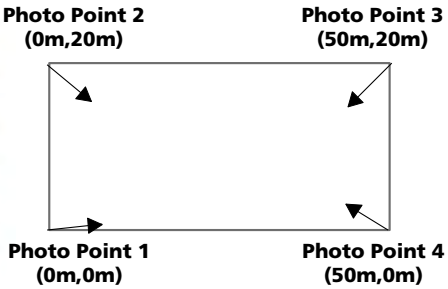
LCNWR Roads

N

Meters

0 2,000 4,000

Plot Layout



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Produced by SCDZ
March 2016

U.S. Fish & Wildlife Service

Leslie Canyon National Wildlife Refuge

2014 Photographs of Uplands Plot 402_016

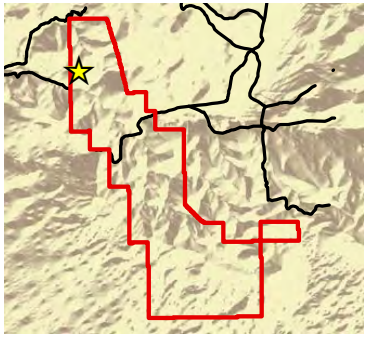
Photo Point 2 (0m,20m corner): 275 degrees

Photo Point 3 (50m,20m corner): 343 degrees

Photo Point 1 (0m,0m corner): 202 degrees

Photo Point 4 (50m,0m corner): 85 degrees

Plot Location

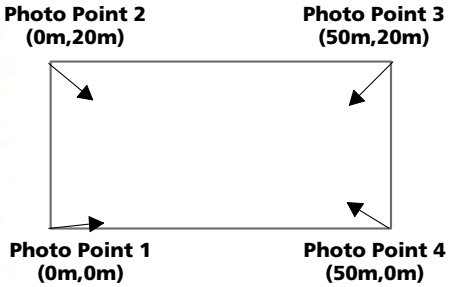


Uplands Plot
LCNWR Boundary
LCNWR Roads

N

Meters
0 2,000 4,000

Plot Layout



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Produced by SCDZ
March 2016

U.S. Fish & Wildlife Service

Leslie Canyon National Wildlife Refuge

2014 Photographs of Uplands Plot 402_017

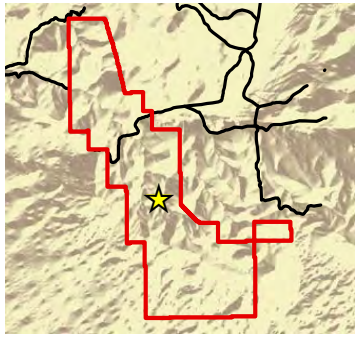
Photo Point 2 (0m,20m corner): 344 degrees

Photo Point 3 (50m,20m corner): 64 degrees

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

Photo Point 4 (50m,0m corner): 158 degrees

Plot Location



Uplands Plot

LCNWR Boundary

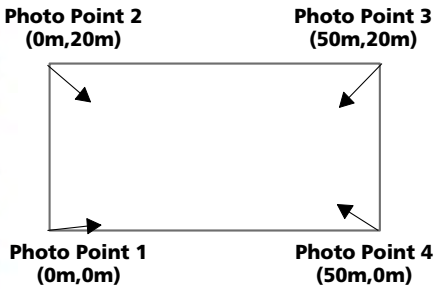
LCNWR Roads

N

Meters

0 2,000 4,000

Plot Layout



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March 2016

U.S. Fish & Wildlife Service

Leslie Canyon National Wildlife Refuge

2014 Photographs of Uplands Plot 402_020

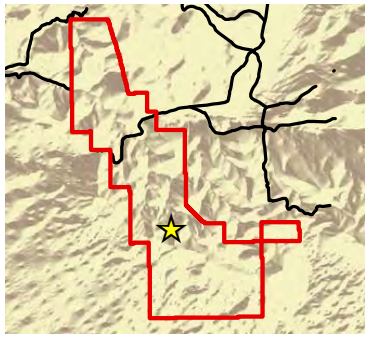
Photo Point 2 (0m,20m corner): 280 degrees

Photo Point 3 (50m,20m corner): 360 degrees

Photo Point 1 (0m,0m corner): 210 degrees

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

Plot Location

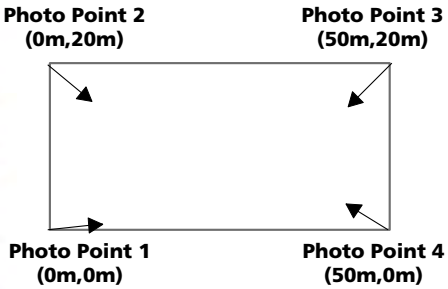


Uplands Plot
LCNWR Boundary
LCNWR Roads

N

Meters
0 2,000 4,000

Plot Layout



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Produced by SCDZ
March 2016

U.S. Fish & Wildlife Service

Leslie Canyon National Wildlife Refuge

2014 Photographs of Uplands Plot 402_022

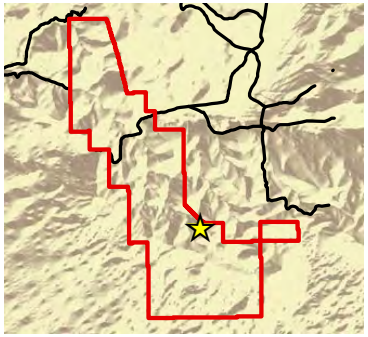
Photo Point 2 (0m,20m corner): 232 degrees

Photo Point 3 (50m,20m corner): 340 degrees

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

Photo Point 4 (50m,0m corner): 54 degrees

Plot Location



Uplands Plot

LCNWR Boundary

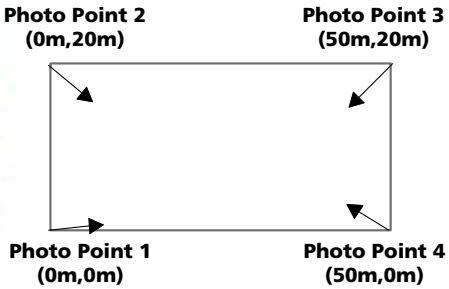
LCNWR Roads

N

Meters

0 2,000 4,000

Plot Layout



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March 2016

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 960/134560, September 2016

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
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Fort Collins, Colorado 80525

www.nature.nps.gov

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