



Vegetation Inventory, Mapping, and Characterization, Chiricahua National Monument

Volume I, Main Report



Border pinyon (*Pinus discolor*) dominates the foreground of a vista of Chiricahua National Monument's iconic rhyolite hoodoos and the Dos Cabezas Mountains.

NPS / J. BLACK

Vegetation inventory, mapping, and characterization, Chiricahua National Monument: Volume I, main report

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Contents

	Page
Figures.....	vi
Tables.....	xv
Abstract.....	xvi
List of Terms or Acronyms.....	xvii
Executive Summary.....	xix
Acknowledgments.....	xxi
Chapter 1: Introduction.....	1
Inventory Project Background.....	1
Scope and Products.....	1
The NPS Vegetation Mapping Inventory Program.....	2
The National Vegetation Classification Standard.....	3
The National Vegetation Classification.....	5
Terminology and Naming Conventions.....	5
Project Area Description.....	7
Location and Setting.....	7
Park Establishment and Purpose.....	10
Climate, Geology, and Hydrology.....	11
Vegetation.....	13
Disturbance History.....	19
Chapter 2: Classification and Mapping of Plant Communities.....	24
Data Collection and Mapping of Plant Communities.....	24
Planning and Scoping.....	24
Digital Imagery Acquisition and Processing.....	24
Methods Overview.....	27
Field Data Collection.....	27
Plot and Polygon Data Management.....	31
Vegetation Classification Analysis.....	31
Methods.....	31

Contents (continued)

	Page
Identification of Macrogroups	34
Classification Results	36
Chapter 3: Implications of the 2011 Horseshoe Two Fire for the Mapping Effort.....	45
Discussion of Accuracy	45
Chapter 4: Map Products	47
Final Classification.....	47
Chapter 5: Association Summaries	53
1. <i>Pinus discolor</i> / <i>Quercus hypoleucoides</i> Woodland Association.....	53
2. [<i>Pinus discolor</i> - <i>Juniperus deppeana</i> - <i>Quercus arizonica</i> - <i>Quercus emoryi</i>] / <i>Arctostaphylos pungens</i> Wooded Shrubland Association (P)	56
3. [<i>Robinia neomexicana</i> - <i>Quercus rugosa</i>] / <i>Holodiscus discolor</i> / <i>Muhlenbergia</i> <i>montana</i> Tree Savanna Association (PS)	59
4. <i>Pinus discolor</i> - (<i>Hesperocyparis arizonica</i>) / <i>Arctostaphylos pungens</i> Wooded Shrubland Association (P)	62
5. <i>Pinus discolor</i> / <i>Cercocarpus montanus</i> Wooded Shrubland Association (PS).....	65
6. <i>Pinus discolor</i> / <i>Quercus toumeyi</i> - (<i>Garrya wrightii</i>) / <i>Muhlenbergia emersleyi</i> Wooded Shrubland Association (P)	68
7. <i>Pinus discolor</i> / <i>Quercus toumeyi</i> - <i>Arctostaphylos pungens</i> Wooded Shrubland Association (P)	71
8. <i>Pinus discolor</i> / <i>Quercus toumeyi</i> - <i>Garrya wrightii</i> Woodland Association (P)	75
9. <i>Pinus discolor</i> / <i>Muhlenbergia emersleyi</i> Woodland Association	78
10. <i>Pinus discolor</i> / <i>Piptochaetium fimbriatum</i> Woodland Association	81
11. <i>Quercus emoryi</i> / <i>Piptochaetium fimbriatum</i> Scrub Woodland Association	84
12. [<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>] Woodland Association (P).....	87
13. (<i>Juniperus deppeana</i>) / <i>Mimosa aculeaticarpa</i> Wooded Shrubland Association (PS).....	90
14. <i>Juniperus deppeana</i> / <i>Bouteloua gracilis</i> Woodland Association.....	93
15. <i>Juniperus deppeana</i> - <i>Quercus emoryi</i> - (<i>Quercus arizonica</i>) / <i>Piptochaetium</i> <i>fimbriatum</i> Woodland Association (P).....	96
16. <i>Pseudotsuga menziesii</i> / <i>Quercus hypoleucoides</i> Forest Association	100

Contents (continued)

	Page
17. (<i>Pseudotsuga menziesii</i> - <i>Hesperocyparis arizonica</i>) / <i>Quercus rugosa</i> - <i>Quercus chrysolepis</i> Forest Association (P)	103
18. <i>Hesperocyparis arizonica</i> / <i>Quercus hypoleuroides</i> Forest Association	106
19. <i>Hesperocyparis arizonica</i> - (<i>Platanus wrightii</i>) / <i>Quercus</i> spp. Intermittently Flooded Forest Association (P)	109
20. [<i>Pinus engelmannii</i> - <i>Hesperocyparis arizonica</i> - <i>Quercus hypoleuroides</i>] Intermittently Flooded Forest Association (P)	112
21. <i>Pinus engelmannii</i> / <i>Quercus hypoleuroides</i> Woodland Association	115
22. [<i>Pinus arizonica</i> - <i>Pinus leiophylla</i>] / <i>Quercus hypoleuroides</i> Forest Association (P)	118
23. <i>Quercus hypoleuroides</i> Shrubland Association (P).....	121
24. [<i>Cercocarpus montanus</i> - <i>Garrya wrightii</i>] / Mixed Perennial Grass Wooded Shrub Savanna Association (P)	124
25. <i>Parthenium incanum</i> / <i>Eragrostis lehmanniana</i> Shrub Savanna Association (P).....	128
26. <i>Prosopis glandulosa</i> / Mixed Grasses Ruderal Shrubland Association	131
27. (<i>Carex ultra</i>) / <i>Juncus balticus</i> - <i>Solidago canadensis</i> Herbaceous Association (PS).....	134
28. (<i>Dasyllirion wheeleri</i> - <i>Agave palmeri</i>) / <i>Eragrostis lehmanniana</i> - <i>Muhlenbergia emersleyi</i> Shrub Herbaceous Association (P).....	137
29. <i>Nolina microcarpa</i> / <i>Muhlenbergia emersleyi</i> Shrub Savanna Association (PS).....	140
Chapter 6: Discussion	143
Role of Fire, Fire History, and Horseshoe Two Effects and Recovery	143
Post-Fire Plant Community Changes	143
Fire and Invasive Grasses	148
Summary	151
Final Products and Geodatabase Delivery.....	151
Literature Cited	152

Figures

	Page
Figure 1. Chiricahua National Monument located in southeastern Arizona, approximately 50 kilometers southeast of the town of Willcox.	7
Figure 2. Shaded relief map of Chiricahua National Monument.	9
Figure 3. Regional biogeography, Chiricahua National Monument.	10
Figure 4. View of a steep canyon with hoodoo rock formations.	11
Figure 5. Mean monthly precipitation (PPT) and maximum (max)/ minimum (min) air temperature for CHIR, based on 1991–2020 climate normal (National Centers for Environmental Information, Station ID USC00021664).	12
Figure 6. Grass- and forb-dominated meadow with scattered mesquite trees (<i>Prosopis glandulosa</i>).	14
Figure 7. Intermittently flooded drainage dominated by silverleaf oak (<i>Quercus hypoleucoides</i>) and Chihuahuan pine (<i>Pinus leiophylla</i>).	14
Figure 8. Semi-desert grassland slope, dominated by native bunch grass and dotted with agave (<i>Agave palmeri</i>), alderleaf mountain mahogany (<i>Cercocarpus montanus</i>) and other shrubs.	15
Figure 9. A wooded shrubland with dense pointleaf manzanita (<i>Arctostaphylos pungens</i>).	16
Figure 10. Visitation at Chiricahua National Monument, 1934–2023.	20
Figure 11. Fire severity of the 2011 Horseshoe Two Fire at CHIR, calculated using delta normalized burn ratio (dNBR) raster layer.	23
Figure 12. Example pan-sharpened multispectral imagery shows the original formation-level map units that served as the basis for mapping and classifying vegetation during this project.	26
Figure 13. Distribution of the 157 completed classification plots at Chiricahua National Monument.	28
Figure 14. Dendrogram showing the clustering of sites (plots and polygons combined; n= 541) based on multi-variate analysis of species combinations and abundances.	33
Figure 15. Non-metric multidimensional scaling (NMDS) diagram of all CHIR classification data (n = 541).	34
Figure 16. The final Chiricahua National Monument vegetation map graphic shows the 29 vegetation associations that were mapped during the Vegetation Inventory.	51
Figure 17. Map legend listing the 29 vegetation associations shown in Figure 16.	52

Figures (continued)

	Page
Figure 18. An example landscape photo showing the more open-canopied woodland variant of the Border Pinyon / Silverleaf Oak Woodland Association.	54
Figure 19. An example landscape photo showing the closed-canopied woodland variant of the Border Pinyon / Silverleaf Oak Woodland Association where the cover averages over 60%.	54
Figure 20. Vegetation map of CHIR with all areas mapped as Border Pinyon / Silverleaf Oak Woodland Association showing in green.	55
Figure 21. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Border Pinyon / Silverleaf Oak Woodland.	55
Figure 22. An example landscape photo showing the more open-canopied woodland variant of the [Border Pinyon - Alligator Juniper - Arizona White Oak - Emory Oak] / Pointleaf Manzanita Wooded Shrubland Association.	57
Figure 23. Photo showing the mixed shrub and trees within the [Border Pinyon - Alligator Juniper - Arizona White Oak - Emory Oak] / Pointleaf Manzanita Wooded Shrubland Association.	57
Figure 24. Map of CHIR with all areas mapped [Border Pinyon - Alligator Juniper - Arizona White Oak - Emory Oak] / Pointleaf Manzanita Wooded Shrubland Association shown in green. A red bounding box around one of these highlighted areas is showing where the example imagery, shown in the next figure, is located.	58
Figure 25. An example area showing the texture and appearance of satellite imagery that was classified and mapped as [Border Pinyon - Alligator Juniper - Arizona White Oak - Emory Oak] / Pointleaf Manzanita Wooded Shrubland Association.	58
Figure 26. A photo showing the dominant species within the [New Mexico Locust - Netleaf Oak] / Rockspirea / Mountain Muhly Tree Savanna Association.	60
Figure 27. Map of CHIR with all areas mapped as [New Mexico Locust-Netleaf Oak] / Rockspirea / Mountain Muhly Tree Savanna Association showing in green. (Note these areas are so small and almost invisible at this scale.	60
Figure 28. An example area showing the texture and appearance of satellite imagery that was classified and mapped as [New Mexico Locust - Netleaf Oak] / Rockspirea / Mountain Muhly Tree Savanna Association.	61
Figure 29. An example landscape photo showing the typical look of the Border Pinyon - (Arizona Cypress) / Pointleaf Manzanita Wooded Shrubland Association, with a dense understory of manzanita and scattered emergent tall pines.	63

Figures (continued)

	Page
Figure 30. Map of CHIR with all areas mapped as Border Pinyon - (Arizona Cypress) / Pointleaf Manzanita Wooded Shrubland Association showing in green.....	63
Figure 31. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Border Pinyon - (Arizona Cypress) / Pointleaf Manzanita Wooded Shrubland Association.....	64
Figure 32. An example landscape photo showing the Border Pinyon/ Alderleaf Mountain Mahogany Wooded Shrubland Association, with the common associate walkingstick cactus (<i>Cylindropuntia spinosior</i>) and agaves shown in the open areas.....	66
Figure 33. Map of CHIR with all areas mapped as Border Pinyon/ Alderleaf Mountain Mahogany Wooded Shrubland Association showing in green.	66
Figure 34. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Border Pinyon/ Alderleaf Mountain Mahogany Wooded Shrubland Association.	67
Figure 35. An example landscape photo showing the Border Pinyon/ Toumey Oak - (Wright's Silktassel)/ Bullgrass Wooded Shrubland Association.	69
Figure 36. Map of CHIR with all areas mapped as Border Pinyon/ Toumey Oak- (Wright's Silktassel)/ Bullgrass Wooded Shrubland Association showing in green.....	69
Figure 37. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Border Pinyon/ Toumey Oak - (Wright's Silktassel)/ Bullgrass Wooded Shrubland Association.....	70
Figure 38. An example landscape photo showing the Border Pinyon / Toumey Oak - Pointleaf Manzanita Wooded Shrubland Association within an area with a steep drainage and hoodoo rock outcrops.....	72
Figure 39. An example landscape photo showing the Border Pinyon / Toumey Oak - Pointleaf Manzanita Wooded Shrubland Association within a low-angle drainage.....	72
Figure 40. Map of CHIR with all areas mapped as Border Pinyon / Toumey Oak - Pointleaf Manzanita Wooded Shrubland Association showing in green.....	73
Figure 41. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Border Pinyon / Toumey Oak - Pointleaf Manzanita Wooded Shrubland Association.....	74
Figure 42. An example landscape photo showing a typical view of the Border Pinyon/ Toumey Oak - Wright's Silktassel Woodland Association.	76

Figures (continued)

	Page
Figure 43. Map of CHIR with all areas mapped as Border Pinyon/ Toumey Oak - Wright's Silktassel Woodland Association showing in green.	76
Figure 44. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Border Pinyon/ Toumey Oak - Wright's Silktassel Woodland Association.	77
Figure 45. An example landscape photo showing the more open-woodland variant of the Border Pinyon / Bullgrass Woodland Association.	79
Figure 46. An example landscape photo showing the grassier variant of the Border Pinyon / Bullgrass Woodland Association.....	79
Figure 47. Map of CHIR with all areas mapped as Border Pinyon / Bullgrass Woodland Association showing in green.	80
Figure 48. An example area showing the texture and appearance of satellite imagery that was classified and mapped as the Border Pinyon / Bullgrass Woodland Association.....	80
Figure 49. A photo showing the Border Pinyon / Pinyon Ricegrass Woodland Association, with a springtime flush of annual forbs.....	82
Figure 50. Map of CHIR with all areas mapped as Border Pinyon / Pinyon Ricegrass Woodland Association showing in green.....	82
Figure 51. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Border Pinyon / Pinyon Ricegrass Woodland Association.....	83
Figure 52. An example landscape photo showing the Emory Oak / Pinyon Ricegrass Scrub Woodland Association.....	85
Figure 53. Map of CHIR with all areas mapped as Emory Oak / Pinyon Ricegrass Scrub Woodland Association showing in green.....	85
Figure 54. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Emory Oak / Pinyon Ricegrass Scrub Woodland Association.....	86
Figure 55. An example landscape photo showing the more open-canopied woodland variant of the Silverleaf Oak - Arizona White Oak Woodland Association.	88
Figure 56. Map of CHIR with all areas mapped as Silverleaf Oak - Arizona White Oak Woodland Association showing in green.....	88
Figure 57. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Silverleaf Oak - Arizona White Oak Woodland Association.....	89

Figures (continued)

	Page
Figure 58. An example landscape photo showing the Alligator Juniper / Catclaw Mimosa Wooded Shrubland Association.....	91
Figure 59. Map of CHIR with all areas mapped as Alligator Juniper / Catclaw Mimosa Wooded Shrubland Association showing in green.	91
Figure 60. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Alligator Juniper / Catclaw Mimosa Wooded Shrubland Association.....	92
Figure 61. An example landscape photo showing a typical stand of the Alligator Juniper / Blue Grama Woodland Association.....	94
Figure 62. Map of CHIR with all areas mapped as Alligator Juniper / Blue Grama Woodland Association showing in green.....	94
Figure 63. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Alligator Juniper / Blue Grama Woodland Association.	95
Figure 64. An example landscape photo showing the Alligator Juniper - Emory Oak - (Arizona White Oak) / Pinyon Ricegrass Woodland Association as it occurs in an area adjacent to the Bonita Canyon drainage.	97
Figure 65. An example landscape photo showing the Alligator Juniper - Emory Oak - (Arizona White Oak)/ Pinyon Ricegrass Woodland Association, where an opening in the tree canopy allows for dense grass patches to grow.	97
Figure 66. Map of CHIR with all areas mapped as Alligator Juniper - Emory Oak - (Arizona White Oak) / Pinyon Ricegrass Woodland Association showing in green.....	98
Figure 67. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Alligator Juniper - Emory Oak - (Arizona White Oak) / Pinyon Ricegrass Woodland Association.	99
Figure 68. An example landscape photo showing the Douglas-fir / Silverleaf Oak Forest Association within one of the larger upper-elevation drainages at CHIR.	101
Figure 69. Map of CHIR with all areas mapped as Douglas-fir / Silverleaf Oak Forest Association showing in green.	101
Figure 70. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Douglas-fir / Silverleaf Oak Forest Association.	102
Figure 71. An example landscape photo of the (Douglas-fir - Arizona Cypress) / Netleaf Oak - Canyon Live Oak Forest Association, highlighting the shade created by the closed canopy forest.....	104

Figures (continued)

	Page
Figure 72. Map of CHIR with all areas mapped as (Douglas-fir - Arizona Cypress) / Netleaf Oak - Canyon Live Oak Forest Association showing in green.	104
Figure 73. An example area showing the texture and appearance of satellite imagery that was classified and mapped as (Douglas-fir - Arizona Cypress) / Netleaf Oak - Canyon Live Oak Forest Association.	105
Figure 74. An example landscape photo of the Arizona cypress / Silverleaf Oak Forest Association, looking upslope near a small drainage.	107
Figure 75. Map of CHIR with all areas mapped as Arizona Cypress / Silverleaf Oak Forest Association showing in green.	107
Figure 76. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Arizona Cypress / Silverleaf Oak Forest Association.	108
Figure 77. An example landscape photo showing the Arizona Cypress - (Arizona Sycamore) / Oak Intermittently Flooded Forest Association.	110
Figure 78. Map of CHIR with all areas mapped as Arizona Cypress - (Arizona Sycamore) / Oak Intermittently Flooded Forest Association shown in green.	110
Figure 79. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Arizona Cypress - (Arizona Sycamore) / Oak Intermittently Flooded Forest Association.	111
Figure 80. An example landscape photo showing the [Apache Pine - Arizona Cypress - Silverleaf Oak] Intermittently Flooded Forest Association, as it occurs in Rhyolite Canyon at CHIR.	113
Figure 81. Map of CHIR with all areas mapped as [Apache Pine - Arizona Cypress - Silverleaf Oak] Intermittently Flooded Forest Association showing in green.	113
Figure 82. An example area showing the texture and appearance of satellite imagery that was classified and mapped as [Apache Pine - Arizona Cypress - Silverleaf Oak] Intermittently Flooded Forest Association.	114
Figure 83. An example landscape photo showing the Apache Pine / Silverleaf Oak Forest Association.	116
Figure 84. Map of CHIR with all areas mapped as Apache Pine / Silverleaf Oak Forest Association showing in green.	116
Figure 85. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Apache Pine / Silverleaf Oak Forest Association.	117

Figures (continued)

	Page
Figure 86. An example landscape photo showing the [Arizona Pine - Chihuahuan Pine] / Silverleaf Oak Forest Association.	119
Figure 87. Map of CHIR with all areas mapped as [Arizona Pine - Chihuahuan Pine] / Silverleaf Oak Forest Association showing in green.	119
Figure 88. An example area showing the texture and appearance of satellite imagery that was classified and mapped as [Arizona Pine - Chihuahuan Pine] / Silverleaf Oak Forest Association.....	120
Figure 89. An example landscape photo showing the Silverleaf Oak Shrubland Association as it occurs at the crest of a hill, at CHIR.....	122
Figure 90. An example landscape photo showing the Silverleaf Oak Shrubland Association looking across one of the mapped areas.....	122
Figure 91. Map of CHIR with all areas mapped as Silverleaf Oak Shrubland Association showing in green.	123
Figure 92. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Silverleaf Oak Shrubland Association.	123
Figure 93. The image shows an example of an area mapped as [Alderleaf Mountain Mahogany - Wright's Silktassel] / Mixed Perennial Grass Wooded Shrub Savanna Association.....	125
Figure 94. A second example of the [Alderleaf Mountain Mahogany - Wright's Silktassel]/ Mixed Perennial Grass Wooded Shrub Savanna Association, showing a rockier site. Lichen-covered exposed bedrock is common in this community.	125
Figure 95. Map of CHIR with all areas mapped as [Alderleaf Mountain Mahogany - Wright's Silktassel]/ Mixed Perennial Grass Wooded Shrub Savanna Association showing in green.	126
Figure 96. An example area showing the texture and appearance of satellite imagery that was classified and mapped as [Alderleaf Mountain Mahogany - Wright's Silktassel] / Mixed Perennial Grass Wooded Shrub Savanna Association.	127
Figure 97. An example landscape photo showing the Mariola / Lehmann Lovegrass Shrub Savanna Association at CHIR.	129
Figure 98. Map of CHIR with all areas mapped as Mariola / Lehmann Lovegrass Shrub Savanna Association showing in green.....	129
Figure 99. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Mariola / Lehmann Lovegrass Shrub Savanna Association.	130

Figures (continued)

	Page
Figure 100. An example landscape photo showing the Honey Mesquite / Mixed Grass Ruderal Shrubland Association during a post-monsoon season when grasses and forbs are flowering.	132
Figure 101. An example landscape photo showing the Honey Mesquite / Mixed Grass Ruderal Shrubland Association at the end of the pre-summer warm season.	132
Figure 102. Map of CHIR with all areas mapped as Honey Mesquite / Mixed Grass Ruderal Shrubland showing in green.	133
Figure 103. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Honey Mesquite / Mixed Grass Ruderal Shrubland.	133
Figure 104. Photo showing the (Cochise Sedge) / Mountain Rush - Canada Goldenrod Herbaceous Association in Silver Spur Meadow at CHIR.	135
Figure 105. Map of CHIR with all areas mapped as (Cochise Sedge) / Mountain Rush - Canada Goldenrod Herbaceous Association showing in green.	135
Figure 106. An example area showing the texture and appearance of satellite imagery that was classified and mapped as (Cochise Sedge) / Mountain Rush - Canada Goldenrod Herbaceous Association.	136
Figure 107. A photo showing a typically landscape view of the (Common Sotol - Palmer's Century Plant) / Lehmann Lovegrass - Bullgrass Shrub Herbaceous Association.	138
Figure 108. Map of CHIR with all areas mapped as (Common Sotol - Palmer's Century Plant) / Lehmann Lovegrass - Bullgrass Shrub Herbaceous Association showing in green.	138
Figure 109. An example area showing the texture and appearance of satellite imagery that was classified and mapped as (Common Sotol - Palmer's Century Plant) / Lehmann Lovegrass - Bullgrass Shrub Herbaceous Association.	139
Figure 110. The photo shows a view across the single polygon that was mapped as Beargrass / Bullgrass Shrub Savanna Association.	141
Figure 111. Another view of the Beargrass / Bullgrass Shrub Savanna Association showing a slightly more diverse patch, having some prickly pear cactus (<i>Opuntia</i> spp.) and scrubby short trees here and there.	141
Figure 112. Map of CHIR with all areas mapped as Beargrass / Bullgrass Shrub Savanna Association showing in green.	142
Figure 113. An example area showing the texture and appearance of the satellite imagery that was classified and mapped as Beargrass / Bullgrass Shrub Savanna Association.	142

Figures (continued)

	Page
Figure 114. Photo comparison of three SODN monitoring sites pre-fire (left column), immediately post-fire (middle column) and >6 years post-fire (right column), highlighting the loss of plant cover and eventual regrowth especially of sprouting oak species (<i>Quercus</i> spp.).	144
Figure 115. Data from SODN monitoring plots across all elevation/soil strata at CHIR, showing percent cover of border pinyon (<i>Pinus discolor</i>) from 2007 to 2010 vs. from 2017 to 2021 (across height categories).....	145
Figure 116. Data from SODN monitoring plots across all elevation/soil strata at CHIR, showing percent cover of Toumey oak (<i>Quercus toumeyi</i>) from 2007 to 2010 vs. from 2017 to 2021 (across height categories).....	146
Figure 117. Segmented bubble plot graph showing the relative abundance of three key species in monitoring plots within the 502 stratum at CHIR (n=12), both pre-fire (T1 = 2007–2010) and post-fire (T3 = 2017–2021).....	147
Figure 118. Graph showing the proportion of SODN long-term monitoring plots with Lehmann’s lovegrass present, shown by elevation stratum and time visited.	149
Figure 119. The results of the 2022 exotic plant early detection surveys, along roads and trails in the western side of CHIR.	150

Tables

	Page
Table 1. Summary of USNVC revised hierarchy levels and criteria for natural vegetation with examples.	4
Table 2. Specific attributes were collected on the vegetation and landscape datasheets for both polygons and classification plots.	30
Table 3. The 29 plant associations within their USNVC hierarchy, including the Macrogroup, Group, Alliance, Association, and NVC code.	38
Table 4. Number of classification (IP) plots, number of polygons, and total area within the project boundary for each association.....	48

Abstract

The Sonoran Desert Network (SODN) conducted an inventory, classification, and mapping of vegetation communities at Chiricahua National Monument (CHIR) from 2007 to 2011. This report is Volume I of two volumes, summarizing 29 vegetation communities (associations) identified at the monument and providing them within the context of the United States National Vegetation Classification (USNVC), the hierarchical system guiding all National Park Service (NPS) vegetation inventories. Volume II contains the full association descriptions. The project combined existing plot data with new plot-scale and larger-scale ground observations of the dominant species combinations, their abundance, structural characteristics, and landscape traits to develop the dataset from which the classification was derived. Teams also mapped vegetation communities using printed satellite imagery and real-time GPS locations to pinpoint locations and draw boundaries between changing communities. These boundaries were later digitized and became the map.

In June 2011, after data collection had been completed, a severe wildfire, Horseshoe Two, impacted nearly all of the monument, resulting in a matrix of lightly to severely burned areas. This event—the only extensive wildfire in the monument since the late 19th century—substantially altered major swaths of the park’s dominant upland plant communities and made it impossible to conduct a meaningful or appropriate post-mapping accuracy assessment. As a result, this map and the vegetation types provide a detailed perspective of pre-fire conditions and serve as a template against which to compare vegetation recovery and restoration following this seminal fire event.

List of Terms or Acronyms

AA: Accuracy assessment

Ac: Acres

CEGL: Community Element Code–Global

CES: NatureServe ecological system

CHIR: Chiricahua National Monument

Cm: Centimeter

DOQQ: Digital orthophoto quarter quadrangle

ERDAS: Earth Resources Data Analysis System

ESA: Ecological Society of America

ESRI: Environmental Systems Research Institute

FGDC: Federal Geographic Data Committee

Ft: Foot/Feet

GCP: Ground control point

GIS: Geographic information system

GPS: Global positioning system

Ha: Hectares

I&M: Inventory and Monitoring Program

ITIS: Integrated Taxonomic Information System

Km: Kilometers

M: Meters

Mi: Miles

MMU: Minimum mapping unit

NA: Not applicable

NAD83: North American Datum of 1983

NHS: National Historic Site

NM: National Monument

NMAS: National Map Accuracy Standards

NP: National Park

NPS: National Park Service

NS: NatureServe

NVC: National Vegetation Classification

NVIP: National Vegetation Inventory Program

RMSE: Root mean square error

RRQRR: Reversed Randomized Quadrant-Recursive Raster

SODN: Sonoran Desert Network (National Park Service)

spp.: Species (plural)

TNC: The Nature Conservancy

UNESCO: United Nations Educational, Scientific, and Cultural Organization

USDA: US Department of Agriculture

USGS: US Geological Survey

USNVCS: United States National Vegetation Classification Standard (or System)

UTM: Universal Transverse Mercator

Executive Summary

A vegetation mapping and characterization effort was conducted at Chiricahua National Monument (CHIR) over several separate phases from 2007 to 2022 by the Sonoran Desert Network (SODN) office. This vegetation mapping effort was completed under the National Park Service (NPS) vegetation mapping inventory program which aims to complete baseline mapping inventories at over 270 national park units. The vegetation map data were collected to provide park managers with a digital map product that met national standards of spatial and thematic accuracy, while also placing the vegetation into a regional and even national context. The data standard was designed to facilitate the production of uniform statistics about vegetation across the nation, enable the translation of data collected at various scales, and allow data sharing, aggregation, and comparison across regions.

The vegetation mapping and characterization process began with the delineation of draft polygons from remote sensing imagery. Field crews then visited each polygon to collect qualitative vegetation cover data and further refine polygon boundaries. Concurrently, vegetation data were collected at both randomly and subjectively placed plots. The field effort for this project lasted from the fall of 2007 to the spring of 2010. In June of 2011, the Horseshoe Two megafire burned much of the monument, drastically altering the vegetation of the area and immediately rendering the recently completed map outdated. In discussions with park and program staff, it was decided that—in the absence of additional funding—the map would be paused for several years while ongoing postfire assessments and vegetation monitoring provided insights into the trajectory of vegetation recovery.

Classification to the association level of the United States National Vegetation Classification System (USNVCS) was revised in 2022 to incorporate the most recent changes and additions within the National Vegetation Classification (NVC) which encompasses all the currently accepted and described vegetation types. The classification was based on analysis of both plot data and field-collected polygon data. Typically, a map thematic accuracy assessment would have been conducted following the completion of the mapping and classification phases; however, since the classification and map represent the pre-fire state of the monument's vegetation, a meaningful accuracy assessment was not possible post-fire. In place of an accuracy assessment, we provide a discussion on the effects of the fire on the monument's vegetation using evidence from several published studies, data from ongoing SODN monitoring projects, and field-based observations.

A total of 29 distinct associations were described and mapped at Chiricahua National Monument, ranging from shrub savannas dominated by perennial grasses and succulents to mixed conifer forests. The majority of the monument was covered in open woodlands and shrublands of border pinyon (*Pinus discolor*), Toumey oak (*Quercus toumeyii*), and/or pointleaf manzanita (*Arctostaphylos pungens*). The rocky, steep-sided, high-elevation drainages were inhabited by large conifers such as Arizona cypress (*Hesperocyparis arizonica*), Chihuahuan pine (*Pinus leiophylla*), Apache pine (*P. engelmannii*), Arizona pine (*P. arizonica*), and Douglas-fir (*Pseudotsuga menziesii*) with an understory of oaks (*Quercus* spp.), especially silverleaf oak (*Q. hypoleucoides*). The wider, lower elevation drainages and adjacent floodplains supported woodlands often dominated by Arizona oak (*Quercus arizonica*), Emory oak (*Q. emoryi*), and alligator juniper (*Juniperus deppeana*).

Nine of the 29 identified types were accepted types within the National Vegetation Classification (NVC). Of the remaining 20 types, we propose that 15 be added to the NVC, while the rest are designated as “park specials” as they are most likely the result of specific local disturbances or conditions and are unlikely to be widespread outside of the study area.

Final products developed for this project include two report volumes, a digital map, a tabular database containing the classification plot data and full vegetation descriptions for all associations found at the monument. The map was designed to facilitate ecologically based natural resources management and research. The vector (polygon) map is in digital format within a geodatabase structure that allows for complex relationships to be established between spatial and tabular data and makes accessing the product easy and seamless. The GIS format allows user flexibility and will also enable updates to be made as new information becomes available (such as revised NVC codes or vegetation type names) or in the event of major disturbance events that could impact the vegetation.

Despite the unfortunate timing of the Horseshoe Two Fire, this mapping and classification effort provide a unique and detailed snapshot of vegetation distribution and types that occurred at CHIR prior to this once-in-a-century event. Although outdated as soon as the fire engulfed the monument, these products provide important reference conditions and serve as a baseline against which scientists and managers can assess the recovery and changes to park vegetation and develop and evaluate management actions over the many decades of recovery from this momentous event. In combination with information on fire effects (summarized in Section 1) and continued long-term ecological monitoring, these products provide an important perspective for understanding and protecting these ecosystems.

Acknowledgments

The authors would like to extend their thanks to the staff of Chiricahua National Monument (CHIR) during the 2007 to 2011 period for their support of this project throughout its many phases. Many wonderful people were involved in collecting the field data, entering, and verifying the data, providing input into classification work, and the final steps of creating the project map and reports. Beth Fallon led the field effort during those early years and assisted with the initial community descriptions. We would like to thank CHIR staff—biologist Nicole Gonzalez and resource manager JoAnn Blalack—and Rocky Mountain National Park ecologist Scott Esser for providing thoughtful reviews of this report.

Chapter 1: Introduction

Inventory Project Background

This report describes the methods and results of a multi-year Vegetation Inventory project (2008–2011) to classify, describe, and map vegetation at Chiricahua National Monument, located in Cochise County in the southeastern corner of Arizona. In 1999, the Director of the NPS approved the Natural Resource Challenge to encourage national parks to focus on the preservation of the nation’s natural heritage through science, natural resource inventories, and expanded resource monitoring. The Natural Resource Challenge provided funding for 12 baseline inventories to be completed in each of the 270 park units that contain significant natural resources. The National Vegetation Mapping Inventory Program (NVMIP) is one of these 12 baseline inventories.

The National Park Service’s (NPS) Sonoran Desert Network (SODN), part of the service-wide Inventory and Monitoring (I&M) Program, organized and coordinated the vegetation inventory, classification, and mapping at Chiricahua National Monument (CHIR). For CHIR, as well as the other network parks, the SODN uses baseline vegetation data upon which to develop and implement specific monitoring programs. Park managers also need baseline data and information on park vegetation resources for management purposes, such as planning new facilities (trails, campgrounds), prescribed fire planning, habitat, and rare plant protection or restoration efforts.

Vegetation is a primary resource of natural areas, and the description of vegetation composition, structure, and distribution is fundamental to effective land management. The term “vegetation” encompasses plants at multiple scales, from the most refined floristic levels (referred to as “plant communities” or “plant associations” in this report) to the broadest physiognomic or lifeform levels, such as “tropical rainforest” or “savanna”.

The [NPS Vegetation Mapping Inventory Program](#) has set standards for these inventories to follow, including a minimum mapping unit of 0.5 hectares, 80% thematic accuracy per class, and spatial accuracy meeting the US National Map Accuracy Standards developed by the Federal Geographic Data Committee (FGDC). In addition to meeting the program standards, every effort was made to provide the mapping and classification data to the park in a manner best suited to its specific management objectives and needs.

Scope and Products

The aim of this project was to create a vegetation map at the National Vegetation Classification Standard Association level for a study area of approximately 5,242 hectares (12,954 acres) which included a small acreage outside the official boundary. To accurately assess, classify and describe these formerly undescribed vegetation communities found within the monument, it was necessary to sample extensively across the monument to collect data for classification purposes. In addition, existing data from network monitoring plots were also included. The monument area covers a relatively complex landscape of topography, geology, and hydrologic influence.

Products developed for Chiricahua National Monument as part of this project include:

- A final report (this document), including a dichotomous vegetation key and full vegetation community-type descriptions at the USNVC Association level.
- Digital geo-referenced photos of each vegetation plot and additional observation points within map units.
- A geodatabase containing mapped vegetation data, plot data and location, permanent photo point locations, and satellite imagery.
- Printable digital graphics of final map polygons (i.e., vegetation maps in poster format).
- Federal Geographic Data Committee-compliant metadata for all spatial database files and field data.

The NPS Vegetation Mapping Inventory Program

The NPS Vegetation Mapping Inventory Program aims to classify, describe, and map detailed vegetation communities in more than 270 national parks across the United States. NPS is the primary funding agency, providing support to the parks through base funds from the Inventory and Monitoring Division. Data products from the program can be downloaded from [NPS' Inventory & Monitoring \(I&M\) Vegetation Inventory Products](#) or [NPS' IRMA DataStore](#).

The vegetation inventory program supports consistent vegetation classification, mapping, and accuracy assessment protocols and standards across all park-mapping projects. The program has established guidance for all vegetation-mapping projects in four documents:

- [Technical guidance](#), including classification guidance.
- Methodology for Assessing the Utility of Existing Data for Vegetation Mapping (TNC and ESRI 1996; NPS edited 2009 version).
- [Geospatial Standards – Federal Geographic Data Committee \(fgdc.gov\)](#).
- [Accuracy Assessment Guidance \(Thematic accuracy assessment procedures, NPSVI version 2.0\)](#).

In addition, the program has defined national standards for all park vegetation classification and mapping projects:

- Vegetation classification follows the Federal Geographic Data Committee (FGDC) standard for vegetation classification, the National Vegetation Classification Standard (NVCS).
- Spatial data formatting follows the FGDC standards for spatial data transfer.
- Metadata for each spatial dataset uses the FGDC metadata standard.
- All plant names used in the classification are consistent with the nationally standardized list maintained by the United States Department of Agriculture (USDA) in the [PLANTS Database](#).

- The minimum mapping unit (MMU) is 0.5 hectares (1.24 ac).

The National Vegetation Classification Standard

Patterns of vegetation vary continuously over landscapes. Classification systems attempt to categorize these patterns by identifying and describing assemblages of plants that repeat under similar environmental conditions. The United States National Vegetation Classification Standard (USNVCS) provides a classification framework that serves as the standard for all NPS vegetation mapping projects (Comer et al. 2003; TNC and ESRI 1994a). In 1997, the FGDC formally adopted USNVCS Version 1 (FGDC 1997). At the time of its adoption, it was recognized as incomplete and work to refine and further develop it began immediately. In October 2007, the FGDC vegetation subcommittee released USNVCS Version 2 (working draft), which was formally endorsed in February 2008 (FGDC 2008).

The USNVCS evolved from vegetation classification primarily conducted over more than two decades by The Nature Conservancy (TNC), NatureServe, and the Natural Heritage Program network (Grossman et al. 1998). It derives in part from earlier vegetation classification frameworks produced by the United Nations Educational, Scientific, and Cultural Organization (UNESCO 1973; Driscoll et al. 1984). The use of this standardized classification system helps ensure data compatibility throughout the National Park Service and other agencies. The USNVCS was designed to facilitate the production of uniform statistics about vegetation across the nation, enable the translation of data collected at various scales, and allow data sharing, aggregation, and comparison across regions.

The USNVCS is a hierarchical system that allows vegetation classification to occur at multiple scales. Existing vegetation is classified on the basis of both physiognomic and floristic criteria. The upper three levels—Formation Class, Formation Subclass, and Formation—are physiognomic, based primarily on growth form, structure, and cover, indicating characteristics that reflect geographically widespread (global) topographic factors. The middle three levels—Division, Macrogroup, and Group—were new to the USNVCS hierarchy and focus largely on biogeographic and habitat factors along broad continental-to-regional topographic, edaphic, and disturbance gradients. The lower two levels—Alliance and Association—are floristic, based primarily on species composition and abundance. Table 1 shows the revised Version 2, under which this project was conducted and which is currently being utilized by NatureServe and the Ecological Society of America (ESA) vegetation panel to substantially update the structure and content of the USNVCS.

The USNVCS also distinguishes between natural and cultural vegetation, with the former primarily determined by ecological processes and the latter by regular human activity. Vegetated areas intermediate between the two—such as those influenced by human activities like logging, fire, and grazing, as well as by ecological processes—are defined as semi-natural.

Table 1. Summary of USNVC revised hierarchy levels and criteria for natural vegetation with examples.

Levels	Hierarchy Level	Criteria	Examples
Upper: Physiognomy plays a predominant role	L1—Formation Class	Broad combinations of general dominant growth forms that are adapted to basic temperature (energy budget), moisture, and substrate/aquatic conditions.	Mesomorphic Tree Vegetation Class (Forest and Woodland)
	L2—Formation Subclass	Combinations of general dominant and diagnostic growth forms that reflect global macroclimatic factors driven primarily by latitude and continental position or that reflect overriding substrate/aquatic conditions.	Temperate & Boreal Forest & Woodland Subclass
	L3—Formation	Combinations of dominant and diagnostic growth forms that reflect global macroclimatic factors as modified by altitude, seasonality of precipitation, substrates, and hydrologic conditions.	Warm Temperate Forest & Woodland Formation
Middle: Floristics and physiognomy play predominant roles	L4—Division	Combinations of dominant and diagnostic growth forms and a broad set of diagnostic plant species that reflect biogeographic differences in composition and continental differences in mesoclimate, geology, substrates, hydrology, and disturbance regimes.	<i>Juniperus deppeana</i> - <i>Quercus buckleyi</i> / <i>Rhus virens</i> Madrean-Balconian Forest & Woodland Division
	L5—Macrogroup	Combinations of moderate sets of diagnostic plant species and diagnostic growth forms that reflect biogeographic differences in composition and sub-continental to regional differences in mesoclimate, geology, substrates, hydrology, and disturbance regimes.	<i>Pinus leiophylla</i> - <i>Pseudotsuga menziesii</i> / <i>Quercus hypoleucoides</i> Madrean Montane Forest & Woodland Macrogroup
	L6—Group	Combinations of relatively narrow sets of diagnostic plant species (including dominants and co-dominants), broadly similar composition, and diagnostic growth forms that reflect regional mesoclimate, geology, substrates, hydrology, and disturbance regimes.	<i>Pinus engelmannii</i> - <i>Pinus leiophylla</i> - <i>Pinus arizonica</i> Forest & Woodland Group (Madrean Lower Montane Pine - Oak Forest and Woodland)
Lower: Floristics plays a predominant role	L7—Alliance	Diagnostic species, including some from the dominant growth form or layer, and moderately similar composition that reflect regional to subregional climate, substrates, hydrology, moisture/nutrient factors, and disturbance regimes.	<i>Hesperocyparis arizonica</i> Forest & Woodland Alliance (Arizona Cypress Forest and Woodland)
	L8—Association	Diagnostic species, usually from multiple growth forms or layers, and more narrowly similar composition that reflect topo-edaphic climate, substrates, hydrology, and disturbance regimes.	<i>Hesperocyparis arizonica</i> / <i>Quercus hypoleucoides</i> Forest (Arizona Cypress / Silverleaf Oak Forest)

The National Vegetation Classification

The USNVCS provides a framework for levels of classification but does not provide descriptions of all existing vegetation types at all levels. Those descriptions comprise the National Vegetation Classification (USNVC), which is populated by data from various completed vegetation mapping inventory projects, such as the present one, and other sources. The NVC, which is predominantly maintained by NatureServe and used by many federal agencies, including the NPS, includes the plant communities (associations and alliances) defined for the United States.

NatureServe manages a database of USNVC plant community entities. Their online database, [NatureServe Explorer](#), provides public access to regularly updated versions of the USNVC plant community listings and descriptions. NatureServe's documentation of associations and, in some cases, alliances has been the most accessible listing available until recently. However, the plant community listings within the USNVC are not yet complete and are currently being revised to fall within Version 2 of the FGDC hierarchy. The other website hosting [USNVC data](#) posts all new descriptions as well as information on the changes to the hierarchy and displays these vegetation type descriptions in the new hierarchy (see Table 1). Many, but not all, vegetation associations listed on this site are linked to the full and updated descriptions on the NatureServe Explorer site.

This project has utilized information available in the [USNVC Database](#) and NatureServe to classify vegetation at CHIR to the association level, with group and alliance membership noted when known. Existing USNVC associations were used whenever possible. However, in frequent cases where no published USNVC association adequately described vegetation types observed during this project, new associations were described and shown within the existing USNVCS framework using the authors' best ecological judgment. New vegetation associations proposed here are based solely on data collected during this effort, and naming conventions were developed as fitting to identify dominant and diagnostic species groupings.

For more information on the USNVC, visit the [NPS Vegetation Mapping Inventory Program](#) or see Grossman et al. (1998).

Terminology and Naming Conventions

Alliances and associations are classified based on both the dominant (greatest canopy cover) species in the upper strata of a contiguous vegetation unit and on diagnostic species (any plant taxon or group of taxa whose relative constancy or abundance can be used to differentiate one vegetation type from another). Associations, which describe and identify the characteristic range of species composition, diagnostic species, and physiognomy of a community, are the most specific and basic classification unit and are hierarchically subsumed within alliances (Jennings et al. 2009). Typically, each association is included in only one alliance, while each alliance may include many associations.

Associations define distinct plant compositions that repeat across the landscape and are generally named using both the dominant species in the uppermost stratum of the vegetation and one or more dominant species in the lower strata (or a diagnostic species in any stratum). The strata used in this project are defined as follows:

- Top canopy: greater than 5 meters in height
- Canopy: between 2 and 5 meters in height
- Subcanopy: between 0.5 and 2 meters in height
- Field: below 0.5 meters in height

Associations are defined as having consistent species composition, uniform physiognomy, and similar habitat conditions. Naming conventions and syntax for all USNVC names are as follows:

- A hyphen with a space on either side (-) separates the names of species occurring in the same stratum.
- A slash (/) with a space on either side separates the names of species occurring in different strata.
- Species that occur in the uppermost stratum are listed first, followed successively by those in the lower strata.
- The order of species names generally reflects decreasing levels of dominance, constancy, or indicator value.
- Parentheses around a species name indicate the species is less consistently found either in all associations of an alliance or in all occurrences of an association.
- Square brackets around two species' names indicate that the species are co-dominant or trade dominance, with either or both being dominant in each stand.
- Association names include the dominant species of the significant strata, followed by the structural class in which they are classified (e.g., forest, woodland, or herbaceous).
- A “(P)” at the end of an association name implies that the type is proposed (i.e., was identified and described based on the results of this or another recent SODN project) and is not yet a formally accepted vegetation type within the USNVC. These proposed types are reviewed on an ongoing basis and may be added to the USNVC when sufficient data has been collected, and funding is available to support their addition.
- A “(PS)” at the end of an association name denotes that the type is a “park special”, meaning it has been described as a *unique community that is expected to be found only at that park unit*. This typically occurs when an area has a unique disturbance or management history.

Vascular and nonvascular plant species nomenclature for Association names follows the nationally standardized list maintained by USDA in the [PLANTS database](#) with very few exceptions. Examples of association names from CHIR:

Pinus discolor / *Quercus toumeyi* - (*Garrya wrightii*) / *Muhlenbergia emersleyi* Wooded Shrubland Association (P)

(*Pseudotsuga menziesii* - *Hesperocyparis arizonica*) / *Quercus rugosa* - *Quercus chrysolepis* Forest Association (P)

Project Area Description

Location and Setting

Chiricahua National Monument is located in southeastern Arizona, approximately 50 km southeast of Willcox, Arizona, and encompasses ~4,866 hectares (12,025 ac) on the northwestern side of the Chiricahua Mountains (Figure 1). The Chiricahua Mountain Range is an inactive volcanic range approximately 32 kilometers wide and 64 kilometers long. It forms part of the Apache Highland section of the Basin and Range Province (Dimmitt et al. 2015). The monument is considered one of the region's “Sky-Island” mountains (Dimmitt et al. 2015), within what is commonly referred to as the Madrean Archipelago—an area of high mountain peaks surrounded by low-elevation deserts between the southern end of the Rocky Mountains and the northern end of the Sierra Madre Occidental. Elevations at the monument range from 1,562 meters in the western portion to 2,358 meters at the northern boundary and 86% of the monument’s acreage is designated wilderness (National Park Service 2005).

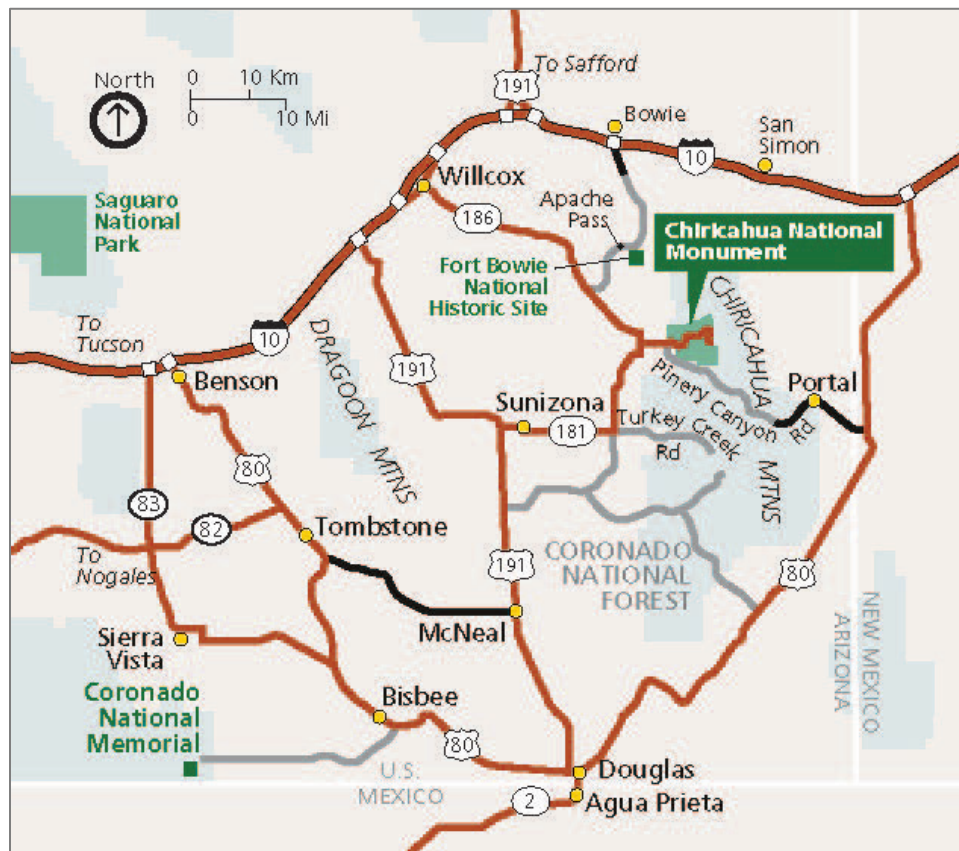
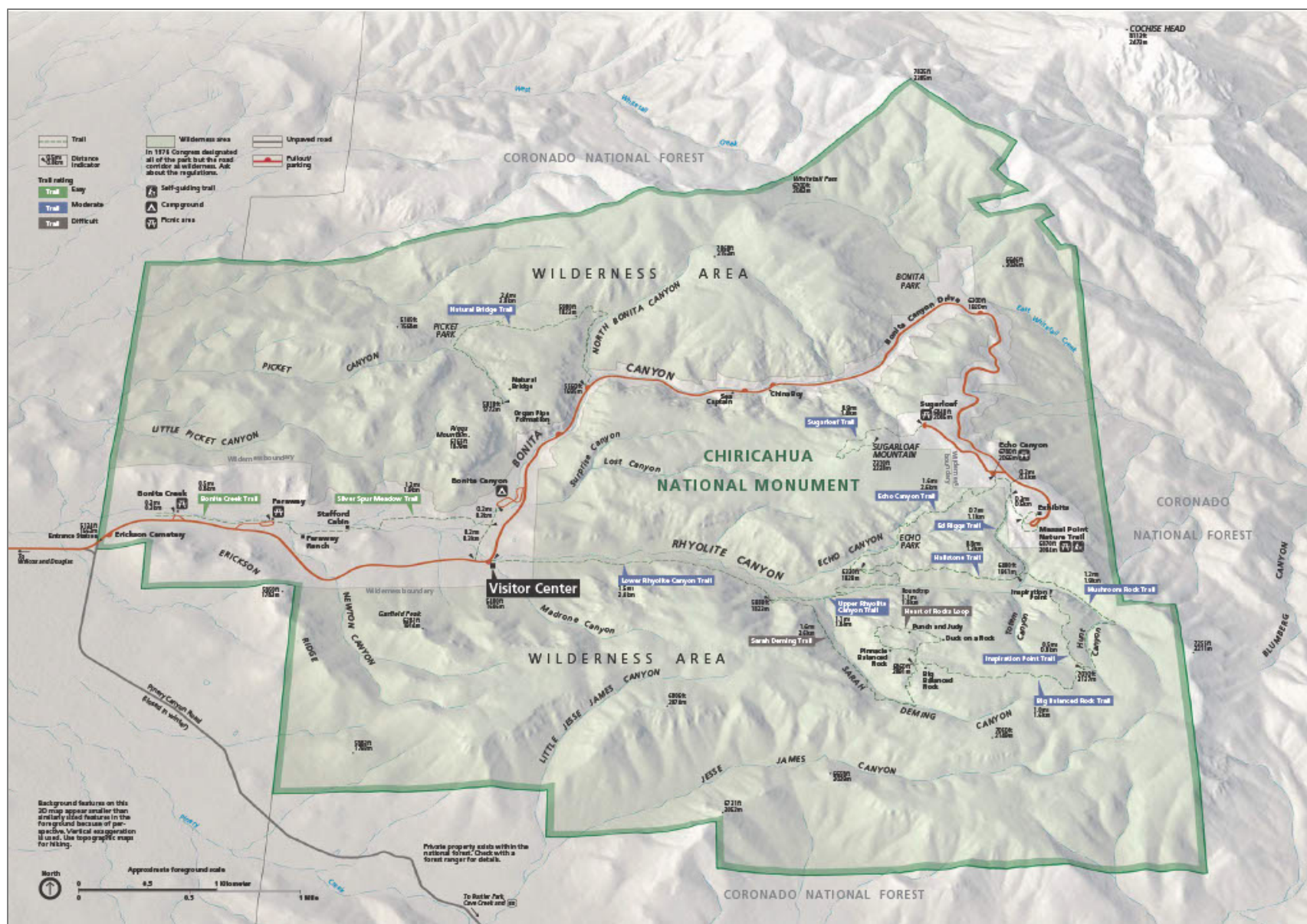


Figure 1. Chiricahua National Monument located in southeastern Arizona, approximately 50 kilometers southeast of the town of Willcox. NPS

The topography varies greatly throughout the monument, from lower-elevation grassy meadows to steep rocky canyons and high plateaus (Figure 2). Vegetation follows these gradients, ranging from grass-dominated savannas to mid-elevation chaparral, scrub, and pine-oak woodlands to upper-elevation mixed-conifer forests. The monument is bounded to the north, south, and east by US Forest Service lands and to the west by privately owned ranching properties (Powell et al. 2008).

Chiricahua National Monument lies at an ecological crossroads of four of North America's major eco-regions (Groves et al. 2002). The hot and dry Sonoran Desert meets the somewhat milder Chihuahuan Desert, and the southern Rocky Mountains transition to the northern Sierra Madre Occidental (Figure 3). This mixing of life zones results in a very diverse ecosystem, which is reflected in the variety of plant and animal life that is present (National Park Service et al. 2005). The monument falls within the Apache Highlands ecoregion (Turner et al. 2004), which incorporates the entire Madrean Archipelago/Sky Island region and spans portions of Arizona and New Mexico in the United States and portions of Sonora and Chihuahua in Mexico. It is best known for its archipelago of sky islands, which are high-elevation mountain ranges supporting pine-oak woodlands and mixed conifer forests rising above the valley basins where one finds desert scrub and grasslands dominant (Turner et al. 2004).



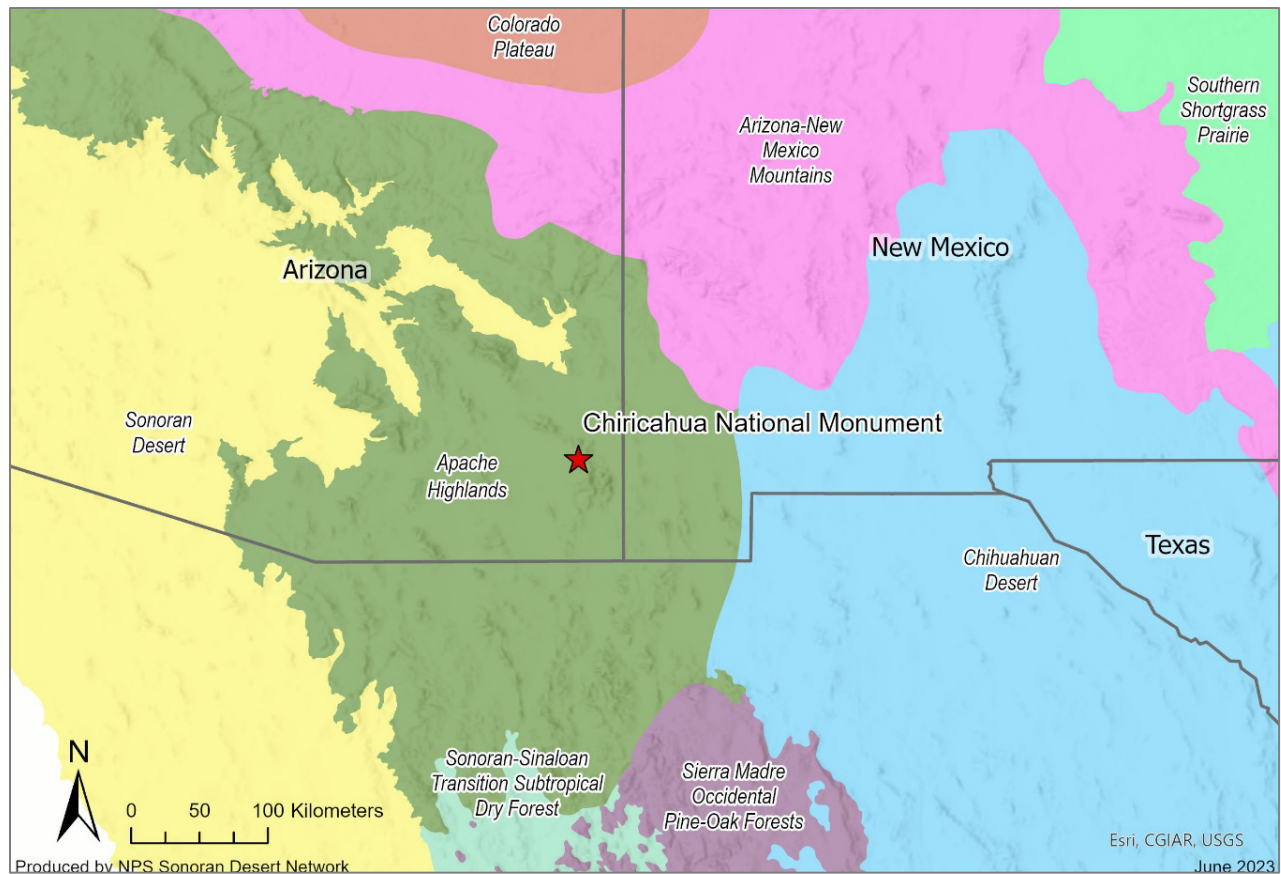


Figure 3. Regional biogeography, Chiricahua National Monument. NPS

Park Establishment and Purpose

The monument was established in 1924 to preserve unique volcanic structures and rock formations (Figure 4; US Presidential Proclamation No. 1692). The formations are the result of an eruption of the Turkey Creek Caldera during the middle Tertiary period (Denny and Peacock 2000). Other important historical and prehistoric sites are located within the monument, including Civilian Conservation Corps (CCC) structures, early ranch settlements (Faraway Ranch and Stafford Cabin), and a historic Buffalo Soldier military encampment. The monument also contains several locations of great cultural importance to our tribal partners.



Figure 4. View of a steep canyon with hoodoo rock formations. NPS

Climate, Geology, and Hydrology

Climate

The area experiences bimodal precipitation typical of the Sonoran Desert and Apache Highlands ecoregions, with heavy summer monsoon storms and lighter, prolonged rains during the winter months. On average, about one-half of the annual precipitation falls between July and September (Powell et al. 2008). The climate is arid to semi-arid, with summer temperatures reaching and often exceeding 40°C. Winter temperatures dip below freezing, and snow is common in winter months (Figure 5). More detailed information on climate and climate monitoring at CHIR is available at [SODN Monitoring Reports](#).

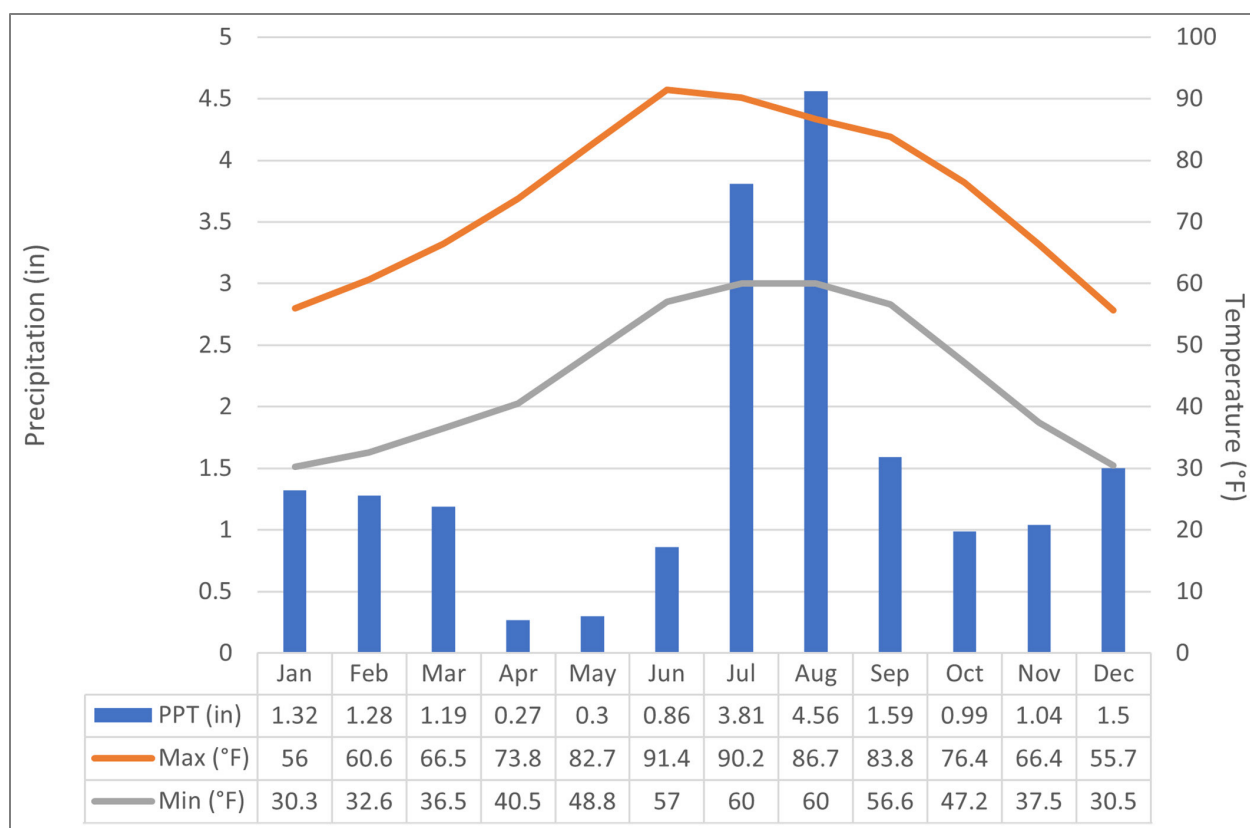


Figure 5. Mean monthly precipitation (PPT) and maximum (max)/ minimum (min) air temperature for CHIR, based on 1991–2020 climate normal (National Centers for Environmental Information, Station ID USC00021664). NPS

Soils and Geology

Most of the monument is dominated by very steep mountain-side slopes and nearly vertical cliffs and escarpments dissected by small drainages. The complex nature of the geology is mainly a result of the eruption of the Turkey Creek caldera and later volcanic events. The soils are derived mainly from the rhyolitic ash-flow tuff or dacite lava flows and are shallow, commonly less than 51 cm to bedrock (Denny & Peacock, 2000). The tuff contains joints and fractures formed as the tuff cooled and contracted (Graham 2009). Erosion caused by water flowing through these joints, in addition to wind erosion, frost wedging caused by freezing and thawing cycles, plant root wedging, and lichen weathering, has created the rock formations characteristic of the monument (Bezy 2001 and Graham 2009). The National Park Service hosts a [geodiversity atlas page](#) that links to published resources related to the full suite of natural geological and soil resources and processes that occur in the park.

Hydrology

Within the Rhyolite Canyon Tuff are less permeable, densely welded tuff layers (Pallister and du Bray 1997), which may laterally divert water either to a surface exposure, resulting in a spring, or to a fracture, resulting in deeper infiltration (Raymond et al. 2024). CHIR is mainly within the Willcox groundwater basin, with a small northeastern portion in the Safford groundwater basin. Groundwater storage at CHIR occurs within fractured rock and the alluvium of the canyon bottoms (Dimmitt et al.

2015). Snowmelt appears to account for 60% of the groundwater recharge at CHIR, despite only accounting for 30% of the annual precipitation (Earman et al. 2006). The slow percolation of winter precipitation through the fractures and alluvium recharges local aquifers and supports perennial springs and intermittent pools and flowing reaches often present in the canyon bottoms. The high-intensity storms, characteristic of summer precipitation, are more likely to runoff and be lost to evapotranspiration, resulting in less effective recharge of local aquifers than the relatively slow and steady winter precipitation (Raymond et al. 2024). There are five major drainages within the monument, of which the largest two, Bonita and Rhyolite canyons (see Figure 2), have intermittent flow supporting riparian species (Powell et al. 2008), such as Arizona cypress (*Hesperocyparis arizonica*), netleaf hackberry (*Celtis reticulata*), and Arizona sycamore (*Platanus wrightii*).

Vegetation

Due in large part to its aforementioned position between four major ecoregions, CHIR boasts a relatively high diversity of both plants and animals. The monument supports at least 803 documented plant taxa (Dimmitt et al. 2015), including some dominant species of Chihuahuan and Madrean (referring to the Sierra Madre Occidental Mountain Range) origins, such as Madrean pines (*Pinus discolor*, *P. arizonica*, *P. engelmannii*, and *P. leiophylla*) and Madrean oaks (*Quercus arizonica*, *Q. emoryi*, *Q. hypoleucoides*, *Q. toumeyi*, and *Q. rugosa*). Typically, the herbaceous component is dominated by grasses including longtongue muhly (*Muhlenbergia longiligula*), bullgrass (*M. emersleyi*), and pinyon ricegrass (*Piptochaetium fimbriatum*). See Hubbard et al. 2015 for additional details on characteristic flora within the monument.

CHIR has a diverse and rugged environment that creates multiple habitat types including riparian gallery forests, grasslands (Figure 6), shrub savannas, open woodlands, chaparral, and forested drainages and mountain tops (Hubbard et al. 2015). The vast craggy bedrock expanses of the monument have shallow soils in pockets, and vegetation frequently becomes sparse. The primary structural types of the monument are chaparral, oak-dominated woodlands, and pine-oak forests (Figure 7), with semi-desert grasslands occupying the lower elevations of the monument's western edge (Figure 8).

Chaparral communities cover large swaths of the monument's broad mountain slopes and are dominated by low-growing, evergreen shrub species such as Toumey oak (*Quercus toumeyi*), pointleaf manzanita (*Arctostaphylos pungens*), mountain mahogany (*Cercocarpus montanus*), silktassel (*Garrya wrightii*), and sumacs (*Rhus* spp.; Hubbard et al. 2015). Border pinyon (*Pinus discolor*), a small fire-intolerant tree, was frequent and at times abundant in these communities but has declined dramatically following the Horseshoe Two Fire. Chaparral communities are well adapted to heat, fire, and drought, with most species sprouting prolifically from root crowns (e.g., oaks) or readily germinating (e.g., manzanita) after burning. Border pinyon, in contrast, is highly susceptible to fire, and its previous abundance in these communities was likely due to fire exclusion during the 20th century (Swetnam et al. 1989).



Figure 6. Grass- and forb-dominated meadow with scattered mesquite trees (*Prosopis glandulosa*). NPS



Figure 7. Intermittently flooded drainage dominated by silverleaf oak (*Quercus hypoleucoides*) and Chihuahuan pine (*Pinus leiophylla*). NPS



Figure 8. Semi-desert grassland slope, dominated by native bunch grass and dotted with agave (*Agave palmeri*), alderleaf mountain mahogany (*Cercocarpus montanus*) and other shrubs. NPS

Surrounding the mountain slopes in the mid-elevations, shallow ephemeral drainages support a mixed community of oak, alligator juniper, and shrubs. Following these drainages into the higher elevations and deeper-sided and more sheltered canyons, the species composition changes to be dominated by different oaks, primarily silverleaf (*Q. hypoleucoides*), mixed pine (*P. arizonica*, *P. engelmannii*, and *P. leiophylla*) and eventually Douglas-fir (*Pseudotsuga menziesii*). The two main intermittent drainages in the monument, Rhyolite and Bonita canyons, are forested areas composed of riparian vegetation, with dominant Arizona pine (*Pinus arizonica*) and Arizona cypress (*Hesperocyparis arizonica*).

The forests and woodlands at CHIR are composed primarily of Madrean pines or madrones (*Arbutus arizonica*) and evergreen oaks (*Quercus hypoleucoides*, *Q. arizonica*, *Q. emoryi*, or *Q. rugosa*). These wooded areas intermingle and transition to the more open canopied wooded shrublands dense with manzanita (*Arctostaphylos pungens*; Figure 9) and Toumey oak (*Q. toumeyii*) or pinyon-juniper woodlands (Hubbard et al. 2015; Dimmitt et al. 2015).



Figure 9. A wooded shrubland with dense pointleaf manzanita (*Arctostaphylos pungens*). NPS

Previous Vegetation Studies

The vegetation has been the subject of many previous studies, including an earlier mapping effort. The earlier mapping, titled “The Vegetation Type Survey of Chiricahua National Monument”, was completed by two junior foresters of the then Branch of Forestry within the NPS and took place over two years, from 1937 to 1939. The park had been transferred from USFS to the NPS in 1934, and a large parcel was added in 1938, bringing it to 10,887 acres. The junior foresters collected data and photographs and created a map by hand-sketching boundaries onto a topographic map which were then attributed with dominant species that “appeared in the type to 20%” and by design only included species that could be viewed from above, meaning any understory dominants were not recorded on the map. Plants collected during this effort were sent to Boyce Thompson Arboretum in Superior, Arizona, (for identification, perhaps also accessioned), and two copies per specimen were sent to the NPS herbarium, Department of Botany, University of California, Berkeley, California.

The objectives of this project were much the same as they were for our current work over 70 years later, which aimed to provide data as a basis for fire hazard and protection planning, insect and disease control, recreation use planning, wildlife, reforestation, and erosion control planning and “generally augmenting the supply of knowledge concerning the floral and other natural features of the monument” (Roseberry and Dole 1939). Their inventory produced a report and map showing relatively detailed map units combining structural observation (forest vs. shrubland) with the dominant species present. The report identifies and describes 14 types roughly akin to the group or sometimes alliance level in the NVC, listed as chaparral, barren, grassland, residential, sagebrush, timberland chaparral, woodland chaparral, semi-desert chaparral, woodland grass, woodland, Douglas-fir, pine, pine-Douglas-fir, and pinyon-juniper-cypress. Within each of these, sub-dominant species assemblages were identified each with their total acreage estimates given. There is not

enough information in this older report on the methodology used, nor any location data other than coarse section-township-range identifiers, that would allow a direct comparison between these finer “map units” and the associations as described and mapped in this project.

The Sonoran Desert Network (SODN) monitoring program began implementing long-term monitoring of vegetation communities at CHIR in early 2007 when the first permanent site was established following the Uplands Vegetation and Soils monitoring protocol (Hubbard et al. 2015). Additional sites were subsequently established over a 4-year period across all elevation zones at the monument, using a spatially balanced and random allocation design proportional to the area within each elevation and soil rock fragment stratum (Hubbard et al. 2015). A total of 47 plots were established between 2007 and 2011, with 10 of these sites established post-fire in 2011. All plots were scheduled to be re-sampled every five years thereafter. Using a power analysis to evaluate the power to detect trends in vegetation parameters of interest (Hubbard et al. 2015), the decision was made to keep only the 37 pre-fire plots in the long-term schedule, as this reduced sample size permitted direct pre-and post-fire comparisons while still achieving the statistical power and species detection objectives of the protocol. Due to the anticipated major fire effects on vegetation communities, SODN staff revised the revisit schedule and sampled 37 plots 1-year post-fire (2012) and then returned to the initial schedule of sampling every five years post-establishment, with the third round of sampling completed from 2017 to 2021. Data from these sites were referenced in the classification work for this project. An additional complete panel (=37 plots) of sampling was planned for three years post-fire (2015) but not implemented due to a lack of available funding.

Fire effects monitoring work was initiated at CHIR in 1988 and has continued with varying consistency (due to funding and staffing availability) to the present. After the 2011 Horseshoe Two Fire, the interagency fire program based out of Saguaro National Park undertook a sampling of ~26 previously established monitoring plots across herbaceous and wooded areas of the park. These plots are resampled at specific pre- and post-fire intervals to collect data on fire effects on vegetation and fuel loading. Data from that program are scheduled to be reviewed and analyzed beginning in fall 2024.

In addition, CHIR has long been an area of interest to researchers and has been the subject of many short-term research projects, many of which can be found in [NPS' IRMA DataStore](#) and [NPS' Inventory & Monitoring \(I&M\) Vegetation Inventory Products](#).

Exotic (Non-native) Plants

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

fire suppression, are thought to have contributed to the susceptibility of arid lands to invasion and the subsequent loss of native species and decreased biodiversity (Brown and Archer 1999).

Reduced species richness and biological soil crust cover are indicative of communities degraded by grazing, and these factors have been linked to invasion by non-native grasses in place of native species that are less able to adapt to such pressures (Shinneman and Baker 2009). In general, the southwestern semi-desert grasslands, savannas, and riparian community types are at greatest risk of invasion due to modified disturbance regimes involving fire and herbivory.

Though multiple plant species lists were created for the monument between the late 1930s and the late 1990s, the first known systematic attempt to document and map non-native species was made by Halvorson and Guertin in 2003 (summarized in Powell et al. 2008). The Sonoran Desert Network's 37 permanent soil and vegetation monitoring plots (Hubbard et al. 2015) provide insight into the distribution and spread of non-native species in areas with little direct anthropogenic disturbance. In 2011, 2012, and 2022, SODN field staff additionally mapped populations of non-native plants along roads and trails, which can act as vectors that facilitate the spread and establishment of invasive species. At the time of writing, at least 62 non-native species are known to occur at CHIR, representing approximately 7% of the monument's flora. Sixty-one of these species are included in a list compiled by Powell et al. (2008) from herbarium records and previous survey efforts. One additional grass species, yellow bluestem (*Bothriochloa ischaemum*), was first documented in the park ca. 2011.

The majority of the non-native plants documented at CHIR are not widespread in the park, and many are associated with the Faraway Ranch historic site (Powell et al. 2008; SODN 2022). However, a few species, including rescuegrass (*Bromus catharticus*), bermudagrass (*Cynodon dactylon*), mouse barley (*Hordeum murinum*), prickly lettuce (*Lactuca serriola*), London rocket (*Sisymbrium irio*), and sow thistle (*Sonchus* spp.), all regionally widespread, are apparently well-established at CHIR, particularly in lower Bonita Canyon between the visitor center and the park entrance (SODN 2022). Two non-native perennial grasses, Lehmann lovegrass (*Eragrostis lehmanniana*) and weeping lovegrass (*Eragrostis curvula*), are widespread throughout the park and occur at varying densities in a variety of habitats (SODN 2022). Yellow bluestem (*Bothriochloa ischaemum*) is currently restricted to disturbed sides of roads and trails in low-elevation areas (SODN 2022) but is relatively new to the monument and may continue to spread. A few species, including Russian thistle (*Salsola* spp.), horehound (*Marrubium vulgare*), and puncturevine (*Tribulus terrestris*), have been the targets of recent treatment by the NPS Southwest Invasive Plant Management Team (SWIPMT). Crew members have carried out manual treatment (hand-pulling) of these species at lower Bonita Canyon and Erickson Ranch and have reseeded some of the treated areas with native seed (SWIPMT 2021).

Lehmann lovegrass is of particular management concern at CHIR due to its potential impact on native vegetation at the monument. This species was introduced to southern Arizona for forage and erosion control purposes in the 1930s and has since become widespread in the semidesert grasslands in the region (Anable et al. 1992; Schussman et al. 2006; Burruss et al. 2022). Even in undisturbed habitats, Lehmann lovegrass can almost completely displace native vegetation, leading to a variety of

ecological consequences such as altered soil evapotranspiration (Moran et al. 2009) and higher intensity fires due to increased fuel loads (Williams and Baruch 2000) in invaded areas. Wildlife species that depend on native plant species or require open habitats are likely to be adversely affected as relatively sparse native grasslands are overtaken by dense stands of Lehmann lovegrass (Steidl et al. 2013). Insect abundance and diversity have been shown to decrease with increasing Lehmann lovegrass cover (Litt and Steidl 2010; Andersen et al. 2019). Lehmann lovegrass was present in CHIR by the early 1990s (Powell et al. 2008). It was observed in 12 of 15 SODN long-term vegetation monitoring plots located below 6,000 feet (1,829 m) elevation between 2007 and 2010 but was only present in 5 of 23 plots above 6,000 feet during this same time period (Hubbard et al. 2015). By 2021, it was present in all plots below 6,000 feet and in 16 of 23 plots above 6,000 feet (SODN 2022).

In the April 2022 exotic plant early-detection surveys, Lehmann lovegrass was found to be abundant in the lowest elevation areas of the park (e.g., Bonita Canyon Road between the park entrance and the visitor center) and in areas that appeared to have experienced the highest burn severity during the 2011 Horseshoe Two Fire (e.g., parts of the Natural Bridge Trail). Though still consistently present at higher elevations, it was observed to generally form low-density patches of less than 5% canopy cover except on burned slopes with southern exposure, such as along the Hailstone Trail (SODN 2022).

Disturbance History

Aside from wildfire (discussed in depth below), past and to a lesser extent present human activity is a primary source of ecological disturbance in Chiricahua National Monument.

Human History

Prior to the late 19th century, the area was occupied by the Chiricahua Apache, who used it as hunting and foraging grounds but apparently did not establish permanent settlements (Erickson and Johnson 2013). In the 1880s, two homesteads, which would later become Faraway Ranch, were established in lower Bonita Canyon. The ranch encompassed multiple acres of land cleared for buildings, gardens, fields, and orchards, and it was occupied until the NPS acquired the land in 1978 (Erickson and Johnson 2013). Surrounding lands, including a leased allotment that encompassed much of the present-day monument, were used for grazing cattle and horses until 1968 (Wegman-French 2006). According to Powell et al. (2008), cattle grazing is no longer a significant source of disturbance in the monument, though occasional instances of livestock trespass have occurred since the cancellation of grazing permits.

Mining has also been a source of anthropogenic disturbance at CHIR. The King of Lead Mine, located just outside the northern boundary of the monument, produced lead, silver, zinc, gold, and copper between 1924 and 1970 (USGS). Tailings associated with the mine have continued to leach heavy metals, sulfates, calcium, and chloride, impacting water sources in the monument (Powell et al. 2008).

Aside from a spike in visitation in the 1990s, the park has generally received between 40,000 and 70,000 visitors annually since the mid-1950s (Figure 10). Little significant disturbance from park visitation has been reported outside of designated day use areas, campgrounds, and trails. According to Dimmitt et al. (2015), a small area near the Massai Point trailhead has been heavily disturbed by visitors straying from established roads and trails, but the impact of this appears to be minimal as the area is rocky and not particularly susceptible to erosion.

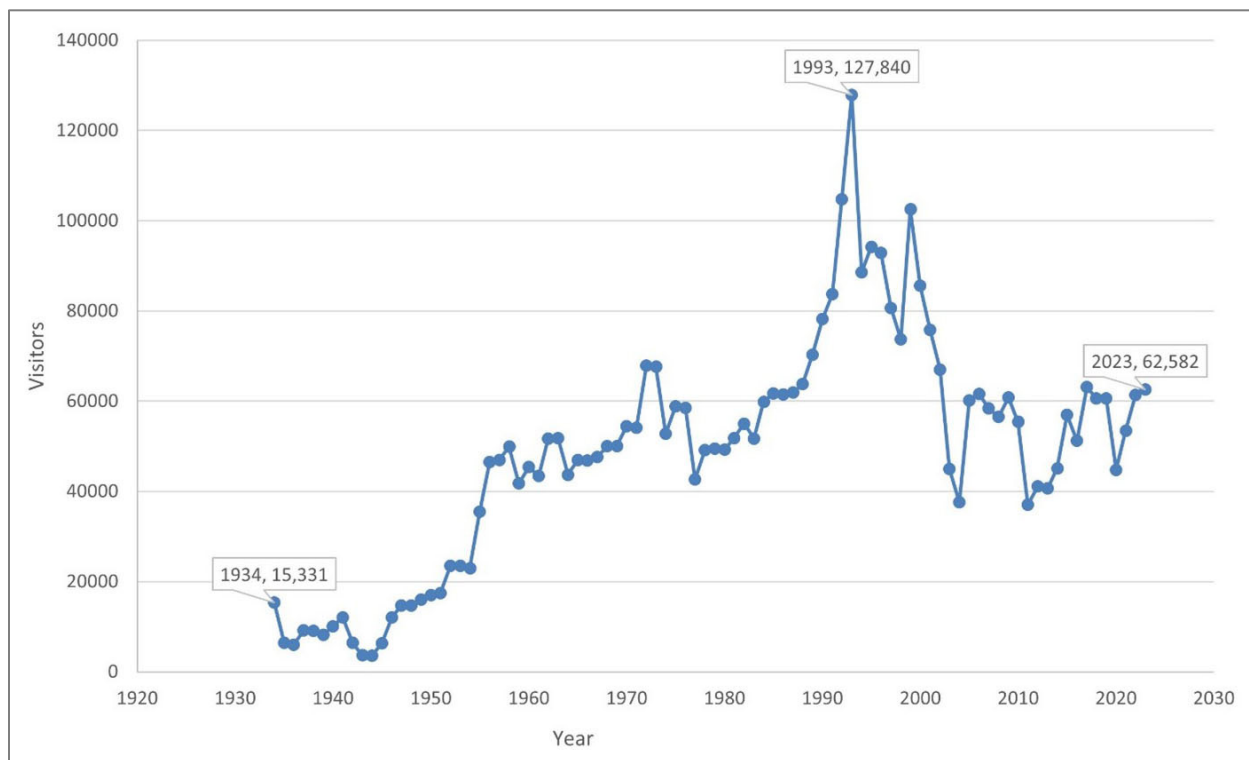


Figure 10. Visitation at Chiricahua National Monument, 1934–2023. NPS

Wildfire History

Fire heavily influences vegetation composition and structure in the arid regions of the southwestern US and northern Mexico. Historic fire regimes, which were largely influenced by fire use among various Indigenous peoples, were interrupted by widespread cattle grazing and active fire suppression beginning in the late 19th and early 20th centuries (Kaib et al. 1996; Bahre 1998), resulting in a decades-long buildup of fuel loads and increasing presence of fire-sensitive woody shrub and tree species in vegetation types that had previously experienced frequent fire (O'Connor et al. 2014). Pre-suppression fire regimes at CHIR are well-documented by several dendrochronological studies (Swetnam et al. 1989) and can be roughly separated into three categories based on broad vegetation communities. Semi-desert grasslands and oak-pine woodlands dominated by Chihuahuan pine (*Pinus leiophylla*), Apache pine (*P. engelmannii*), Arizona oak (*Quercus arizonica*), Emory oak (*Q. emoryi*), and silverleaf oak (*Q. hypoleucoides*), experienced frequent, low-severity fires with intervals of approximately 5 to 15 years (Swetnam et al. 1989; Kaib et al. 1996; Baisan and Morino 2000; Taylor et al. 2021). These fires maintained open understories but largely spared mature trees, while grasses

and oaks quickly resprouted. In contrast, pinyon-juniper-cypress woodlands, defined by the presence of the fire-sensitive conifer species border pinyon pine (*Pinus discolor*) and/or Arizona cypress (*Hesperocyparis arizonica*), occurred primarily in areas protected from frequent fire by high soil moisture or physical barriers (such as exposed bedrock areas) and infrequently burned (on intervals ranging from 80 to 400 years) at mixed severity, often resulting in high mortality of mature trees and a subsequent period of high seedling recruitment (Baisan and Morino 2000; Taylor et al. 2021). Similarly, chaparral communities dominated by pointleaf manzanita (*Arctostaphylos pungens*) and shrubby oaks such as Toumey oak (*Quercus toumeyii*) were characterized by moderate- to long-interval (20–100 years), high-severity fires (Baisan and Morino 2000).

The last widespread wildfire in CHIR before the era of modern fire suppression occurred in 1886 (Swetnam et al. 1989; Baisan and Morino 2000). Around the turn of the 20th century, the US Forest Service implemented active fire suppression policies (Swetnam et al. 1989). A smaller wildfire burned parts of the monument in 1924 (Baisan and Morino 2000), after which wildfire appears to have been entirely absent from CHIR until 1984, when the Picket Canyon wildfire burned 91 acres in the northwest corner of the monument (US Monitoring Trends in Burn Severity¹ [[MTBS](#)] Program). Prescribed fire was introduced to the monument in the late 1980s, and a total of 1,076 acres (approximately 9% of the total area of the monument) were burned in 14 fire events between 1987 and 2003 ([MTBS](#)).

Recent Wildfire—Horseshoe Two

The Horseshoe Two Fire was ignited on May 8, 2011, in Horseshoe Pass in the southeastern portion of the Chiricahua Mountains (NPS 2011), approximately 12.5 miles southeast of CHIR. Over the following month, the fire proceeded to burn the majority of the mountain range, aided by high winds, low humidity, and high temperatures (NPS 2011), and possible vegetation mortality caused by the combination of extreme drought conditions and a severe freeze event in February 2011 (NOAA; Poulos 2014; Williams et al. 2014). On June 8, the fire first entered the southeast corner of CHIR, and then burned through East Whitetail Canyon outside the monument (NPS 2011). On June 9, the fire entered the monument a second time, burning westward through Rhyolite and Jesse James canyons. Fire crews successfully used retardant and burnout operations to protect park structures (NPS 2011). By the time the fire was declared 100% contained on June 25, 2011, it had burned a total of 222,954 acres, encompassing the full 12,176 acres of CHIR (NPS 2011).

While the Horseshoe Two Fire burned through the vast majority of CHIR, burn severity varied widely between different parts of the monument, and unburned patches occurred where local conditions limited fire spread. To help determine the extent and severity of fire damage, SODN field staff visited 52 established monitoring sites throughout CHIR in the weeks and months following the fire—from June to September 2011. This included the 37 sites that are part of SODN’s long-term vegetation monitoring, as well as 15 sites that had been established but were not kept within the long-term sample. At each site staff recorded vegetation and soil burn severity as one of five classes:

¹ MTBS is an interagency program whose goal is to consistently map the burn severity and extent of large fires across all lands of the United States from 1984 to present.

unburned, scorched, lightly burned, moderately burned, or heavily burned, based on a standard NPS fire effects monitoring protocol (NPS 2003). Eight sites were found to be unburned, three were scorched, twelve were lightly burned, twenty-seven were moderately burned, and two were heavily burned (SODN 2011). This field effort was done to inform our monitoring work, increase the accuracy of the Burned Area Reflectance Classification (BARC) map of fire severity, and assist the park in understanding fire impacts. Additionally, it now serves to inform how we might interpret or understand medium- and long-term vegetation changes related to fire effects.

To estimate the total coverage of each of these burn severity classes across the entire monument, we obtained a raster map of delta normalized burn ratio (dNBR) sourced from MTBS, which is an indicator of burn severity mapped as part of the standard Burned Area Response (BAR) of any large wildfire (Eidenshink et al. 2007). We sampled this raster to extract the severity value at the location of each SODN monitoring site visited post-fire using ESRI ArcMap software. Based on this sample, we identified the range of dNBR values that best corresponded with each burn severity class observed in the field. The scorched and lightly burned classes were combined to form a low severity class, as the range of dNBR values at plots categorized as scorched fell entirely within the range of values extracted from the dNBR for lightly burned plots. Based on this classification, we estimate that

- 16% remained unburned (dNBR < 165),
- 46% burned at low severity (dNBR 165–420),
- 25% burned at moderate severity (dNBR 420–600),
- 13% burned at high severity (dNBR > 600).

Burn severity was highest on the high-elevation, moderately steep, and relatively undissected upper slopes located in the southeast and northeast corners of the monument and in the vicinity of Sugarloaf Mountain (Figure 11). Bonita and Rhyolite canyons, which are the most mesic areas of the monument, were largely unburned or lightly burned. Similarly, the highly dissected, rocky slopes in the central part of the monument and around the Echo Canyon, Ed Riggs, Hailstone, Big Balanced Rock, and Sara Deming trails experienced relatively low burn severity. The lowest elevation part of the monument, encompassing the park entrance, Faraway Ranch, the administration area, and the visitor center, includes swaths of unburned areas, likely owing to firefighting efforts. Otherwise, these areas burned mostly at low severity with occasional small patches of moderate or high severity. The northwest corner of the monument largely burned at low severity, with some areas of high severity primarily on north-facing slopes. Statistical analyses of burn severity data have indicated that dNBR was influenced primarily by weather at the time of the fire, elevation, slope angle and ruggedness, topographic position, as well as vegetation type and density (Poulos et al. 2021; Taylor et al. 2021).

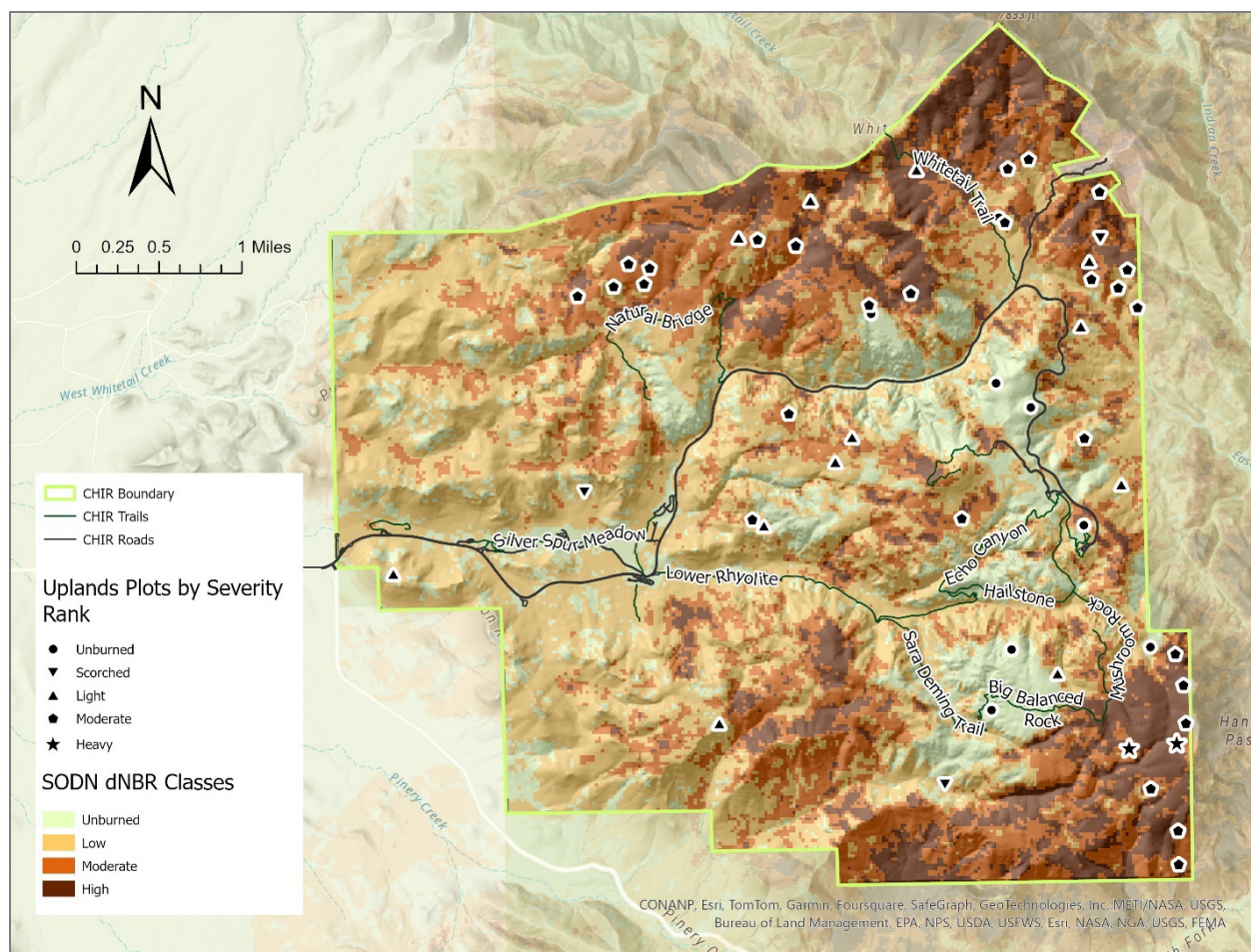


Figure 11. Fire severity of the 2011 Horseshoe Two Fire at CHIR, calculated using delta normalized burn ratio (dNBR) raster layer. Locations of vegetation plots where fire severity was measured on the ground by SODN field staff between June and September 2011 are symbolized by severity type. NPS

In May 2018, the Pinery Fire burned approximately 1,400 acres north of Pinery Canyon Road, including approximately 740 acres in the southwest corner of CHIR, almost entirely at low severity ([MTBS](#); Eidenshink et al. 2007). This is the only known fire to have occurred in the monument since the Horseshoe Two Fire, and due to its small size and low severity, it likely had little impact on the distribution of vegetation communities within the monument.

Chapter 2: Classification and Mapping of Plant Communities

Data Collection and Mapping of Plant Communities

Planning and Scoping

A general planning and scoping meeting was held on September 27, 2007, at the United States Forest Service (USFS) Sierra Vista Ranger Station. As Chiricahua National Monument (CHIR) is administered jointly with two other Southeast Arizona parks, Fort Bowie National Historic Site (FOBO) and Coronado National Memorial (CORO), the meeting addressed the work plan for all three units. Representatives from land management agencies neighboring the three units were present, including Fort Huachuca (Department of Defense), USFS, Arizona state parks, and the United States Geological Survey (USGS). The overarching purpose was to discuss the logistics of the effort and to identify any site-specific needs or modifications to the standard mapping process outlined. In addition, other agencies were invited to gauge the interest in expanding the mapping boundary and working collaboratively. While no such expansion was agreed upon, the meeting provided all present with details of the national program standards and the possibility of future cross-walking should similar projects be undertaken.

In later logistical meetings, it was agreed that CHIR would provide considerable support for the field crews, who would need to spend several months at CHIR to collect all the necessary classification data and subsequently conduct mapping. An available housing unit became the mapping teams' home away from home for approximately one year.

The FOBO and CHIR mapping and classification projects were the first to be initiated within the Sonoran Desert Network (SODN) and, as such, were the focus of SODN's early methodological testing. Several weeks of field trials took place, during which data collection methods were tested, evaluated, and revised.

Digital Imagery Acquisition and Processing

The imagery of CHIR used in this project was acquired by DigitalGlobe, Inc.'s Quickbird satellite in April 2005 as a new, tasked acquisition for a previous project. However, it was available to us for this mapping work through our project partners at the former Office of Arid Lands Studies (OALS), Arizona Remote Sensing Center, University of Arizona. Image preprocessing and initial interpretation of the vegetation formation level (woodland, grassland, road, etc.) were conducted by OALS staff. The imagery product purchased was the "Ortho-ready Standard" bundle of four spectral bands (blue, green, red, and near-infrared) at 2.4-m spatial resolution, plus the broadband panchromatic data at 0.6-m resolution.

The geographic area of coverage that was purchased was large, including CHIR, FOBO, and the mountainous area between the two. The imagery was acquired in two swaths on April 15 and 20, 2005. The larger of the two swaths of imagery was initially too large to work with in ERDAS Imagine v.8.7 (>2 GB), so the image was a subset in ENVI prior to geo-rectification and analysis.

The imagery was orthorectified with ERDAS (Leica) OrthoBase software, using a USGS National Elevation Dataset DEM, field-collected GPS coordinates of ground control points (GCPs), and the Quickbird Rational Polynomial Coefficient (RPC) model. During the rectification process, the coordinates of GCP locations were entered into a table and compared to image coordinates for the same control point locations. An optimal set of GCPs was selected for each image, and the images were rectified using a polynomial model with cubic convolution resampling.

Following orthorectification, the multispectral imagery was pan-sharpened for visual interpretation using the resolution merge tool in ERDAS Imagine. Principal components and cubic convolution were selected as merge parameters. Pan-sharpening is the process of merging the high-resolution 0.6-m panchromatic image with the 2.4-m multispectral image to produce a multispectral image with 0.6-m resolution.

The draft formation-level map was produced through visual interpretation of the pan-sharpened imagery, some basic supervised classification efforts using visible image texture and color properties (i.e., visual cover differences like between grassland and forest), and heads-up digitizing in ArcGIS to delineate polygons. Following the formation key² we previously developed, we identified eight initial formations based on the percentages of tree, shrub, and herbaceous cover: forest, woodland, intermittently flooded woodland/forest, wooded shrubland, shrubland, wooded herbaceous, shrub herbaceous, and herbaceous (Figure 12). Each polygon in the draft formation map was assigned a unique alphanumeric identifier for reference throughout the project. When formation polygons were split (see field methods), new “daughter” polygons were given appropriate IDs that were traceable to the parent (original) polygon. We prepared an index of 11×17-inch hardcopy prints of the tentative formation polygons overlaid on the background imagery at 1:4,000 scale with a 100-m UTM grid for use in the field-based mapping. The field team also had the digital formation map and the imagery available on handheld GPS-linked computers, allowing them to zoom in for viewing at multiple scales.

² Supplemental materials for this report, including the vegetation formation key, are available in NPS’ IRMA DataStore: [Vegetation Mapping Inventory Project for Chiricahua National Monument](#).

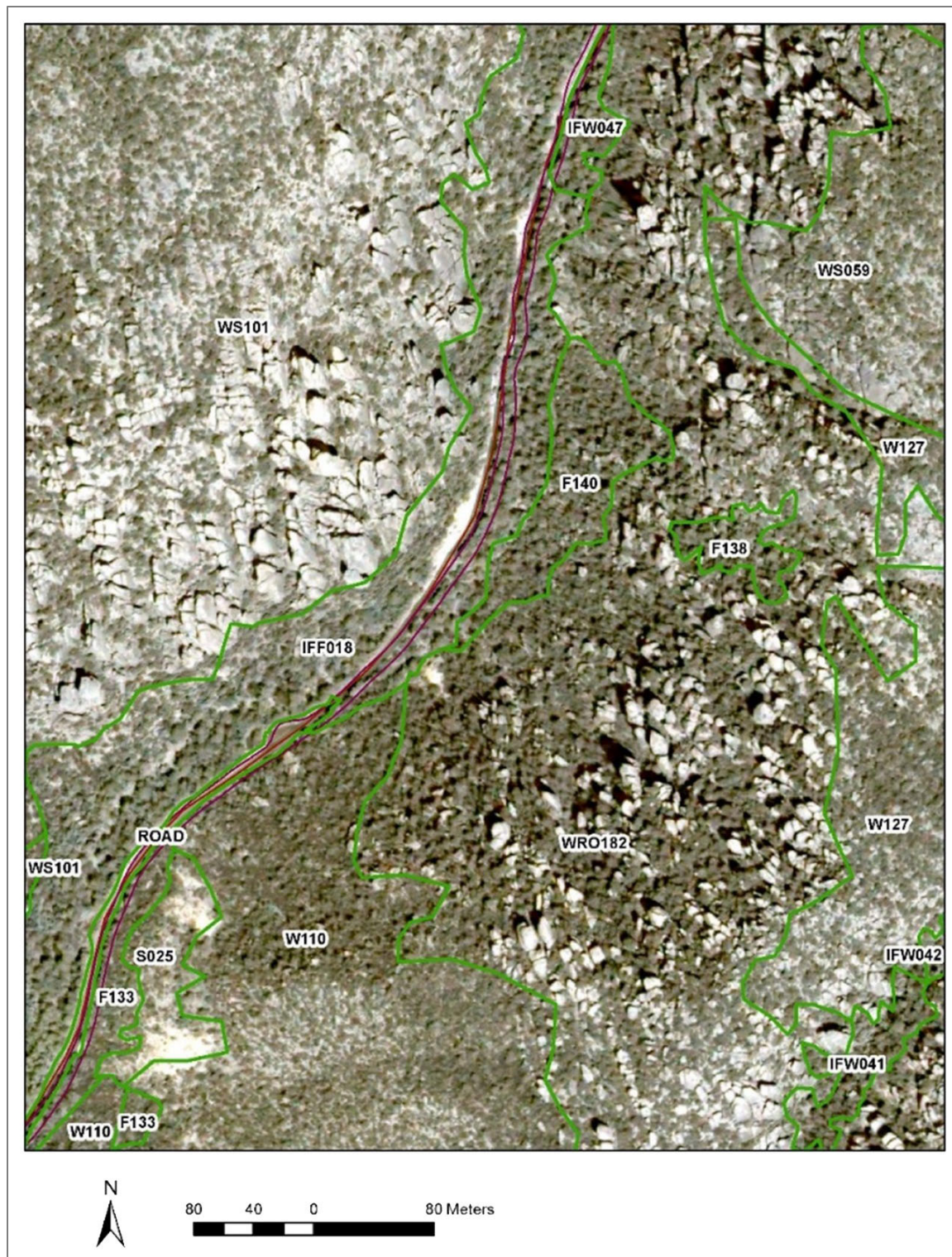


Figure 12. Example pan-sharpened multispectral imagery shows the original formation-level map units that served as the basis for mapping and classifying vegetation during this project. Labels indicate the preliminary formation assigned to each area. Shown are WS = wooded shrubland, W = woodland, IFF/IFW = intermittently flooded forest/woodland, S = shrubland, WRO = wooded rock outcrop, F = forest. NPS

Methods Overview

The methods used to classify and map vegetation generally followed the guidelines outlined in the NPS [Vegetation Inventory Program technical guidance and support documents](#); however, our approach was more integrated than the traditional practice. Our integrated approach was taken because USNVC types for the Apache Highlands and Sonoran Desert ecoregions were largely undeveloped at the time and we needed to both create and map these types. The usual iterative classification and mapping approach—where ecologists collect plot data to develop a classification, then have photo interpreters delineate polygons solely using imagery—would have added several years and considerable cost to the project. Instead, we used an integrated team of observers who concurrently collected plot and polygon scale data for classification while also modifying or creating map unit (polygons) in the field. A draft base map for the entire park had been created a priori by the OALS office based on visible image texture/color properties (see Figure 12). These draft polygons served as a starting point for mapping and were edited on paper hardcopy maps to meld ground observations, imagery, topography, and species occurrence data to refine the boundaries and types. The park was divided up into sub-maps using a grid overlay of the park, that allowed the crews to survey the park in manageable sections and assisted with navigation and planning. For each sub-map, the field crews were also given printed sheets of the same scale showing a topographic map and raw satellite imagery (without draft polygon lines) to aid observers in determining where a particular formation may extend or end without the bias of a preformed polygon. All field edits were subsequently transferred into digital format and later attributed with community-level data.

Field Data Collection

Classification Plots

The 2009 Standards for associations and alliances of the US National Vegetation Classification (Jennings et al. 2009) state the need for vegetation units to be sampled and described through the use of plot data. They recommend that plots be distributed in homogeneous areas to minimize sampling in areas with high physiognomic, floristic, and environmental variation, which would make interpretation of the plot data difficult. Determination of plot locations can be achieved via subjective or objective means; however, the former method necessitates prior knowledge of the various types to be sampled, and the latter can provide a less biased set of plots. One further consideration is that objectively placed plots may miss rare or unusual types. To address these issues, we sampled primarily by objectively locating plots using a spatially balanced random design augmented by a smaller number of plots subjectively located to account for known or suspected types that may have been under- or un-sampled by the probabilistic design.

Prior to commencing fieldwork, plot locations were preselected using the spatially balanced RRQRR (Reversed Randomized Quadrant-Recursive Raster) algorithm to provide an objective, park-wide sampling basis for vegetation classification (Theobald et al. 2007). Using this method, 200 non-stratified points were distributed across the entirety of CHIR. The number of plots distributed and sampled was determined by the authors, using their best judgment, knowledge of the park's vegetation diversity, and estimates of potential vegetation types, and with the knowledge that data

would also be collected at the mapping scale, within various sized mapped areas (elsewhere referred to as “polygon” data).

In total, 157 classification plots were sampled (Figure 13), of which 54 were subjectively placed to capture underrepresented or unique communities. Many of the original 200 were discarded due to safety considerations and inaccessibility—a major issue at CHIR, where extremely steep topography limits safe access in many areas of the monument.

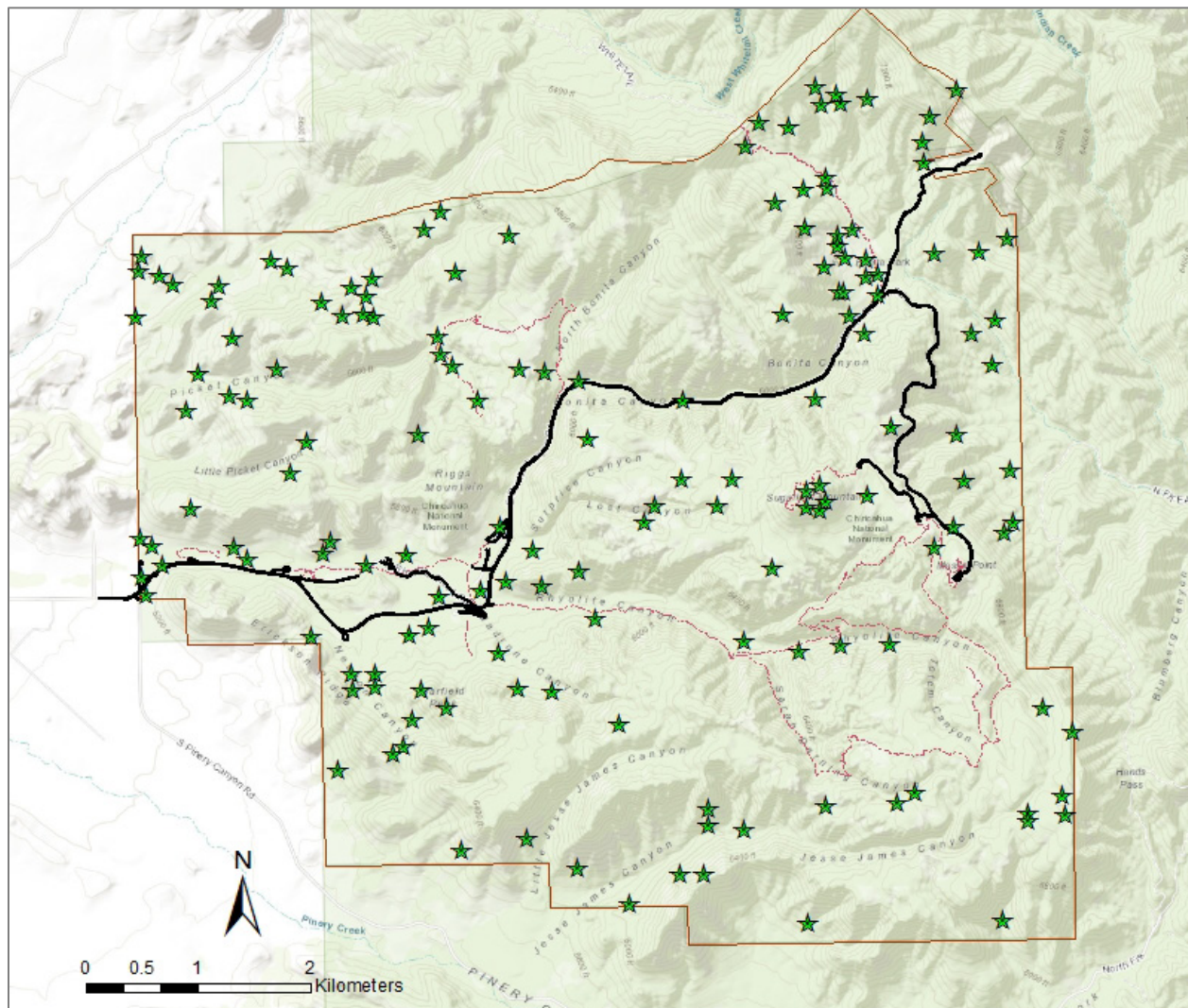


Figure 13. Distribution of the 157 completed classification plots at Chiricahua National Monument. NPS

All data were collected by an NPS crew of 4–6 people, typically working in pairs. Data collection occurred over approximately two years, with initial work done in early spring of 2008; however, the majority was completed from June to October 2008 and then from January 2009 until March 2010, spanning a total of approximately 310 person-days (2 crews x ~156 field days). Working in teams of two or more to facilitate a multiple-observer, consensus-based approach, a field crew visited each of the distributed points and associated draft polygons.

In the earliest iteration of the plot data collection, vegetation was evaluated by dominance and rank only, with crews listing the top three dominant plants in the tree (>2 m), shrub (<2 m) and field (a.k.a. herbaceous) strata, and ranking them in order of dominance as 1, 2, or 3. If plants shared dominance, the corresponding ranking number could be issued to two different species. Common associates found within the polygons were also listed, but no rank was assigned. Within a few weeks, the need for more detailed field data became evident. Field datasheets³ were updated to include a space for the “Keyed Formation”, which was based on the vegetation formation key developed by SODN to indicate the basic formation type of the polygon and included the following categories: forest, woodland, wooded shrubland, shrubland, herbaceous, and rock or bare soil.

Other changes included the re-evaluation of the tree, shrub, and field categories and changing the categories to be based on strata instead of life-form, resulting in the following: top canopy (>5 m), canopy (2–5 m), sub-canopy (0.5–2 m), and field (0.5 m or less). These new categories were supplemented by the addition of height in meters, lifeform (tree, shrub, or N/A for the field layer), and canopy cover classes indicated by a number code, along with the rank information previously collected. The introduction of the cover classes to the survey design resulted in more detailed field information on the vegetation communities and ultimately led to improvements in the vegetation typing process. Rank was not included for common associates, but cover classes and height were included. The more detailed method was formalized and followed for the bulk of the plots, with all plots and most of the polygons under the former method being revisited to have data updated.

The generated points served as one corner of a 1000 m² classification plot. Ideally, the plot represented the surrounding community; however, when it did not, the protocol allowed for crews to evaluate the surrounding vegetation and move the point up to 50 meters if deemed necessary. Crews laid out the plots to best capture the sampled community, both in terms of orientation and shape. Various shapes were employed to capture the targeted community, but the preponderance of plots was square, with sides measuring 31.6 meters. Within these plots, the crews collected ocular estimates on absolute canopy cover for all vascular plant species in four height strata: field (0–0.5 m), sub-canopy (0.5–2 m), canopy (2–5 m), and top canopy (>5 m). For these strata, crew members placed each documented species into one of nine broad cover classes: 1 (< 1%), 2 (1–5%), 3 (6–10%), 4 (11–25%), 5 (26–33%), 6 (34–50%), 7 (51–75%), 8 (76–95%), and 9 (96–100%). In general, crews only included perennial native and non-native species, and non-native annual species (due to their importance to invasive plant management); however, native annuals were documented only in the infrequent event that they provided a substantial amount of cover or were indicative of the community. Up to three species per stratum were also subjectively assigned a dominance rank based on their cover class and/or importance to the sampled vegetation community.

Additionally, crews recorded the average plant height (for the canopy and top canopy height strata only), lifeform of tree or shrub (excluding the field stratum), disturbance types (using the NVC-constrained vocabulary), total absolute cover by strata, and a range of soil and landscape

³ Supplemental materials for this report are available in NPS’ IRMA DataStore: [Vegetation Mapping Inventory Project for Chiricahua National Monument](#).

characteristics (Table 2; [datasheets in supplemental materials](#)⁴). The landscape data collected included the landform on which the site was situated (floodplain, alluvial terrace, mountain, etc.), as well as percentage slope, slope position, aspect, and parent material. In addition, crews recorded some soil cover metrics, including estimating the relative cover of different surface types, including rock, biological soil crusts, litter classes, and erosion features. At each plot, a single photograph was taken at a 45-degree angle into the plot from one of the corners. Brief narratives were written to (1) describe the tentative association type of the immediate area, noting the ways in which this association/area differed from the adjacent areas, and (2) provide a separate landscape narrative noting topographic features contributing to the divisions of floristic similarities.

Table 2. Specific attributes were collected on the vegetation and landscape datasheets for both polygons and classification plots.

Type of Information	Items Noted
Plot/Polygon metadata	Date, time, observer name(s), recorder name(s), park code, sub-map number, protocol version
Plot/Polygon documentation	Location, original ID, field ID, new ID, tentative formation, keyed formation, area (standard for all plots)
Environmental description	Topographic position, landform type, parent material, slope class, erosion features, aspect
Surface cover (% cover classes)	Bare soil, gravel, rock, bedrock outcrops, physical crust, biological soil crust, down wood, litter
Vegetation description	Qualitative narrative: community structure, notable inclusions, leaf phenology, community structure
Vegetation strata data	Lifform, dominance rank, cover class and height in each of four height classes (0–0.5 m, 0.5–2 m, 2–5 m, >5 m), associated species
Plant species	Scientific name (6-letter codes were used)
Other vegetation characteristics	Homogeneity, stand maturity, similarity to other types, mortality, disturbance

Classification Polygons

Immediately following plot-level data collection, crews used hardcopy prints of imagery and GPS devices to evaluate and modify, where necessary, draft polygons to define the extent of each vegetation association more precisely. The field crew ground-truthed each area to verify formation assignment (e.g., woodland vs. forest) and to validate boundary placement. Where possible, crews walked the entire boundary and through the interior of each proposed polygon (a.k.a. map unit) while hand-drawing its extent onto the printed imagery. If a polygon had incorrect boundaries, it was edited accordingly on the paper maps and given a new name when necessary. Hand edits were later digitized using ESRI ArcMap software.

⁴ Supplemental materials for this report, including the vegetation formation key, are available in NPS' IRMA DataStore: [Vegetation Mapping Inventory Project for Chiricahua National Monument](#).

As with classification plots, crews collected qualitative data on the dominant and commonly associated species that defined the captured association as well as landscape features within each of these variably sized polygons (Table 2). In the narrative section, crews recorded a tentative association name, differences from the surrounding vegetation, defining landscape features, and features used to bind the polygon. A sequence of four representative photographs was taken in the four cardinal directions from near the center of the polygon, which was marked with a GPS point for future repeat photography.

Plot and Polygon Data Management

All plot and polygon data were entered into a Microsoft Access (2007) database created in-house by the SODN data manager. Digital data were subsequently quality-checked for accuracy against the original datasheets, and any transcription errors were rectified prior to analysis. The data were also validated by an alternate mapping team member (who did not collect the original data under review) for logical errors or unusual species entries. These processes followed the quality standards outlined in the global operating standards written by the SODN data management program (Angell 2005). All datasheets were copied and stored separately from the original set.

At the end of each field day, crews transferred all edits made to field maps to a set of “master” paper maps that did not go into the field. Each polygon was then edited in ArcMap to reflect any boundary changes collected in the field on paper maps, and each polygon feature was attributed to reflect any changes in polygon identification numbers and tentative association names. The datasets are housed in a file geodatabase structure (.gdb), enabling the establishment of topology rules and relationships. Strict nomenclature was enforced for polygons, such that unique names were assigned to each polygon; these reflected the verified physiognomic formation type with a prefix of representative letters (W = Woodland, SS = shrub savanna, etc.) followed by a number.

Photographs were verified to be present for each polygon (x 4) and plot (x 1) and for correct naming conventions. Photo point locations (shapefiles) were similarly quality-checked for spatial accuracy and attribute completeness. After all data checks were completed, field data were reviewed and analyzed by the entire project team. Master paper maps and original datasheets are archived at the NPS Western Archaeological Conservation Center (WACC).

Vegetation Classification Analysis

Methods

Using the program Plymouth Routines In Multivariate Ecological Research version 7 (PRIMER) (Clark and Gorley, 2006 and 2015), we employed a multivariate approach to delineate vegetation communities using our sampled classification plots (n = 157), the subset of the SODN long-term monitoring plots that were sampled pre-fire (n = 34), and polygon data (n = 350), resulting in a total of 541 sites. Midpoint cover class values for all species at all plot and polygon locations were exported from the Access database post-quality assessment and imported into PRIMER for analysis (Clarke & Warwick, 2001). Long-term monitoring was converted from percent cover to the equivalent mid-point of the classification cover classes to enable comparison with the less precise classification plot and polygon data. The resulting data matrix had species as variables (rows), plots,

including classification polygons, as samples (columns), and mid-point cover values as the matrix values. These data were first square-root transformed to balance the contributions from very common and less common species in the measure of similarity between two samples (Clarke and Warwick 2001). Then, using the resemblance tool in PRIMER, these transformed values were converted into a similarity matrix using the Bray–Curtis similarity coefficient (Bray and Curtis 1957). This matrix contains a value comparing the similarity of every combination of samples with values ranging from 0, indicating no similarity, to 100, indicating identical samples.

Using this matrix, we employed a group average hierarchical cluster analysis (Cluster tool) with an associated dendrogram (Figure 14) to aid in assigning plots to groups based on the similarity/dissimilarity of documented species and their associated cover values. Within the cluster routine, we performed a SIMPROF (similarity profile) permutation test which looks for statistically significant groupings and identifies them using color. In Figure 14, the significance was set at 95%. SIMPROF is a permutation test of the null hypothesis that “a specified set of samples, which are not a priori divided into groups, do not differ from one another in a multivariate structure” (Clarke and Gorley 2006).

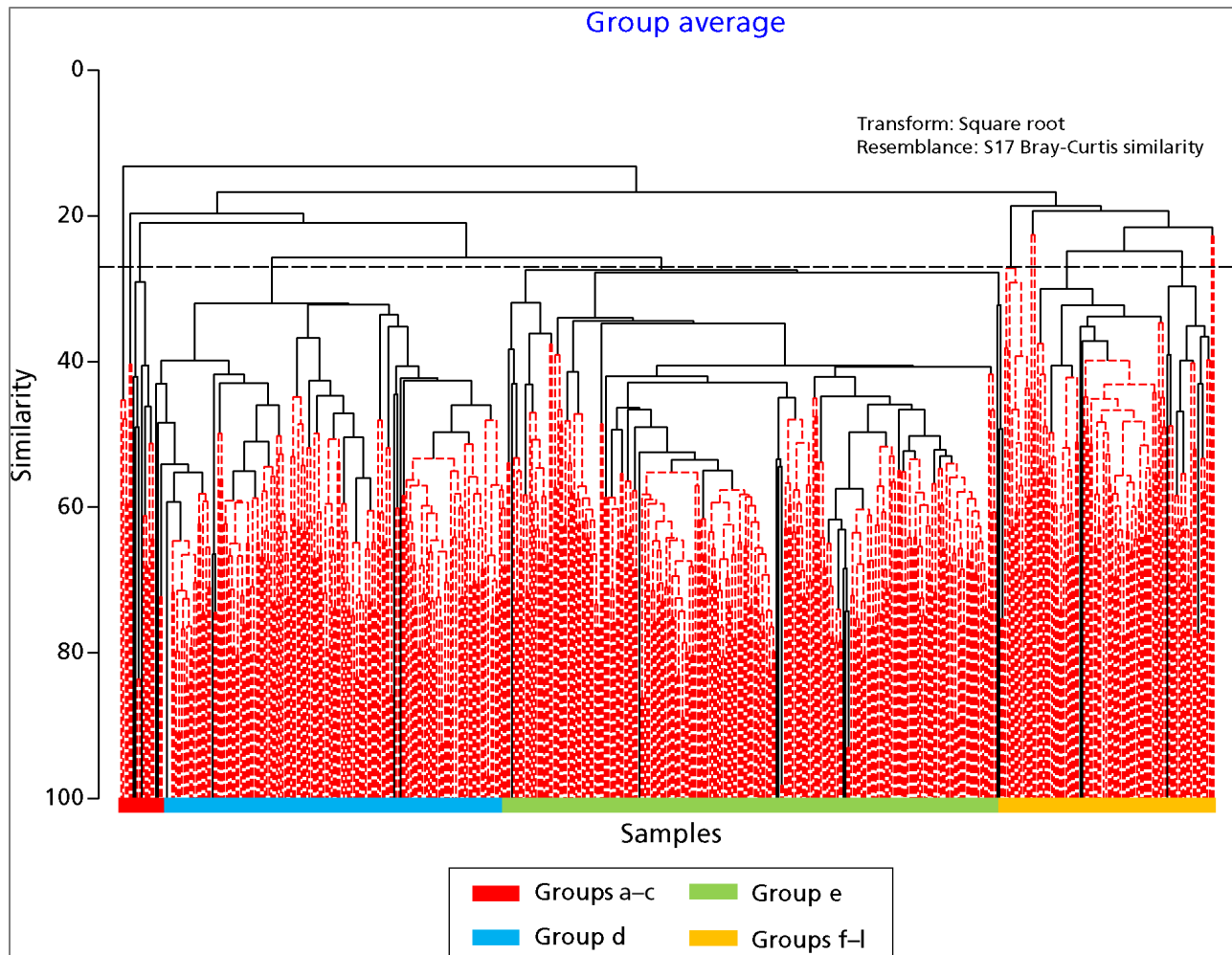


Figure 14. Dendrogram showing the clustering of sites (plots and polygons combined; $n = 541$) based on multi-variate analysis of species combinations and abundances. The horizontal dashed line indicates similarity groupings at 27% within-group similarity. Where dendrogram lines turn from black to red, this indicates the point at which further levels of similarity are no longer significant ($p = 95\%$). Cluster groupings were evaluated at levels ranging from approximately 27% up to 45%. NPS

The same resemblance matrix was used to further analyze and visualize the data by employing nonmetric multidimensional scaling (NMDS). In the resulting diagram (Figure 15), the similarity/dissimilarity of vegetation composition can be assessed based on the distance between points (samples). An additional routine, SIMPER (similarity percentages) was performed to calculate the contribution of each species' abundance (%) to the overall dissimilarity between each pair of groups. It is calculated from the Bray–Curtis dissimilarity matrix and can be run using either user-defined or SIMPROF groupings and while we used both, we primarily relied on the user-defined option since the SIMPROF groups employ too fine a scale of similarity for this application. Using the NMDS, SIMPROF groups, and SIMPER profiles, we further explored the finer grouping within each cluster.

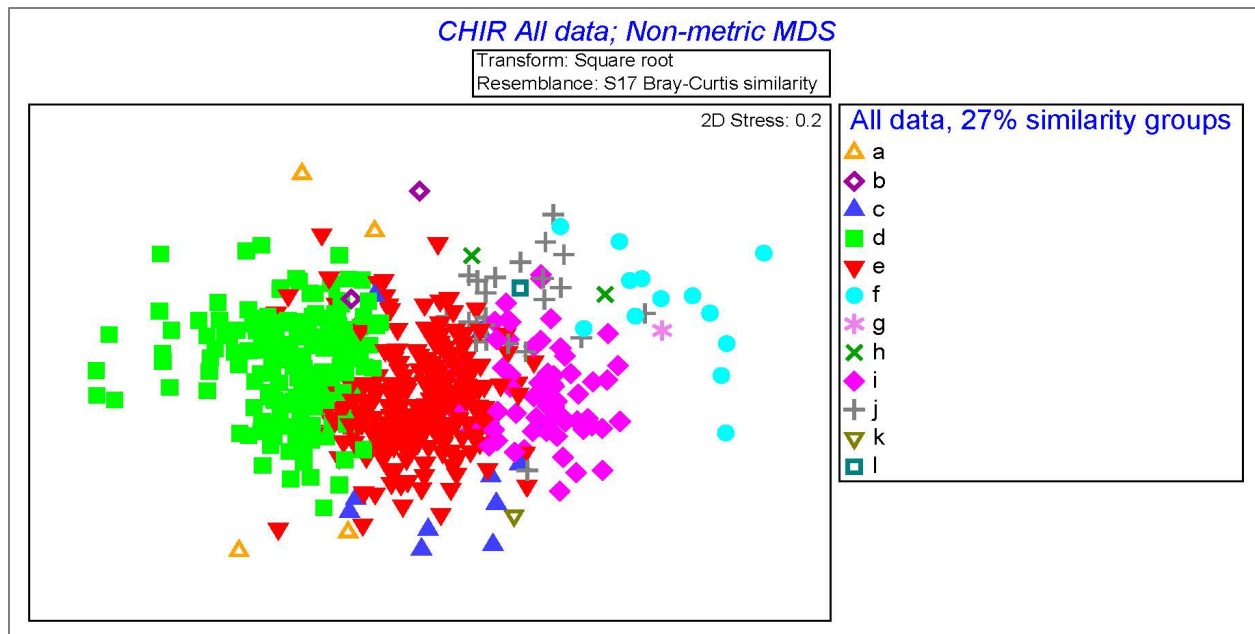


Figure 15. Non-metric multidimensional scaling (NMDS) diagram of all CHIR classification data (n = 541). The three largest floristic complexes d, e, and i intergrade along the x axis and represent the transition from pine-oak forest (group d, green squares), to pine-oak-juniper woodlands and chaparral (group e, red downward-facing triangles), to semi-desert grassland and shrublands (group i, pink diamonds). Herbaceous dominated communities are primarily represented in the top right clusters labeled f to l. NPS

Identification of Macrogroups

Initial dendrogram and SIMPROF test analyses were evaluated at within-group similarity levels between 27 and 40% (see Figure 14; see dashed line at 27%). In instances where larger clusters of sites, such as groups d and e, also had distinct and significant sub-clusters, those were reviewed in more detail. This initial data evaluation step returned the following groups and identified the characteristic and diagnostic species defining them. The first letters indicate the ‘parent group’ (d) followed by numbers and/or letters indicate sub-groupings (d1a = group d, subgroup 1, type a). Species listed below are those identified during the SIMPER analyses as the species contributing the most towards the within-group similarity (Clarke and Warwick 2001). These groupings served as the starting point for our classification work and environmental data such as soils, aspect, elevation plus photographs and written descriptions were used to supplement the analysis, leading to the final classification determinations.

Initial Groupings and Characteristic Floristic Composition

Cluster a: 4 sites.

Unique small area dominated by netleaf oak (*Quercus rugosa*), mountain muhly (*Muhlenbergia montana*) and bullgrass (*Muhlenbergia emersleyi*) with New Mexico locust (*Robinia neomexicana*) and creambush (*Holodiscus discolor*).

Cluster b: 2 sites.

Two sites, both of which were determined to fit best under group e2d even though they had low border pinyon (*Pinus discolor*) and Toumey oak (*Quercus toumeyii*) cover compared to the average plot in that group. One polygon site occupied a section of ridge with very high bedrock content and, therefore, lower tree cover.

Cluster c: 11 sites.

Open woodland/wooded shrubland dominated by alderleaf mountain mahogany (*Cercocarpus montanus*), side-oats grama (*Bouteloua curtipendula*), cliff muhly (*Muhlenbergia polycaulis*), walkingstick cactus (*Cylindropuntia spinosior*) and associate species border pinyon (*Pinus discolor*).

Cluster d: 174 sites.

This large cluster of pine-oak forest and woodland areas is broadly characterized by combinations of silverleaf oak (*Quercus hypoleucoides*), netleaf oak (*Quercus rugosa*), Chihuahuan pine (*Pinus leiophylla*), Apache pine (*Pinus engelmannii*), Douglas-fir (*Pseudotsuga menziesii*), border pinyon (*Pinus discolor*), manzanita (*Arctostaphylos pungens*), Arizona cypress (*Hesperocyparis arizonica*) and bullgrass (*Muhlenbergia emersleyi*).

Cluster d1a: Border pinyon (*Pinus discolor*), Arizona cypress (*Hesperocyparis arizonica*), and manzanita (*Arctostaphylos pungens*) woodlands and wooded shrublands.

Cluster d1b: Border pinyon (*Pinus discolor*), Arizona cypress (*Hesperocyparis arizonica*), and netleaf oak (*Quercus rugosa*) woodlands and wooded shrublands.

Cluster d2: Douglas-fir (*Pseudotsuga menziesii*) and silverleaf oak (*Quercus hypoleucoides*) woodlands and forests.

Cluster d3: Chihuahuan pine (*Pinus leiophylla*), Apache pine (*Pinus engelmannii*) and silverleaf oak (*Quercus hypoleucoides*) forests and intermittently flooded forests (drainages).

Cluster e: 246 sites.

The largest floristic complex at the monument is composed of communities with varying combinations and dominance of the following species: border pinyon (*Pinus discolor*), manzanita (*Arctostaphylos pungens*), Toumey oak (*Quercus toumeyii*), bullgrass (*Muhlenbergia emersleyi*), alligator juniper (*Juniperus deppeana*), Wright's silktassel (*Garrya wrightii*), beargrass (*Nolina macrocarpa*), and Arizona white oak (*Quercus arizonica*), among others. These are Pinyon-Juniper-Oak communities, often with large shrub component and shorter-statured trees.

Cluster e1: Primarily sites within the Bonita Canyon drainage: Arizona white oak (*Quercus arizonica*), alligator juniper (*Juniperus deppeana*), Emory oak (*Quercus emoryi*), pinyon ricegrass (*Piptochaetium fimbriatum*), border pinyon (*Pinus discolor*), and manzanita (*Arctostaphylos pungens*).

Cluster e2a: bullgrass (*Muhlenbergia emersleyi*), Toumey oak (*Quercus toumeyii*), sotol (*Dasylirion wheeleri*), Texas bluestem (*Schizachyrium cirratum*), manzanita (*Arctostaphylos pungens*), beargrass (*Nolina macrocarpa*), border pinyon (*Pinus discolor*), Lehmann's lovegrass (non-native; *Eragrostis lehmanniana*), and bristly wolfstail (*Muhlenbergia alopecuroides*).

Cluster e2b: border pinyon (*Pinus discolor*), Arizona white oak (*Quercus arizonica*), beargrass (*Nolina macrocarpa*), mountain yucca (*Yucca madrensis*), and bullgrass (*Muhlenbergia emersleyi*).

Cluster e2c (only 2 sites): catclaw mimosa (*Mimosa aculeaticarpa*), manzanita (*Arctostaphylos pungens*), and bullgrass (*Muhlenbergia emersleyi*) with low cover juniper (*Juniperus deppeana* and *J. arizonica*).

Cluster e2d: border pinyon (*Pinus discolor*), Toumey oak (*Quercus toumeyii*), manzanita (*Arctostaphylos pungens*), bullgrass (*Muhlenbergia emersleyi*) with lesser alligator juniper (*Juniperus deppeana*).

Cluster e2e: manzanita (*Arctostaphylos pungens*), bullgrass (*Muhlenbergia emersleyi*), border pinyon (*Pinus discolor*), and alligator juniper (*Juniperus deppeana*).

Cluster e3: Wright's silktassel (*Garrya wrightii*), alderleaf mountain mahogany (*Cercocarpus montanus*), side-oats grama (*Bouteloua curtipendula*), evergreen sumac (*Rhus virens*), gumhead (*Gymnosperma glutinosum*), and Arizona white oak (*Quercus arizonica*).

Cluster f-l: 104 sites combined—f (13), g (1), h (2), i (64), j (22), k (1), l (1).

Herbaceous-dominated communities, including native and non-native perennial grasses, with varying shrub and tree components. These types include the communities considered semi-desert grassland and shrublands.

Cluster f: characterized by blue grama (*Bouteloua gracilis*), Lehmann's lovegrass (non-native; *Eragrostis lehmanniana*), honey mesquite (*Prosopis glandulosa*), and burroweed (*Isocoma tenuisecta*).

Cluster i: characterized by combinations of sotol (*Dasylirion wheeleri*), Palmer's agave (*Agave palmeri*), beargrass (*Nolina macrocarpa*), Lehmann's lovegrass (non-native; *Eragrostis lehmanniana*), bullgrass (*Muhlenbergia emersleyi*), mariola (*Parthenium incanum*), sideoats grama (*Bouteloua curtipendula*), cane bluestem (*Bothriochloa barbinodis*), alligator juniper (*Juniperus deppeana*), and turpentine bush (*Ericameria laricifolia*).

Cluster j: characterized by dominant alligator juniper (*Juniperus deppeana*), blue grama (*Bouteloua gracilis*), sideoats grama (*Bouteloua curtipendula*), yucca (*Yucca madrensis*) and beargrass (*Nolina macrocarpa*), with occasional Arizona white oak (*Quercus arizonica*), Emory oak (*Quercus emoryi*), and manzanita (*Arctostaphylos pungens*).

Clusters g, h, k, and l were all single site or 2 site groups, and after careful evaluation of the species assemblages, cover data, photographs, geographic locations, and field notes, these were evaluated as fitting best within the other cluster groupings.

Classification Results

With the above clusters as a starting point, we used field data, notes, and photographs to further refine groupings to the level of associations. In total, we identified 29 separate vegetation

associations. When possible, our associations were matched with existing accepted associations from the [US National Vegetation Classification \(USNVC\)](#) using published descriptions. If no NVC association was available, we attempted to match our associations with those proposed in previous SODN mapping project reports (e.g., Galvin and Studd 2021). Each association was assigned a unique code. For associations that correspond with accepted USNVC associations, codes consist of the prefix “CEGL” followed by a unique six-digit numeric identifier. When no similar association was found that matched our classes, we assigned it a unique in-house identifier beginning with “NPSSODN” followed by a three-digit numeric identifier.

The USNVC continues to evolve as new data observations of vegetation communities from across their entire range are collected and incorporated into the system. Of the 29 associations identified during this project, nine had existing associations described within the USNVC. Fifteen are designated as “provisional” to be included in future USNVC updates and are noted by a “(P)” at the end of the name; of these, two have been previously proposed in SODN vegetation map reports (Studd, Galvin, and Hubbard 2018; Galvin and Studd 2021). Finally, five have been designated as “park specials” (PS), which generally have narrow distributions within the park and are restricted to small patches, often with histories of localized disturbance, and therefore seem unlikely to occur elsewhere.

The 29 plant associations are shown in Table 3 within their USNVC hierarchy, including the Macrogroup, Group, Alliance, Association, and NVC code. For context, the Macrogroup description available in [USNVC](#) is listed below the table. CHIR-based descriptions of individual plant associations are summarized in Chapter 4 and provided in full in Volume II of this report.

All proposed associations have been placed within the most appropriate floristic alliance within the USNVC system; however, as there are many plant associations described in this report that are provisional, pending acceptance into the national classification, this classification remains provisional and subject to change pending review by the appropriate entities.

Table 3. The 29 plant associations within their USNVC hierarchy, including the Macrogroup, Group, Alliance, Association, and NVC code.

Type Number	Macrogroup	Group	Alliance	Association	NVC Code
1	M010: Madrean Lowland Evergreen Woodland	G200: <i>Pinus cembroides</i> - <i>Pinus discolor</i> - <i>Juniperus coahuilensis</i> Woodland	A3131: <i>Pinus cembroides</i> - <i>Pinus discolor</i> - <i>Pinus edulis</i> / Shrub Understory Woodland	<i>Pinus discolor</i> / <i>Quercus hypoleucoides</i> Woodland	CEGL000771
2	M010	G200	A3131	[<i>Pinus discolor</i> - <i>Juniperus deppeana</i> - <i>Quercus arizonica</i> - <i>Quercus emoryi</i>] / <i>Arctostaphylos pungens</i> Wooded Shrubland (P)	NPSSODN182
3	M010	G200	A3131	[<i>Robinia neomexicana</i> - <i>Quercus rugosa</i>] / <i>Holodiscus discolor</i> / <i>Muhlenbergia montana</i> Tree Savanna (PS)	NPSSODN184
4	M010	G200	A3131	<i>Pinus discolor</i> - (<i>Hesperocyparis arizonica</i>) / <i>Arctostaphylos pungens</i> Wooded Shrubland (P)	NPSSODN189
5	M010	G200	A3131	<i>Pinus discolor</i> / <i>Cercocarpus montanus</i> Wooded Shrubland (PS)	NPSSODN190
6	M010	G200	A3131	<i>Pinus discolor</i> / <i>Quercus toumeyi</i> - (<i>Garrya wrightii</i>) / <i>Muhlenbergia emersleyi</i> Wooded Shrubland (P)	NPSSODN191
7	M010	G200	A3131	<i>Pinus discolor</i> / <i>Quercus toumeyi</i> - <i>Arctostaphylos pungens</i> Wooded Shrubland (P)	NPSSODN192
8	M010	G200	A3131	<i>Pinus discolor</i> / <i>Quercus toumeyi</i> - <i>Garrya wrightii</i> Woodland (P)	NPSSODN193
9	M010	G200	A3132: <i>Pinus cembroides</i> - <i>Pinus discolor</i> - <i>Pinus edulis</i> / Grass Understory Woodland	<i>Pinus discolor</i> / <i>Muhlenbergia emersleyi</i> Woodland	CEGL000767

^A The placement of the association (and other similar ones) within Alliance A3101 is currently under review (as of September 2024) and it has provisionally been placed into newly revised Alliance A2271 *Quercus arizonica*–*Quercus grisea* / Grassy Woodland Alliance based on data from recent classification projects in the New Mexico region (Muldavin et al. 2024). At the time of this writing the revised placement was not yet accepted or reflected in the [USNVC database](#) and is still “proposed” within the NatureServe database; therefore, we have decided to leave it here with the understanding this and many other placements will change as more data, including from this project, are subsumed into the greater classification work.

^B This association is unplaced. Consideration was given to place this within the M301 Western North American Ruderal Marsh, Wet Meadow, and Shrubland Macrogroup; however, that only includes areas dominated by ruderal and non-native species, whereas this meadow at CHIR is dominated by native wetland species.

Table 3 (continued). The 29 plant associations within their USNVC hierarchy, including the Macrogroup, Group, Alliance, Association, and NVC code.

Type Number	Macrogroup	Group	Alliance	Association	NVC Code
10	M010	G200	A3132	<i>Pinus discolor</i> / <i>Piptochaetium fimbriatum</i> Woodland	CEGL000768
11	M010	G201: <i>Quercus arizonica</i> - <i>Quercus emoryi</i> - <i>Quercus oblongifolia</i> Woodland	A3101: <i>Quercus arizonica</i> - <i>Quercus emoryi</i> - <i>Quercus grisea</i> Scrub Woodland	<i>Quercus emoryi</i> / <i>Piptochaetium fimbriatum</i> Scrub Woodland	CEGL000686 ^A
12	M010	G201	A3101	[<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>] Woodland (P)	NPSSODN164
13	M010	G487: <i>Juniperus coahuilensis</i> - <i>Juniperus deppeana</i> - <i>Juniperus monosperma</i> Open Woodland	A3133: <i>Juniperus coahuilensis</i> - <i>Juniperus deppeana</i> - <i>Juniperus monosperma</i> / Shrub Understory Open Woodland	(<i>Juniperus deppeana</i>) / <i>Mimosa aculeaticarpa</i> Wooded Shrubland (PS)	NPSSODN179
14	M010	G487	A3134: <i>Juniperus coahuilensis</i> - <i>Juniperus deppeana</i> - <i>Juniperus monosperma</i> / Grass Understory Open Woodland Alliance	<i>Juniperus deppeana</i> / <i>Bouteloua gracilis</i> Woodland	CEGL000693
15	M010	G487	A3134	<i>Juniperus deppeana</i> - <i>Quercus emoryi</i> - (<i>Quercus arizonica</i>) / <i>Piptochaetium fimbriatum</i> Woodland (P)	NPSSODN186
16	M011: Madrean Montane Forest and Woodland	G202: <i>Pseudotsuga menziesii</i> - <i>Pinus strobiformis</i> / <i>Quercus hypoleucoides</i> Forest & Woodland	A3108: <i>Pseudotsuga menziesii</i> / <i>Quercus hypoleucoides</i> - <i>Quercus rugosa</i> Forest & Woodland	<i>Pseudotsuga menziesii</i> / <i>Quercus hypoleucoides</i> Forest	CEGL000453
17	M011	G202	A3108	(<i>Pseudotsuga menziesii</i> - <i>Hesperocyparis arizonica</i>) / <i>Quercus rugosa</i> - <i>Quercus chrysolepis</i> Forest (P)	NPSSODN180
18	M011	G203: <i>Pinus engelmannii</i> - <i>Pinus leiophylla</i> - <i>Pinus arizonica</i> Forest & Woodland	A0163: <i>Hesperocyparis arizonica</i> Forest & Woodland	<i>Hesperocyparis arizonica</i> / <i>Quercus hypoleucoides</i> Forest	CEGL000352

^A The placement of the association (and other similar ones) within Alliance A3101 is currently under review (as of September 2024) and it has provisionally been placed into newly revised Alliance A2271 *Quercus arizonica*–*Quercus grisea* / Grassy Woodland Alliance based on data from recent classification projects in the New Mexico region (Muldavin et al. 2024). At the time of this writing the revised placement was not yet accepted or reflected in the [USNVC database](#) and is still “proposed” within the NatureServe database; therefore, we have decided to leave it here with the understanding this and many other placements will change as more data, including from this project, are subsumed into the greater classification work.

^B This association is unplaced. Consideration was given to place this within the M301 Western North American Ruderal Marsh, Wet Meadow, and Shrubland Macrogroup; however, that only includes areas dominated by ruderal and non-native species, whereas this meadow at CHIR is dominated by native wetland species.

Table 3 (continued). The 29 plant associations within their USNVC hierarchy, including the Macrogroup, Group, Alliance, Association, and NVC code.

Type Number	Macrogroup	Group	Alliance	Association	NVC Code
19	M011	G203	A0163	<i>Hesperocyparis arizonica</i> - (<i>Platanus wrightii</i>) / <i>Quercus</i> spp. Intermittently Flooded Forest (P)	NPSSODN185
20	M011	G203	A0163	[<i>Pinus engelmannii</i> - <i>Hesperocyparis arizonica</i> - <i>Quercus hypoleucoides</i>] Intermittently Flooded Forest (P)	NPSSODN183
21	M011	G203	A3112: <i>Pinus arizonica</i> - <i>Pinus engelmannii</i> - <i>Pinus leiophylla</i> Woodland	<i>Pinus engelmannii</i> / <i>Quercus hypoleucoides</i> Woodland	CEGL000801
22	M011	G203	A3112: <i>Pinus arizonica</i> - <i>Pinus engelmannii</i> - <i>Pinus leiophylla</i> Woodland	[<i>Pinus arizonica</i> - <i>Pinus leiophylla</i>] / <i>Quercus hypoleucoides</i> Forest (P)	NPSSODN181
23	M091: Warm Interior Chaparral	G281: <i>Quercus turbinella</i> - <i>Ceanothus greggii</i> - <i>Arctostaphylos pungens</i> Chaparral	A3791: <i>Cercocarpus montanus</i> Madrean Montane Chaparral	<i>Quercus hypoleucoides</i> Shrubland (P)	NPSSODN194
24	M091	G281	A3791: <i>Cercocarpus montanus</i> Madrean Montane Chaparral	[<i>Cercocarpus montanus</i> - <i>Garrya wrightii</i>] / Mixed Perennial Grass Wooded Shrub Savanna (P)	NPSSODN050
25	M512: North American Warm Desert Ruderal Scrub and Grassland	G677: <i>Eragrostis lehmanniana</i> - <i>Bromus rubens</i> - <i>Brassica tournefortii</i> Warm Desert Ruderal Grassland	A2687: <i>Eragrostis lehmanniana</i> - <i>Eragrostis curvula</i> Ruderal Desert Grassland	<i>Parthenium incanum</i> / <i>Eragrostis lehmanniana</i> Shrub Savanna (P)	NPSSODN188
26	M512	G819: <i>Prosopis glandulosa</i> - <i>Prosopis velutina</i> Warm Desert Ruderal Scrub	A3162: <i>Prosopis glandulosa</i> Ruderal Desert Scrub	<i>Prosopis glandulosa</i> / Mixed Grasses Ruderal Shrubland	CEGL001384
27	—	—	—	(<i>Carex ultra</i>) / <i>Juncus balticus</i> - <i>Solidago canadensis</i> Herbaceous (PS)	NPSSODN177 ^B

^A The placement of the association (and other similar ones) within Alliance A3101 is currently under review (as of September 2024) and it has provisionally been placed into newly revised Alliance A2271 *Quercus arizonica*–*Quercus grisea* / Grassy Woodland Alliance based on data from recent classification projects in the New Mexico region (Muldavin et al. 2024). At the time of this writing the revised placement was not yet accepted or reflected in the [USNVC database](#) and is still “proposed” within the NatureServe database; therefore, we have decided to leave it here with the understanding this and many other placements will change as more data, including from this project, are subsumed into the greater classification work.

^B This association is unplaced. Consideration was given to place this within the M301 Western North American Ruderal Marsh, Wet Meadow, and Shrubland Macrogroup; however, that only includes areas dominated by ruderal and non-native species, whereas this meadow at CHIR is dominated by native wetland species.

Table 3 (continued). The 29 plant associations within their USNVC hierarchy, including the Macrogroup, Group, Alliance, Association, and NVC code.

Type Number	Macrogroup	Group	Alliance	Association	NVC Code
28	M087: <i>Bouteloua eriopoda</i> - <i>Muhlenbergia emersleyi</i> - <i>Pleuraphis mutica</i> Chihuahuan Semi-Desert Grassland	G490: <i>Bouteloua eriopoda</i> - <i>Bouteloua ramosa</i> - <i>Muhlenbergia porteri</i> Semi-Desert Grassland	A3205: <i>Dasyilirion</i> spp. / <i>Bouteloua curtipendula</i> - <i>Muhlenbergia setifolia</i> Foothill Desert Grassland	(<i>Dasyilirion wheeleri</i> - <i>Agave palmeri</i>) / <i>Eragrostis lehmanniana</i> – <i>Muhlenbergia emersleyi</i> Shrub Herbaceous (P)	NPSSODN178
29	M087	G490	A3206 <i>Muhlenbergia emersleyi</i> - <i>Muhlenbergia setifolia</i> - <i>Hesperostipa neomexicana</i> Madrean Lower Montane Grassland	<i>Nolina microcarpa</i> / <i>Muhlenbergia emersleyi</i> Shrub Savanna (PS)	NPSSODN187

^A The placement of the association (and other similar ones) within Alliance A3101 is currently under review (as of September 2024) and it has provisionally been placed into newly revised Alliance A2271 *Quercus arizonica*–*Quercus grisea* / Grassy Woodland Alliance based on data from recent classification projects in the New Mexico region (Muldavin et al. 2024). At the time of this writing the revised placement was not yet accepted or reflected in the [USNVC database](#) and is still “proposed” within the NatureServe database; therefore, we have decided to leave it here with the understanding this and many other placements will change as more data, including from this project, are subsumed into the greater classification work.

^B This association is unplaced. Consideration was given to place this within the M301 Western North American Ruderal Marsh, Wet Meadow, and Shrubland Macrogroup; however, that only includes areas dominated by ruderal and non-native species, whereas this meadow at CHIR is dominated by native wetland species.

Macrogroup M010: Madrean Lowland Evergreen Woodland

Madrean Encinal occurs in the Sierra Madre Occidentale and Sierra Madre Orientale in Mexico, extending north into Trans-Pecos Texas, southern New Mexico, and sub-Mogollon Arizona. It is characterized by open-canopied to moderately closed woodlands dominated by Madrean evergreen oaks: *Quercus albocincta*, *Q. arizonica*, *Q. chihuahuensis*, *Q. emoryi*, *Q. grisea*, and *Q. oblongifolia*. In CHIR, *Q. arizonica*, *Q. emoryi*, and *Q. rugosa* are the predominant taller oaks, along with shrubbier *Q. toumeyii*. Stands that are dominated or co-dominated by conifers, such as *Juniperus deppeana* and *Pinus discolor*, are also part of this macrogroup and are reflected at the group level (with *Pinus edulis* replacing *P. discolor* at the northern end of macrogroup distribution).

Note: Nomenclature changes in the taxonomy of *Pinus cembroides* Zucc. are unclear and confusing. *Pinus cembroides* Zucc. var. *bicolor* Little was renamed *Pinus discolor* by D.K. Bailey & Hawksworth and raised to the species level (Kartesz 1999). Both names are still recognized by Kartesz (1999). The eastern Sierra Madre representatives of this type may be different from those of the western Sierra Madre. This is because *Pinus cembroides* occurs in New Mexico and Texas, while *Pinus discolor* occurs in New Mexico and Arizona.

Macrogroup M011: Madrean Montane Forest and Woodland

This Madrean forest and woodland macrogroup occurs at mid- to upper elevations in mountains in northern Mexico and extends into mountains of Trans-Pecos Texas, southern New Mexico, and southern Arizona. It is characterized by open to closed, conifer and mixed conifer-evergreen, broad-leaved tree canopy composed of *Hesperocyparis arizonica*, *Pinus arizonica*, *Pinus engelmannii*, *Pinus leiophylla*, and at higher elevations, by *Pseudotsuga menziesii*, *Abies coahuilensis*, or *Abies concolor* with evergreen oaks, *Quercus arizonica*, *Quercus emoryi*, *Quercus grisea*, *Quercus hypoleucoides*, and *Quercus rugosa*. The tree canopy is often co-dominated by evergreen oak trees such as *Quercus albocincta*, *Quercus arizonica*, *Quercus chrysolepis*, *Quercus emoryi*, *Quercus fulva*, *Quercus grisea*, *Quercus viminea*, *Quercus hypoleucoides*, or *Quercus rugosa* (the latter two at higher elevations). *Arbutus arizonica* and *Arbutus xalapensis*-dominated stands are also included in this macrogroup. Other tree species present may include *Acer grandidentatum*, *Juniperus deppeana*, *Juniperus flaccida*, *Pinus cembroides*, *Pinus discolor*, and *Pinus edulis*. An open to moderately dense shrub layer is often present and includes encinal, chaparral, or montane shrub species, such as *Agave* spp., *Arctostaphylos pringlei*, *Arctostaphylos pungens*, *Ceanothus fendleri*, *Cercocarpus montanus*, *Garrya wrightii*, *Nolina* spp., and *Quercus turbinella*. Deciduous oak species, such as *Quercus gambelii*, *Quercus muehlenbergii*, or *Quercus* × *pauciloba*, may be present. If *Quercus gambelii* is prominent in the shrub layer, then other Madrean elements are also present. Sites are variable, ranging from warm to cool, xeric to dry-mesic, gentle to very steep slopes, and dry benches that occur at lower to mid-montane elevations (1,460–2,700 m). Lower elevation stands are more widespread and tend to be on northerly aspects. Upper elevation stands are found on warmer southerly and westerly aspects in high-elevation ranges. Stands may occur at lower elevations in canyons where there is significant cold-air drainage. Substrates are generally rocky and lithic soils but include finer-textured alluvial soils along streams. Stands with a grass-dominated understory tend to occur on less steep and rocky slopes and have finer-textured soils.

Macrogroup M091: Warm Interior Chaparral

This macrogroup includes all the interior chaparral in the southwestern US and northern Mexico and is composed of a very diverse list of diagnostics, mostly evergreen shrubs, such as *Arctostaphylos pungens*, *Ceanothus greggii*, *Garrya wrightii*, and *Quercus turbinella*, which dominate large areas on foothills, xeric mountain slopes, and canyons. This interior chaparral macrogroup occurs across central Arizona (Mogollon Rim) and southern New Mexico, east in the mountains across Trans-Pecos Texas, and south into the Madrean Occidentale and Madrean Oriental in northern Mexico. Occurrences are also found in desert mountains in the Sonoran and Mojave deserts. The vegetation is characterized by a moderate to dense evergreen shrub layer less than 3 meters tall, dominated by scrub oak and sclerophyllous shrubs. Widespread diagnostic species *Quercus turbinella*, *Arctostaphylos pungens*, or *Ceanothus greggii* frequently dominant large areas. Other characteristic shrubs include *Cercocarpus montanus* var. *paucidentatus*, *Garrya wrightii*, *Quercus toumeyii*, and *Rhus trilobata* with *Arctostaphylos pringlei* and *Arctostaphylos pungens* at higher elevations. The herbaceous layer is variable but is generally composed of semi-arid perennial grasses. Stands are found on foothills, xeric mountain slopes, and canyons in hotter and drier habitats and often dominate along the mid-elevation (1,000–2,500 m) transition zone between desert scrub and montane woodlands. Sites are often steep and rocky.

Macrogroup M512: North American Warm Desert Ruderal Scrub and Grassland

This upland warm desert thornscrub and grassland macrogroup contains disturbed semi-arid grasslands and desert thornscrub that are dominated by non-native species and are found in the southwestern US and northern Mexico. Vegetation of this macrogroup can be a monoculture of a single non-native graminoid species or a mix of several non-native forbs and graminoids. Perennial graminoids include the non-native *Eragrostis curvula*, *Eragrostis lehmanniana*, *Pennisetum ciliare*, *Pennisetum setaceum*, *Sorghum halepense* (mesic sites), and several other species (which have been purposefully seeded to prevent soil erosion or for livestock forage), and/or invasive non-native annual species such as *Brassica tournefortii*, *Bromus rubens*, *Schismus arabicus*, and *Schismus barbatus*. Numerous other non-native herbaceous species may be present to dominant. Dense stands of native ruderal species, such as *Amaranthus palmeri* or *Solanum elaeagnifolium*, resulting from anthropomorphic disturbance, are also included in this macrogroup. This macrogroup includes upland desert scrub strongly dominated by invasive native species (*Prosopis glandulosa* and *Prosopis velutina*) with >95% relative cover and >10% absolute shrub cover. *Prosopis* spp.-dominated stands that occur naturally (non-ruderal) in desert lowlands, drainages, washes, and riparian areas (bosque) are excluded from this ruderal type. It also includes any desert scrub with an exotic species-dominated understory (>90% relative cover) in the herbaceous layer. Invasive non-native shrublands are less common. Stands occur on flat to moderately steep ground and can vary from large areas (100+ hectares) to narrow strips adjacent to roadsides or under powerlines and other disturbed areas. *Eragrostis curvula*- and *Eragrostis lehmanniana*-dominated stands resulting from artificial seeding as part of grassland restoration projects may be exceptionally large. Soils are variable but are mostly well-drained. Disturbed soils may be compacted and eroded.

Macrogroup M087: *Bouteloua eriopoda* - *Muhlenbergia emersleyi* - *Pleuraphis mutica* Chihuahuan Semi-Desert Grassland Macrogroup

Due to this macrogroup occurring primarily within the Chihuahuan Desert zone the macrogroup (broadest) description did not well represent the vegetation as it occurs in southeastern Arizona; therefore, we showed the Group description instead.

Group: This group is a broadly defined desert grassland (shrub-steppe) that is typical of the borderlands of Arizona, New Mexico, and northern Mexico, extending throughout much of the Chihuahuan Desert west to the Sonoran Desert, and north to the Mogollon Rim. The vegetation is characterized by an open to dense herbaceous layer dominated by a diverse mixture of perennial desert grasses. Scattered shrubs and succulents are usually present but usually have lower total cover than the herbaceous layer. Common species include desert grasses such as *Bouteloua eriopoda*, *Bouteloua ramosa*, *Bouteloua rothrockii*, *Muhlenbergia porteri*, as well as widespread species *Bouteloua curtipendula*, *Bouteloua gracilis*, *Bouteloua hirsuta*, and *Eragrostis intermedia*. Also typical are succulents such as *Agave lechuguilla*, rosetophyllous shrubs such as species of *Nolina*, *Dasyllirion*, and *Yucca*, and short (dwarf) shrubs including species of *Calliandra*, *Mimosa*, and *Parthenium*. Scattered tall shrubs and short trees such as species of *Acacia*, *Prosopis*, and various oaks may be present but with low cover. In upper foothills and lower montane zones, *Muhlenbergia emersleyi* and *Muhlenbergia setifolia* are characteristic species. Sites occur on gently sloping alluvial erosional fans and piedmonts (bajadas) that lie along mountain fronts of the isolated basin ranges (e.g., Sky Island Mountain archipelago) extending onto foothill slopes up to 1,670 meters in elevation in the Chihuahuan Desert.

Chapter 3: Implications of the 2011 Horseshoe Two Fire for the Mapping Effort

Discussion of Accuracy

The timing of the Horseshoe Two Fire in the summer of 2011, immediately following the completion of the CHIR classification and mapping effort, had significant implications for evaluating the accuracy of the newly completed products and understanding the vegetation composition across the monument. Due to the scale of this fire—the first landscape-scale fire to occur in the monument in over a century—staff from the Vegetation Mapping Inventory, CHIR, and SODN agreed that conducting an accuracy assessment (AA) of the recently completed map was neither feasible nor meaningful.

Large swaths of the monument were affected by this high-severity fire, reducing the landscape to ashen barrens; additional acreage was impacted by moderate fire, likely influencing species composition and abundance for many years. As a result of the fire, assessing the accuracy of the pre-fire vegetation was impossible. Moreover, due to the fire's effects, future assessments may be challenging as this area could undergo transitions to new community types or structural changes, such as a shift from woodland to shrubland.

Although a complete accuracy assessment was not possible, the integration of imagery analysis combined with the iterative classification and mapping enhances the accuracy of this map compared to the one based solely on computer analysis of imagery and assignment of vegetation classes developed elsewhere in the region. As described in the Field Data Collection section in Chapter 2, field observers collected species abundance and dominance data at the scale of the area “polygon” being observed and mapped, as well as in relevé plots. Often, those areas were defined by naturally occurring breaks or shifts in the environmental conditions—conditions that contribute to changes in vegetation community type, such as the hydrology, topography, slope, aspect, soil type, or disturbance history of each site. These polygons ranged from small (1/2-hectare minimum map unit) to large areas (303 hectares). Each mapped area was usually traversed on foot until the community had been adequately viewed and thought to be a cohesive and consistent association of species. The boundaries were recorded and confirmed on the paper maps. Sometimes areas were observed from vantage points with high-powered spotting scopes when access was difficult or impossible, such as within the steep hoodoo rock formations.

After several months of data collection and preliminary synthesis, the crews were equipped with CHIR-specific knowledge that allowed them to readily identify some of these communities repeating across the monument, which enabled them to collect observational data, including assigning a tentative “association” type. These observations were more rapid but still completed on the ground. They were conducted by traversing a cross-section through an area and concurrently viewing the printed satellite imagery to look for changes in imagery that might correlate to changes in vegetation composition or structural type. This data collection maintained notation of the dominant species in all

height classes, along with notes on landscape position and differences from surrounding areas. Approximately 10% of the ~455 polygons were sampled in this way.

Even with such a high percentage of ground-mapped areas, the Horseshoe Two Fire effects made it impossible to verify the accuracy of the mapping work using standard vegetation inventory accuracy assessment methods (Lea and Curtis, 2010). For comparison, other SODN-led vegetation mapping inventories, such as at Coronado National Memorial (Studd et al. 2018) and Gila Cliff Dwellings National Monument (Studd and Galvin, 2019), were completed using the same methodologies and resulted in map accuracies above 80% (overall accuracies for all classes of 81.4% and 86.7% respectively).

The fire effects and lack of accuracy assessment work also interfered with our ability to test the dichotomous key⁵, which would usually have been field tested ahead of use in the AA. To address this, we conducted a blind evaluation of the key using pre-fire data. A SODN botanist with local knowledge of the species and CHIR worked through the key using the datasheet (showing dominant ranked species and their cover classes) and photographs from a subset of Intermediate Plots (IP plots) and draft polygons located across all associations. A total of 42 plots and polygons were utilized, and the evaluator placed each plot into one of the 29 associations. This sample was selected such that each association would have at least one representative plot, with multiple representatives for larger, more widespread types to capture different variations of the type. Thirty-five of the 42 sites were keyed to the association they were initially placed in, resulting in a user accuracy of 83%. Based on the results from this testing exercise and comments from the evaluator, minor edits were made to the key to improve accuracy and clarity.

Despite the unfortunate timing of the Horseshoe Two Fire, this mapping and classification effort offers a unique and detailed snapshot of vegetation distribution and types that occurred at CHIR prior to this momentous fire event. These products provide essential reference conditions and serve as a baseline against which scientists and managers can assess post-fire recovery and vegetation changes. Combined with fire effects data and ongoing ecological monitoring, they provide crucial insights into protecting and managing these ecosystems and may guide long-term management decisions throughout the recovery process.

⁵ Supplemental materials for this report, including the dichotomous key, are available in NPS' IRMA DataStore: [Vegetation Mapping Inventory Project for Chiricahua National Monument](#).

Chapter 4: Map Products

Final Classification

There are 29 associations with a one-to-one relationship to 29 map classes in the CHIR vegetation map. In addition, there is a 30th map class designated roads/park facilities, which encompasses all developed areas within the project area (roads, buildings, campgrounds, and parking lots). For the final map product, any adjacent areas with the same association type attributed to them were merged to create a more seamless map. Each polygon is treated as a single feature, enabling the map user to easily select and evaluate individual map polygons rather than grouping all polygons of one association as the selection unit.

The classification process identified and placed all of the wooded communities under two main Madrean macrogroups, most commonly with pinyon pine (*Pinus discolor*) or Chihuahuan pine (*Pinus leiophylla*), alligator juniper (*Juniperus deppeana*), Douglas-fir (*Pseudotsuga menziesii*) or Arizona cypress (*Hesperocyparis arizonica*) being the dominant species, all with varying cover of subcanopy oaks. These species highlight the influence of the Madrean ecoregion within this monument. Of the entire park, ~46% was mapped (pre-fire) as pinyon pine or pinyon pine/Toumey oak-dominated woodlands and wooded shrublands with either manzanita or Wright's silktassel as the secondary dominant shrub. These shrubby communities with scattered emergent trees are considered interior chaparral types with strong interdependence with and resilience to wildfire. The deep drainages provide cooler, more mesic environments that support the forest types where the giant trees of the monument are found.

Table 4 presents the number of Intermediate Plots (IP) classified, the corresponding number of polygons, and the total area covered within the project boundary for each of the 29 vegetation associations. Following the map graphics in Figures 16 and 17, two-page summaries of the 29 associations identified and mapped at Chiricahua National Monument are provided. These summaries are abridged versions of the full association descriptions found in Volume II⁶ of this report. Each summary briefly describes the floristic and structural characteristics of the vegetation and is accompanied by one or two representative photos of the association, its distribution throughout the park, and an example of the satellite imagery for one representative polygon. For additional details, readers are encouraged to consult the digital maps and databases accompanying this report in the [report's supplemental materials in DataStore](#).

⁶ Supplemental materials for this report, including Volume II of this report, are available in NPS' IRMA DataStore: [Vegetation Mapping Inventory Project for Chiricahua National Monument](#).

Table 4. Number of classification (IP) plots, number of polygons, and total area within the project boundary for each association.

Type Number	Plant Association (scientific name)	Plant Association (common name)	Classification (IP) Plots	Polygons	Area (ha)
1	<i>Pinus discolor</i> / <i>Quercus hypoleucoides</i> Woodland	Border Pinyon / Silverleaf Oak Woodland	2	12	47.9
2	[<i>Pinus discolor</i> - <i>Juniperus deppeana</i> - <i>Quercus arizonica</i> - <i>Quercus emoryi</i>] / <i>Arctostaphylos pungens</i> Wooded Shrubland	[Border Pinyon – Alligator Juniper – Arizona White Oak – Emory Oak] / Pointleaf Manzanita Wooded Shrubland	2	26	249.3
3	[<i>Robinia neomexicana</i> - <i>Quercus rugosa</i>] / <i>Holodiscus discolor</i> / <i>Muhlenbergia montana</i> Tree Savanna	[New Mexico Locust – Netleaf Oak] / Rockspirea / Mountain Muhly Tree Savanna	3	2	0.9
4	<i>Pinus discolor</i> - (<i>Hesperocyparis arizonica</i>) / <i>Arctostaphylos pungens</i> Wooded Shrubland	Border Pinyon - (Arizona Cypress) / Pointleaf Manzanita Wooded Shrubland	7	16	560.4
5	<i>Pinus discolor</i> / <i>Cercocarpus montanus</i> Wooded Shrubland	Border Pinyon / Alderleaf Mountain Mahogany Woodland	8	2	36.9
6	<i>Pinus discolor</i> / <i>Quercus toumeyi</i> - (<i>Garrya wrightii</i>) / <i>Muhlenbergia emersleyi</i> Wooded Shrubland	Border Pinyon / Toumey Oak - (Wright's Silktassel) / Bullgrass Wooded Shrubland	17	27	927.3
7	<i>Pinus discolor</i> / <i>Quercus toumeyi</i> - <i>Arctostaphylos pungens</i> Wooded Shrubland	Border Pinyon / Toumey Oak - Pointleaf Manzanita Wooded Shrubland	18	27	1366.3
8	<i>Pinus discolor</i> / <i>Quercus toumeyi</i> - <i>Garrya wrightii</i> Woodland	Border Pinyon / Toumey Oak - Wright's Silktassel Woodland	6	20	191.4
9	<i>Pinus discolor</i> / <i>Muhlenbergia emersleyi</i> Woodland	Border Pinyon / Bullgrass Woodland	9	10	439.5
10	<i>Pinus discolor</i> / <i>Piptochaetium fimbriatum</i> Woodland	Border Pinyon / Pinyon Ricegrass Woodland	0	1	3.8
11	<i>Quercus emoryi</i> / <i>Piptochaetium fimbriatum</i> Scrub Woodland	Emory Oak / Pinyon Ricegrass Scrub Woodland	0	4	60.0
12	[<i>Quercus hypoleucoides</i> - <i>Quercus arizonica</i>] Woodland	[Silverleaf Oak - Arizona White Oak] Woodland	3	6	46.1
13	(<i>Juniperus deppeana</i>) / <i>Mimosa aculeaticarpa</i> Wooded Shrubland	(Alligator Juniper) / Cat Claw Mimosa Wooded Shrubland	5	5	10.6

Table 4 (continued). Number of classification (IP) plots, number of polygons, and total area within the project boundary for each association.

Type Number	Plant Association (scientific name)	Plant Association (common name)	Classification (IP) Plots	Polygons	Area (ha)
14	<i>Juniperus deppeana</i> / <i>Bouteloua gracilis</i> Woodland	Alligator Juniper / Blue Grama Woodland	1	12	134.9
15	<i>Juniperus deppeana</i> - <i>Quercus emoryi</i> - (<i>Quercus arizonica</i>) / <i>Piptochaetium fimbriatum</i> Woodland	Alligator Juniper - Emory Oak - (Arizona White Oak) / Pinyon Ricegrass Woodland	0	16	46.5
16	<i>Pseudotsuga menziesii</i> / <i>Quercus hypoleucoides</i> Forest	Douglas-fir / Silverleaf Oak Forest	6	10	99.6
17	(<i>Pseudotsuga menziesii</i> - <i>Hesperocyparis arizonica</i>) / <i>Quercus rugosa</i> - <i>Quercus chrysolepis</i> Forest	(Douglas-fir - Arizona Cypress) / Netleaf Oak - Canyon Live Oak Forest	0	4	10.1
18	<i>Hesperocyparis arizonica</i> / <i>Quercus hypoleucoides</i> Forest	Arizona Cypress / Silverleaf Oak Forest	8	33	261.4
19	<i>Hesperocyparis arizonica</i> - (<i>Platanus wrightii</i>) / <i>Quercus</i> spp. Intermittently Flooded Forest	Arizona Cypress - (Arizona Sycamore) / Oak Species Intermittently Flooded Forest	6	6	63.2
20	[<i>Pinus engelmannii</i> - <i>Hesperocyparis arizonica</i> - <i>Quercus hypoleucoides</i>] Intermittently Flooded Forest	[Apache Pine - Arizona Cypress - Silverleaf Oak] Intermittently Flooded Forest	2	1	53.8
21	<i>Pinus engelmannii</i> / <i>Quercus hypoleucoides</i> Woodland	Chihuahuan Pine / Silverleaf Oak Woodland	18	8	145.5
22	[<i>Pinus arizonica</i> - <i>Pinus leiophylla</i>] / <i>Quercus hypoleucoides</i> Forest	[Arizona Pine - Chihuahuan Pine] / Silverleaf Oak Forest	1	13	103.6
23	<i>Quercus hypoleucoides</i> Shrubland	Silverleaf Oak Shrubland	5	1	19.1
24	[<i>Cercocarpus montanus</i> - <i>Garrya wrightii</i>] / Mixed Perennial Grass Wooded Shrub Savanna	[Alderleaf Mountain Mahogany – Wright's Silktassel] / Mixed Perennial Grass Wooded Shrub Savanna	5	6	61.6
25	<i>Parthenium incanum</i> / <i>Eragrostis lehmanniana</i> Shrub Savanna	Mariola / Lehmann Lovegrass Shrub Savanna	2	10	61.7
26	<i>Prosopis glandulosa</i> / Mixed Grasses Ruderal Shrubland	Honey Mesquite / Mixed Grasses Ruderal Shrubland	10	11	45.8

Table 4 (continued). Number of classification (IP) plots, number of polygons, and total area within the project boundary for each association.

Type Number	Plant Association (scientific name)	Plant Association (common name)	Classification (IP) Plots	Polygons	Area (ha)
27	(<i>Carex ultra</i>) / <i>Juncus balticus</i> - <i>Solidago canadensis</i> Herbaceous	Cochise Sedge / Mountain Rush - Canada Goldenrod Herbaceous	0	1	0.6
28	(<i>Dasyllirion wheeleri</i> - <i>Agave palmeri</i>) / <i>Eragrostis lehmanniana</i> - <i>Muhlenbergia emersleyi</i> Shrub Herbaceous	(Common Sotol - Palmer's Century Plant) / Lehmann Lovegrass – Bullgrass Shrub Herbaceous	11	22	163.4
29	<i>Nolina microcarpa</i> / <i>Muhlenbergia emersleyi</i> Shrub Savanna	Beargrass / Bullgrass Shrub Savanna	3	1	7.15

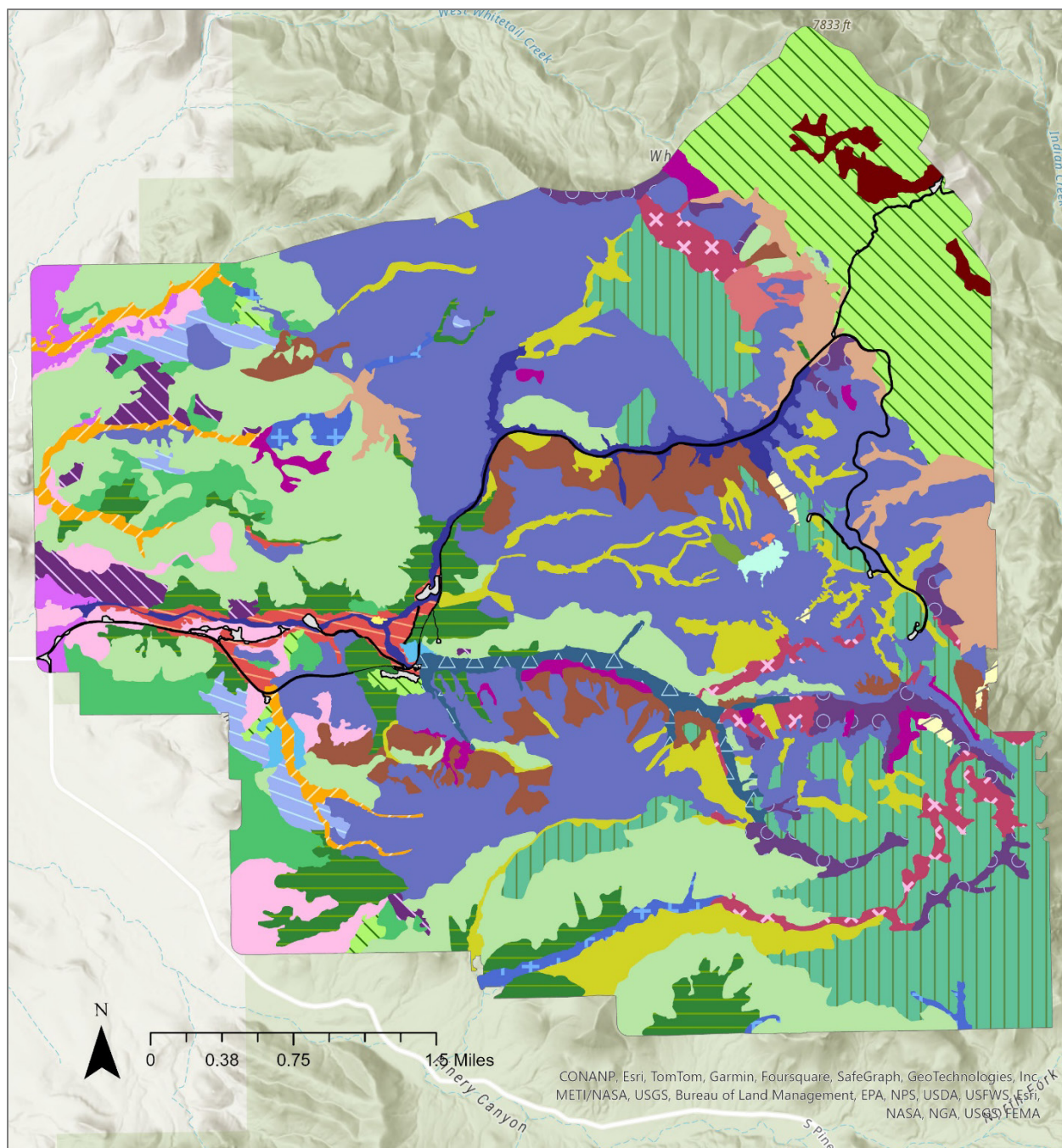


Figure 16. The final Chiricahua National Monument vegetation map graphic shows the 29 vegetation associations that were mapped during the Vegetation Inventory. Each color represents a unique community, as shown in the legend in Figure 17 and listed in Table 4. Roads are shown as snaking black lines, more or less bisecting the monument from west to east. NPS

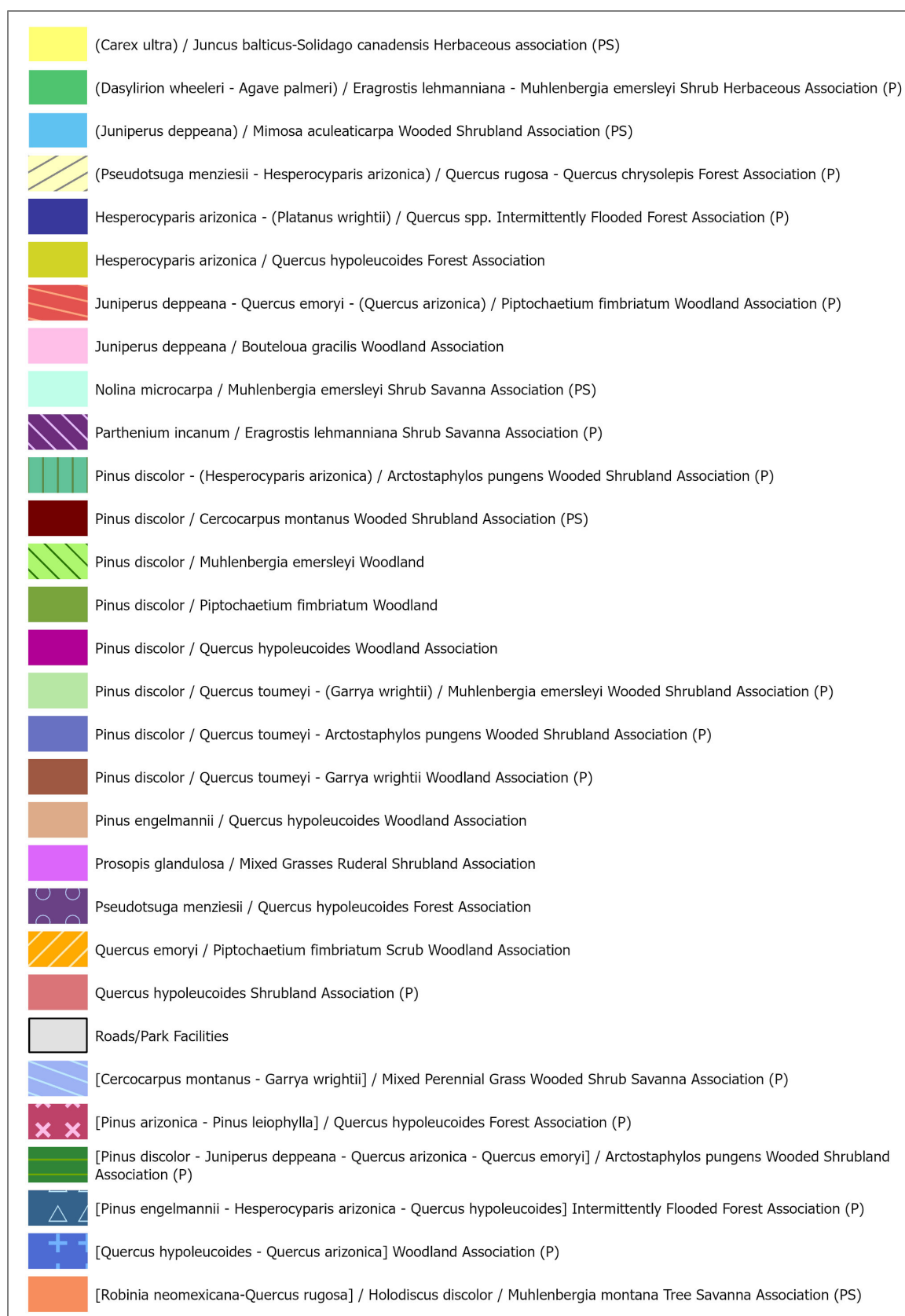


Figure 17. Map legend listing the 29 vegetation associations shown in Figure 16. NPS

Chapter 5: Association Summaries

1. *Pinus discolor* / *Quercus hypoleuroides* Woodland Association

Border Pinyon / Silverleaf Oak Woodland Association

This woodland association is characterized by a canopy dominated by border pinyon (*Pinus discolor*) with an understory dominated by silverleaf oak (*Quercus hypoleuroides*). This woodland varies from a low-cover (~20%) open woodland situated on rocky, steep slopes to a densely wooded area reaching ~80% cover. So, too, can the structure change from short to tall trees (3–12 m).

Border pinyon is present in all examples of this community as a dominant species in the canopy stratum (2–5 m). Silverleaf oak is similarly consistent, though since it is found growing both in shrubby form in the subcanopy stratum (0.5–2 m) and in taller tree form (>2 m), the cover is split between the two strata. Taken together, the total silverleaf oak cover approaches that of the border pinyon. Both Arizona white oak (*Quercus arizonica*) and alligator juniper (*Juniperus deppeana*) are present in more than half the examples of this association at CHIR, but while Arizona oak is often abundant and at times approaches the cover of border pinyon, alligator juniper is generally a sparse associate. Other tree species, including Chihuahuan pine (*Pinus leiophylla*), Douglas-fir (*Pseudotsuga menziesii*), Emory oak (*Quercus emoryi*), and Apache pine (*Pinus engelmannii*) are occasionally present but generate little cover overall.

The subcanopy layer is composed of shrubby silverleaf oak along with some mixture of pointleaf manzanita (*Arctostaphylos pungens*), Wright's silktassel (*Garrya wrightii*), and netleaf oak (*Quercus rugosa*), all of which are occasionally codominant with silverleaf oak. Other notable, but usually low-cover, associate species in this stratum include Toumey oak (*Quercus toumeyii*), mountain yucca (*Yucca madrensis*), beargrass (*Nolina microcarpa*), and evergreen sumac (*Rhus virens*). The field stratum in this community is very sparse, with average total cover falling well below 5%. Bullgrass (*Muhlenbergia emersleyi*) is the most common field species and usually occurs with a diverse, low cover combination of other graminoids, forbs, and ferns, including cliff muhly (*Muhlenbergia polycaulis*), Arizona baccharis (*Baccharis thesioides*), fragrant snakeroot (*Ageratina herbacea*), and Canadian horsetweed (*Conyza canadensis*) and many other species.

This association is found in drainages and on steep north-trending mountain backslopes scattered throughout the monument, between 1,655–2,130 meters (5,430–6,988 ft) elevation. The stands are small with a patchy distribution and are often located in areas of high rock cover.

Common species: *Pinus discolor*, *Quercus hypoleuroides*, *Quercus arizonica*, *Arctostaphylos pungens*, *Muhlenbergia emersleyi*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 18–21.



Figure 18. An example landscape photo showing the more open-canopied woodland variant of the Border Pinyon / Silverleaf Oak Woodland Association. NPS



Figure 19. An example landscape photo showing the closed-canopied woodland variant of the Border Pinyon / Silverleaf Oak Woodland Association where the cover averages over 60%. NPS

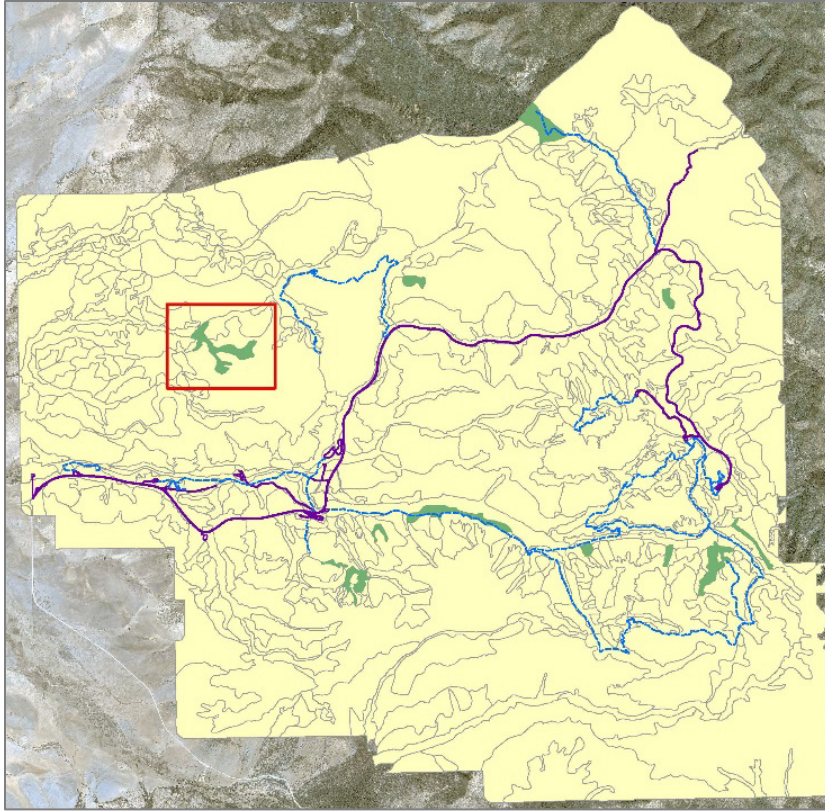


Figure 20. Vegetation map of CHIR with all areas mapped as Border Pinyon / Silverleaf Oak Woodland Association showing in green. NPS



Figure 21. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Border Pinyon / Silverleaf Oak Woodland. NPS

2. [*Pinus discolor* - *Juniperus deppeana* - *Quercus arizonica* - *Quercus emoryi*] / *Arctostaphylos pungens* Wooded Shrubland Association (P)

[Border Pinyon - Alligator Juniper - Arizona White Oak - Emory Oak] / Pointleaf Manzanita Wooded Shrubland Association

This wooded shrubland community is characterized by a variably dense (10–55%) canopy dominated by a combination of border pinyon (*Pinus discolor*), alligator juniper (*Juniperus deppeana*), and oaks (*Quercus arizonica* and *Q. emoryi*). Though any of these species may be absent in a given example of this association, usually at least three of the four are present. Alligator juniper, border pinyon, and Arizona white oak are the most consistent (>0.9) canopy components, and when present, usually generate between 5 and 25% cover, with occasional examples between 25% and 50% for each species. Emory oak (*Q. emoryi*) is slightly less consistent than the other species and when present rarely exceeds 25% cover.

Pointleaf manzanita (*Arctostaphylos pungens*) is the consistent subcanopy dominant, contributing approximately 25% cover on average. Toumey oak (*Quercus toumeyii*) is commonly present (0.65) but usually generates less than 5% cover. Other notable species in the subcanopy include mountain yucca (*Yucca madrensis*), beargrass (*Nolina microcarpa*), Palmer's century plant (*Agave palmeri*), common sotol (*Dasylirion wheeleri*), Wright's silktassel (*Garrya wrightii*), evergreen sumac (*Rhus virens*), and catclaw mimosa (*Mimosa aculeaticarpa*).

The field stratum cover ranges between 2 and 35% and is composed primarily of perennial grasses. Most commonly the cover is generated by a variable combination of bullgrass (*Muhlenbergia emersleyi*), pinyon ricegrass (*Piptochaetium fimbriatum*), Texas bluestem (*Schizachyrium cirratum*), and sideoats grama (*Bouteloua curtipendula*). The nonnative perennial Lehmann lovegrass (*Eragrostis lehmanniana*) sometimes occurs as a low-cover associate.

This wooded shrubland association is found on slopes and in drainages between 1,575- and 2,000-meters elevation (5,167–6,561 ft), primarily in the lower-elevation western half of the monument. It is especially common on the lower slopes of Bonita and Jesse James canyons. The substrate is rocky, with ground cover comprised of gravel and rock of various sizes, interspersed with litter; bedrock outcrops are uncommon.

Common species: *Pinus discolor*, *Juniperus deppeana*, *Quercus arizonica*, *Quercus emoryi*, *Arctostaphylos pungens*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 22–25.



Figure 22. An example landscape photo showing the more open-canopied woodland variant of the [Border Pinyon - Alligator Juniper - Arizona White Oak - Emory Oak] / Pointleaf Manzanita Wooded Shrubland Association. NPS



Figure 23. Photo showing the mixed shrub and trees within the [Border Pinyon - Alligator Juniper - Arizona White Oak - Emory Oak] / Pointleaf Manzanita Wooded Shrubland Association. NPS

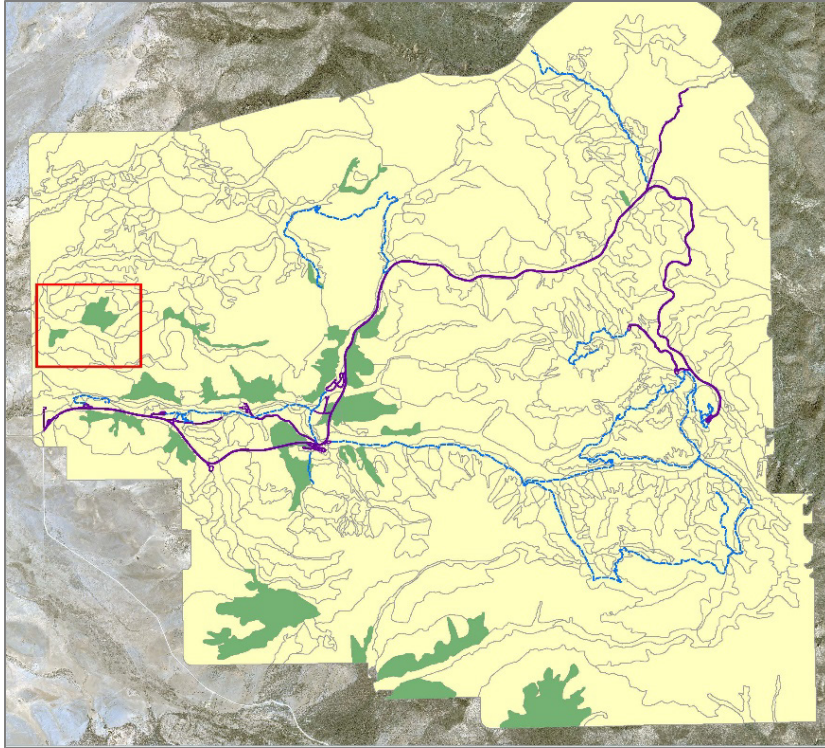


Figure 24. Map of CHIR with all areas mapped [Border Pinyon - Alligator Juniper - Arizona White Oak - Emory Oak] / Pointleaf Manzanita Wooded Shrubland Association shown in green. A red bounding box around one of these highlighted areas is showing where the example imagery, shown in the next figure, is located. NPS



Figure 25. An example area showing the texture and appearance of satellite imagery that was classified and mapped as [Border Pinyon - Alligator Juniper - Arizona White Oak - Emory Oak] / Pointleaf Manzanita Wooded Shrubland Association. NPS

3. [*Robinia neomexicana* - *Quercus rugosa*] / *Holodiscus discolor* / *Muhlenbergia montana* Tree Savanna Association (PS)

[New Mexico Locust - Nettleaf Oak] / Rockspirea / Mountain Muhly Tree Savanna Association

This association is indicated by the presence of New Mexico locust (*Robinia neomexicana*) in the canopy stratum, where it can occur either as the dominant species generating up to 33% cover or as a low-cover associate generating between 1 and 5% cover. This species trades dominance with netleaf oak (*Quercus rugosa*), with one or the other of the two species generally providing most of the cover. Cover estimates for this stratum range between 15% and 30%. Border pinyon (*Pinus discolor*), which generally is short-statured in this type, occasionally reaches the canopy and contributes between 1 and 5% cover in some areas.

The subcanopy is relatively sparse in this association, with total cover estimates ranging from 8% to 10%. Rockspirea (*Holodiscus discolor*) is a dominant species throughout. Border pinyon is a consistent associate in this stratum.

Most of the vegetative cover in this association is within the field stratum, which generally ranges between 50% and 65% total cover. Mountain muhly (*Muhlenbergia montana*) occurs either as the primary dominant or as a co-dominant species along with bullgrass (*Muhlenbergia emersleyi*) or muttongrass (*Poa fendleriana*). Common associate species in this stratum include Lemmon's sage (*Salvia lemmonii*), fragrant snakeroot (*Ageratina herbacea*), and gumhead (*Gymnosperma glutinosum*).

This association occurs only on the north-facing shoulder and backslope of Sugarloaf Mountain, on steep (>35%) slopes between 2,100 and 2,230 meters (6,920–7,310 ft).

Common species: *Robinia neomexicana*, *Quercus rugosa*, *Holodiscus discolor*, *Muhlenbergia montana*, *Muhlenbergia emersleyi*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 26–28.



Figure 26. A photo showing the dominant species within the [New Mexico Locust - Netleaf Oak] / Rockspirea / Mountain Muhly Tree Savanna Association. NPS

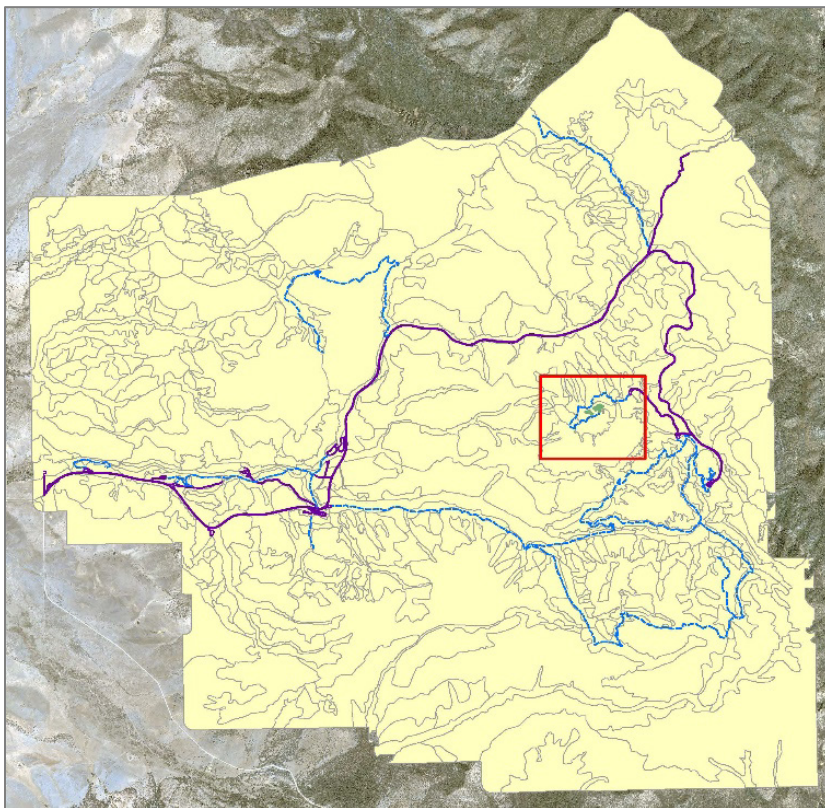


Figure 27. Map of CHIR with all areas mapped as [New Mexico Locust-Netleaf Oak] / Rockspirea / Mountain Muhly Tree Savanna Association showing in green. (Note these areas are so small and almost invisible at this scale. See next image for location in reference to the trail (blue in both images)). NPS

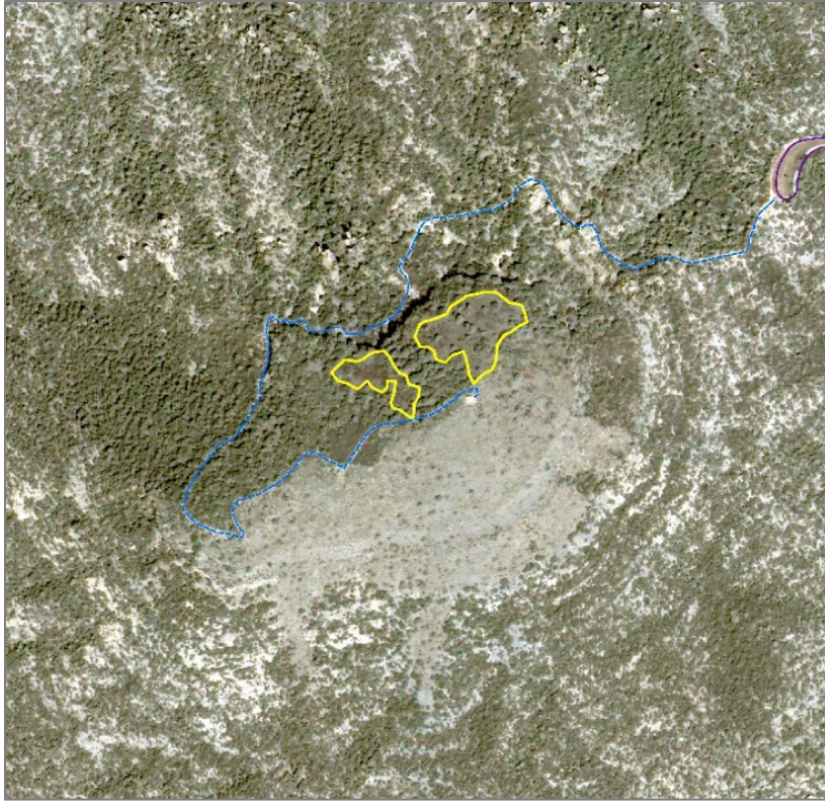


Figure 28. An example area showing the texture and appearance of satellite imagery that was classified and mapped as [New Mexico Locust - Netleaf Oak] / Rockspirea / Mountain Muhly Tree Savanna Association. NPS

4. *Pinus discolor* - (*Hesperocyparis arizonica*) / *Arctostaphylos pungens* Wooded Shrubland Association (P)

Border Pinyon - (Arizona Cypress) / Pointleaf Manzanita Wooded Shrubland Association

This wooded shrubland community is characterized by a moderately open canopy (>2 m) dominated by border pinyon (*Pinus discolor*) with consistent Arizona cypress (*Hesperocyparis arizonica*) that is not restricted to drainages (as it generally is in other associations in CHIR). Border pinyon (*Pinus discolor*) cover averages 12% but occasionally reaches over 50% canopy cover. Alligator juniper (*Juniperus deppeana*), Chihuahuan pine (*Pinus leiophylla*), and Arizona pine (*Pinus arizonica*) can also occur in this stratum.

The subcanopy is strongly dominated by dense (45%) pointleaf manzanita (*Arctostaphylos pungens*). Silverleaf oak (*Quercus hypoleucoides*) is a consistent associate in this stratum, though some individuals may reach the canopy (>2 m). Toumey oak (*Quercus toumeyii*) is present as a common associate species (0.82) typically averaging around 7% in cover; however, in rare examples it may become codominant or even surpass pointleaf manzanita (*A. pungens*).

The field layer is extremely sparse with total cover never exceeding 5%. Bullgrass (*Muhlenbergia emersleyi*) is the most common perennial species observed in the field stratum.

This association is found primarily in the high elevation areas in the southeast corner of the monument between 1,765 and 2,250 meters (5,790–7382 ft) with scattered examples in Little Jesse James Canyon as well as between Bonita Canyon and the northern park boundary. Though it can occur on a wide variety of slope positions, the most typical examples occur on gently to moderately sloped (6–35%) mountain crests, summits, shoulders, and backslopes. Unlike other communities of similar species composition, it does not often occur in areas with hoodoos, though some examples contain significant amounts of exposed bedrock. In general, soil surface cover is dominated by gravel with rock, bedrock, and boulders. The parent material throughout this community is almost always extrusive igneous rock or volcanic tuff.

Common species: *Pinus discolor*, *Hesperocyparis arizonica*, *Arctostaphylos pungens*, *Quercus toumeyii*, *Quercus hypoleucoides*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 29–31.



Figure 29. An example landscape photo showing the typical look of the Border Pinyon - (Arizona Cypress) / Pointleaf Manzanita Wooded Shrubland Association, with a dense understory of manzanita and scattered emergent tall pines. NPS

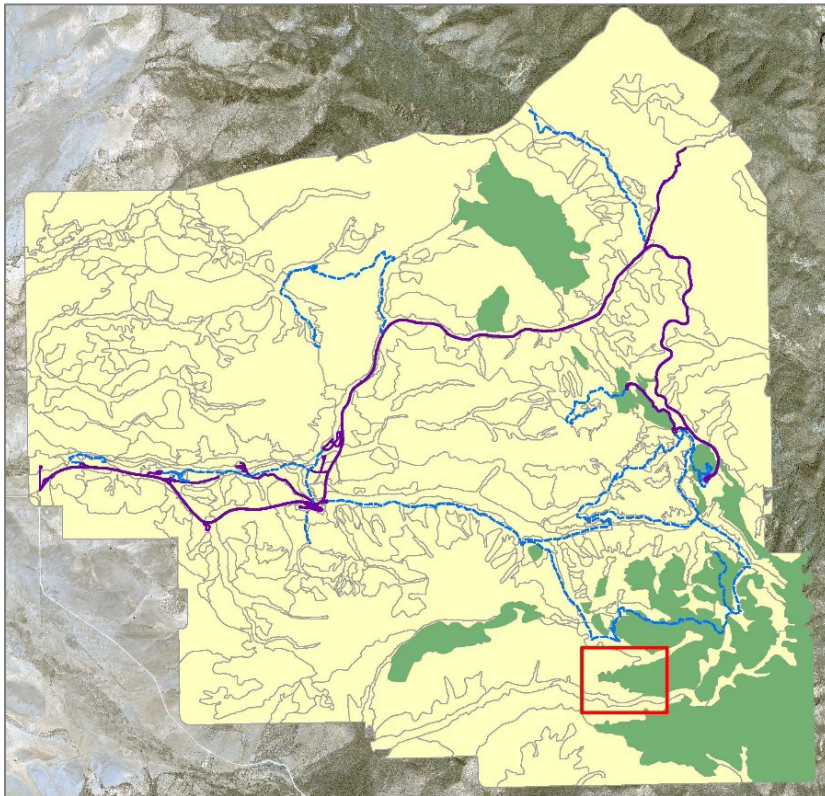


Figure 30. Map of CHIR with all areas mapped as Border Pinyon - (Arizona Cypress) / Pointleaf Manzanita Wooded Shrubland Association showing in green. NPS

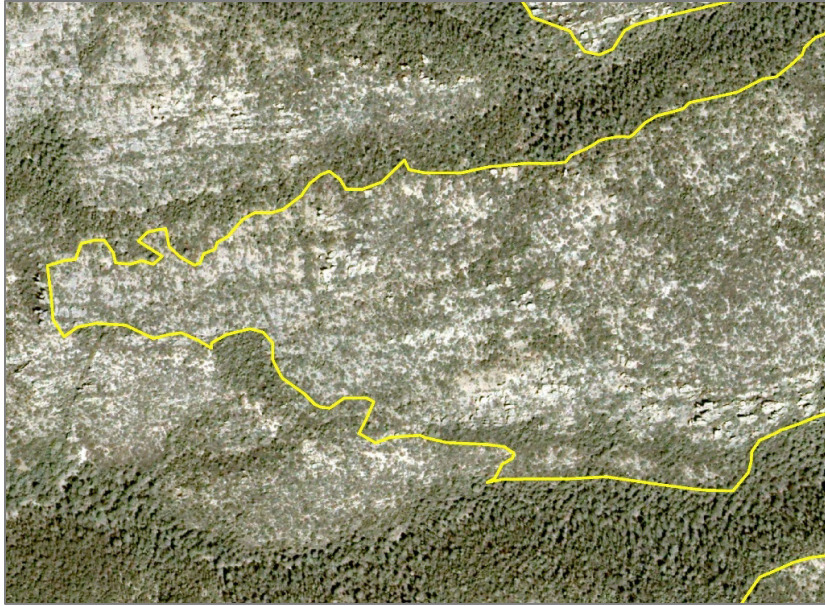


Figure 31. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Border Pinyon - (Arizona Cypress) / Pointleaf Manzanita Wooded Shrubland Association. NPS

5. *Pinus discolor* / *Cercocarpus montanus* Wooded Shrubland Association (PS)

Border Pinyon / Alderleaf Mountain Mahogany Wooded Shrubland Association

This wooded shrubland is characterized by a moderately dense (30%) canopy (>2 m) of border pinyon (*Pinus discolor*) and a moderately dense (25%) subcanopy stratum (0.5–2 m) of alderleaf mountain mahogany (*Cercocarpus montanus*).

Canopy cover in this community ranges from 10 to 50%, with an average cover of 30%. Border pinyon is dominant in the canopy, contributing around 25% cover. Alligator juniper (*Juniperus deppeana*) and Arizona white oak (*Quercus arizonica*) are occasional associates in this stratum but never surpass border pinyon in cover.

Total subcanopy cover ranges from 10 to 35%, with an average value of about 25%. Alderleaf mountain mahogany is the consistent (1.0) dominant and generates between 15 and 20% cover. Taller individuals of this species sometimes reach into the canopy stratum. Walkingstick cactus (*Cylindropuntia spinosior*) is a consistent associate species in the subcanopy (0.5–2 m) but contributes low cover overall.

The field stratum varies from very sparse to dense (5–60%) with an average cover of about 30%. In most cases the field is dominated by bullgrass (*Muhlenbergia emersleyi*) and/or sideoats grama (*Bouteloua curtipendula*). Cliff muhly (*Muhlenbergia polycaulis*) can occasionally be dominant or codominant in this stratum. The non-native invasive Lehmann lovegrass (*Eragrostis lehmanniana*) is present in nearly half of examples.

This uncommon association is restricted to the extreme northeast corner of the monument. It occurs on moderate to steep (>15%) south- and southwest-facing mountain slopes between 1,865 and 2,300 meters (6,115–7,546 ft) in elevation. The surface cover is predominately gravel, rock, and exposed bedrock, occasionally with significant litter cover.

Common species: *Pinus discolor*, *Juniperus deppeana*, *Cercocarpus montanus*, *Muhlenbergia emersleyi*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 32–34.



Figure 32. An example landscape photo showing the Border Pinyon/ Alderleaf Mountain Mahogany Wooded Shrubland Association, with the common associate walkingstick cactus (*Cylindropuntia spinosior*) and agaves shown in the open areas. NPS

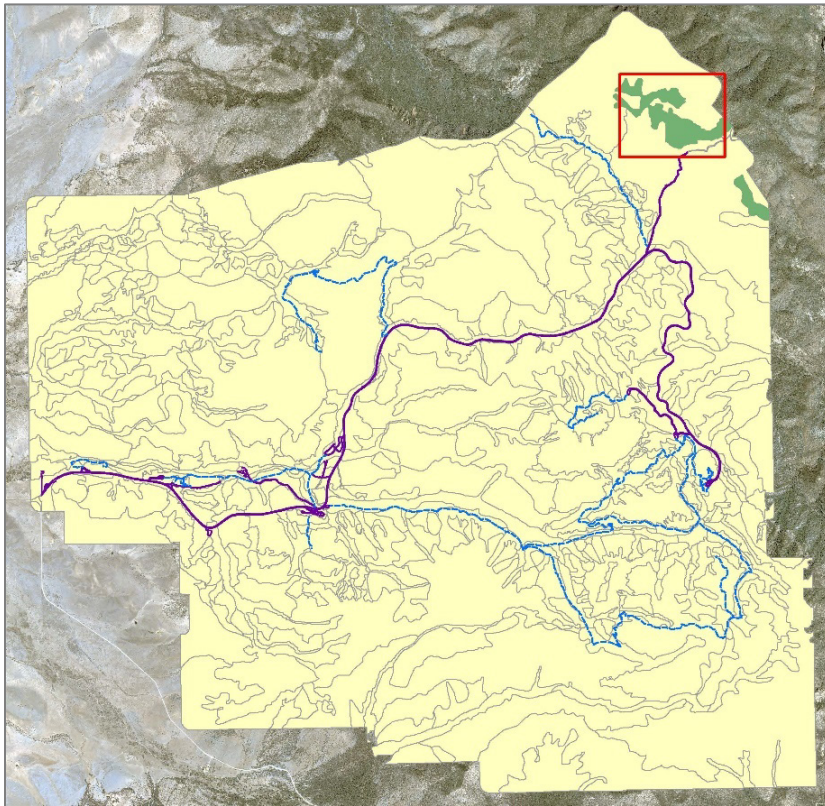


Figure 33. Map of CHIR with all areas mapped as Border Pinyon/ Alderleaf Mountain Mahogany Wooded Shrubland Association showing in green. NPS

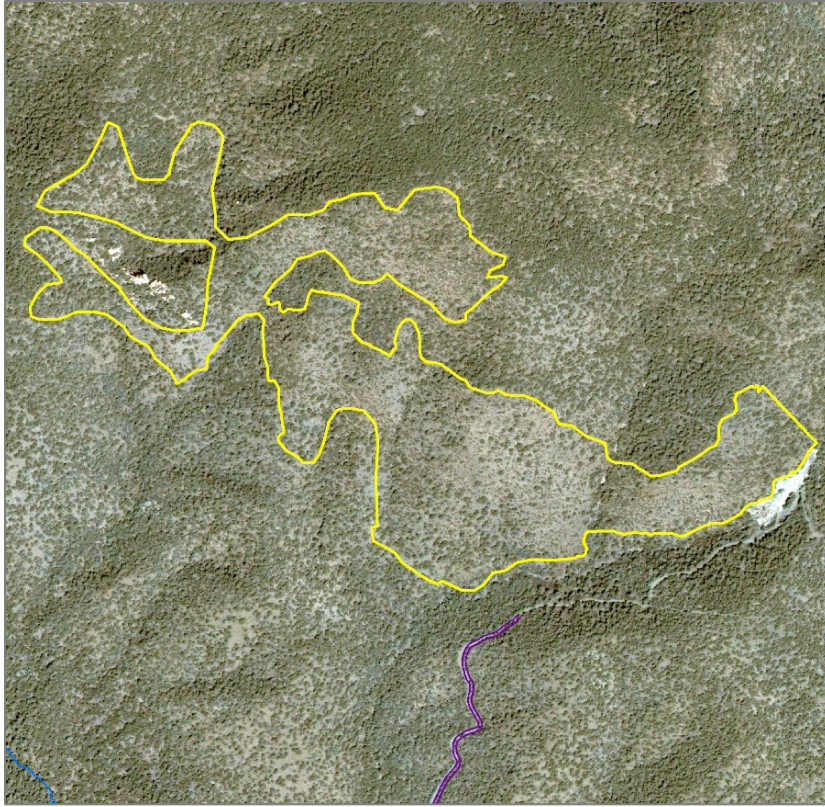


Figure 34. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Border Pinyon/ Alderleaf Mountain Mahogany Wooded Shrubland Association. NPS

6. *Pinus discolor* / *Quercus toumeyi* - (*Garrya wrightii*) / *Muhlenbergia emersleyi* Wooded Shrubland Association (P)

Border Pinyon / Toumey Oak – (Wright’s Silktassel) / Bullgrass Wooded Shrubland Association

This variable wooded shrubland community is characterized by a very open canopy of border pinyon (*Pinus discolor*) with diverse and varied subcanopy and field strata dominated by Toumey oak (*Quercus toumeyi*) and bullgrass (*Muhlenbergia emersleyi*), respectively, with a diverse mix of associate species. It is distinguished from other wooded shrubland communities in the monument by the consistent dominance of Toumey oak, high shrub diversity, and relatively high cover and diversity of perennial grasses. Though it usually occurs as a wooded shrubland community, it can also present as an open, grassy shrubland with very low tree cover at lower elevations.

Border pinyon is consistently present and on average contributes between 5 and 10% canopy cover. Alligator juniper (*Juniperus deppeana*), Arizona juniper (*J. arizonica*), and Emory oak (*Quercus emoryi*) sometimes equal or surpass border pinyon in cover. Ocotillo (*Fouquieria splendens*) often occurs in the low-elevation examples of this community, though it generally contributes little cover.

Toumey oak is the clear and consistent dominant species in the subcanopy. Though pointleaf manzanita (*Arctostaphylos pungens*) is almost always present, it generally contributes lower cover than Toumey oak. Wright’s silktassel (*Garrya wrightii*) is a common associate and often, alone or in combination with evergreen sumac (*Rhus virens*), surpasses the cover of manzanita.

The grassy field stratum is typically dominated by bullgrass and averages about 20% total cover. Other native grasses include Texas bluestem (*Schizachyrium cirratum*), single threeawn (*Aristida schiedeana*), sideoats grama (*Bouteloua curtipendula*), bristly wolfstail (*Muhlenbergia alopecuroides*), plains lovegrass (*Eragrostis intermedia*), blue grama (*Bouteloua gracilis*), cane bluestem (*Bothriochloa barbinodis*), tanglehead (*Heteropogon contortus*), and slender grama (*Bouteloua repens*), which contribute varied cover and may at times be codominant with bullgrass. The non-native invasive Lehmann lovegrass (*Eragrostis lehmanniana*) is commonly present.

This association is widely distributed on hillslopes in the lower elevation areas of the monument.

Common species: *Quercus toumeyi*, *Pinus discolor*, *Arctostaphylos pungens*, *Garrya wrightii*, *Muhlenbergia emersleyi*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 35–37.



Figure 35. An example landscape photo showing the Border Pinyon/ Toumey Oak - (Wright's Silktassel)/ Bullgrass Wooded Shrubland Association. This community is structurally diverse with moderate cover of pinyon trees and a consistent oak Toumey oak understory and high grass cover, seen in the image foreground. NPS

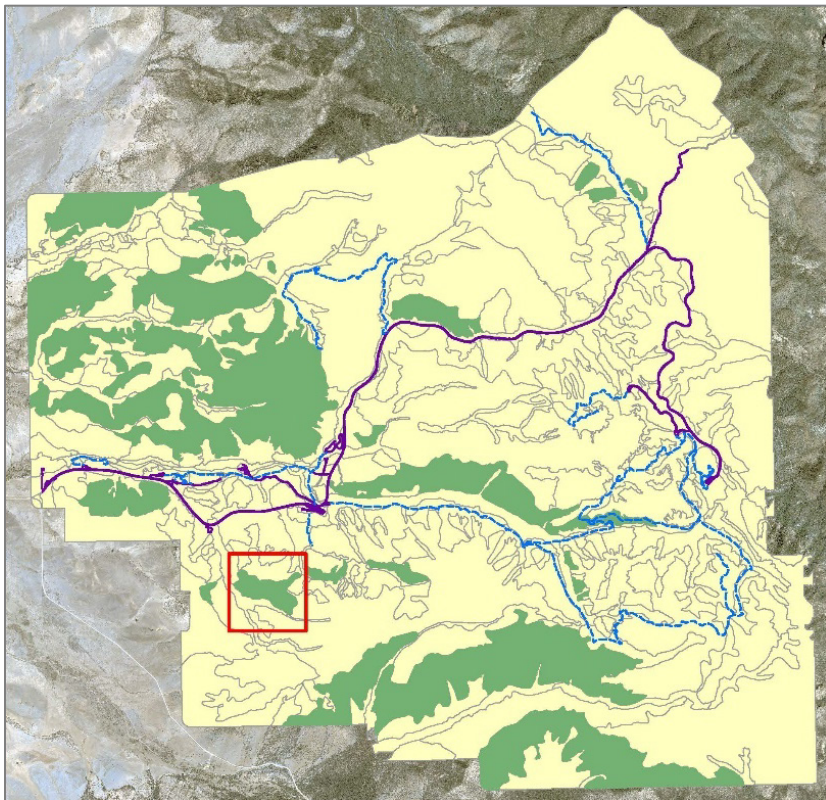


Figure 36. Map of CHIR with all areas mapped as Border Pinyon/ Toumey Oak- (Wright's Silktassel)/ Bullgrass Wooded Shrubland Association showing in green. NPS

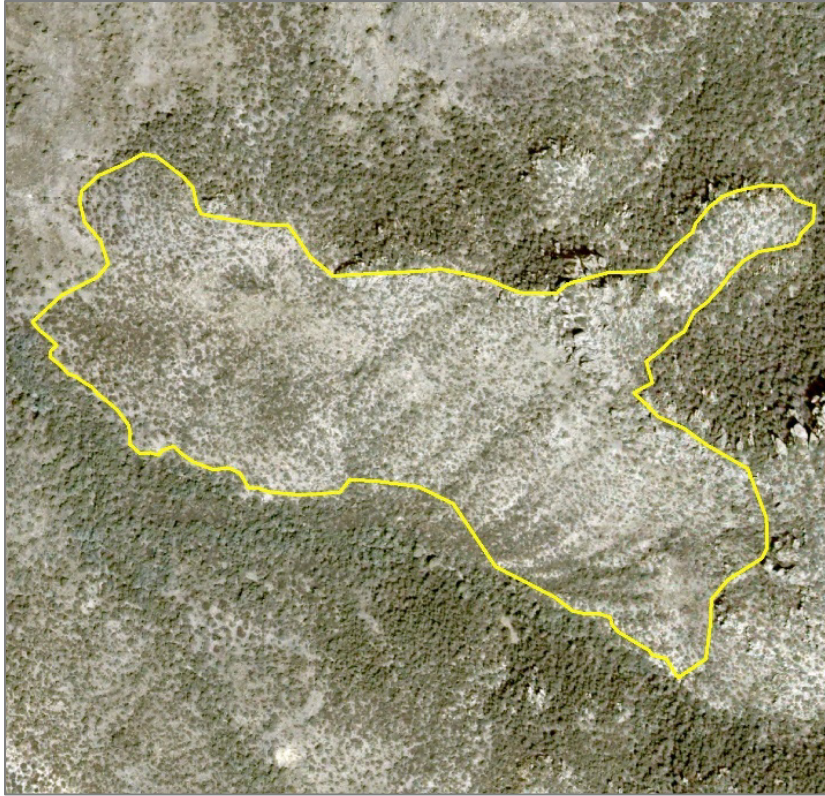


Figure 37. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Border Pinyon/ Toumey Oak - (Wright's Silktassel)/ Bullgrass Wooded Shrubland Association. NPS

7. *Pinus discolor* / *Quercus toumeyi* - *Arctostaphylos pungens* Wooded Shrubland Association (P)

Border Pinyon / Toumey Oak - Pointleaf Manzanita Wooded Shrubland Association

This wooded shrubland community is characterized by an open-to-dense (5–50%) canopy dominated by border pinyon (*Pinus discolor*) and a moderately dense (40%) subcanopy of Toumey oak (*Quercus toumeyi*) and pointleaf manzanita (*Arctostaphylos pungens*).

Border pinyon (*Pinus discolor*) is a consistent canopy dominant contributing between 15 and 25% cover. Alligator juniper (*Juniperus deppeana*) is a common associate contributing less than 5% cover. Other noteworthy canopy species include Arizona white oak (*Quercus arizonica*) and Chihuahuan pine (*Pinus leiophylla*). Arizona cypress (*Hesperocyparis arizonica*) is occasionally present in association with small drainages.

The bulk of cover in this community is contained in the subcanopy. Pointleaf manzanita and Toumey oak are the dominant species, often occurring together but forming stands in which one species is dominant over the other. In some examples, Toumey oak may be absent and replaced by a combination of Wright's silktassel (*Garrya wrightii*) and evergreen sumac (*Rhus virens*). Shrubby examples of both silverleaf oak (*Quercus hypoleucoides*) and netleaf oak (*Q. rugosa*) are occasional associates and may be locally abundant.

The field stratum in this community is very open, with total cover rarely exceeding 10%. Bullgrass (*Muhlenbergia emersleyi*) is present in almost all examples. Other native grasses, including Texas bluestem (*Schizachyrium cirratum*), pinyon ricegrass (*Piptochaetium fimbriatum*), single threeawn (*Aristida schiedeana*), and sideoats grama (*Bouteloua curtipendula*) may also be present.

This very common and widespread association occurs on low-angle (<5%) to steep (>50%) mountain slopes of variable aspect from 1,595 to 2,270 meters (5,235–7,447 ft.) throughout the monument. It commonly occurs among the hoodoos. In general, the soil surface cover is dominated by gravel with rock, bedrock, and boulders.

Common species: *Pinus discolor*, *Quercus toumeyi*, *Arctostaphylos pungens*, *Garrya wrightii*, *Rhus virens*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 38–41.



Figure 38. An example landscape photo showing the Border Pinyon / Toumey Oak - Pointleaf Manzanita Wooded Shrubland Association within an area with a steep drainage and hoodoo rock outcrops. NPS



Figure 39. An example landscape photo showing the Border Pinyon / Toumey Oak - Pointleaf Manzanita Wooded Shrubland Association within a low-angle drainage. NPS

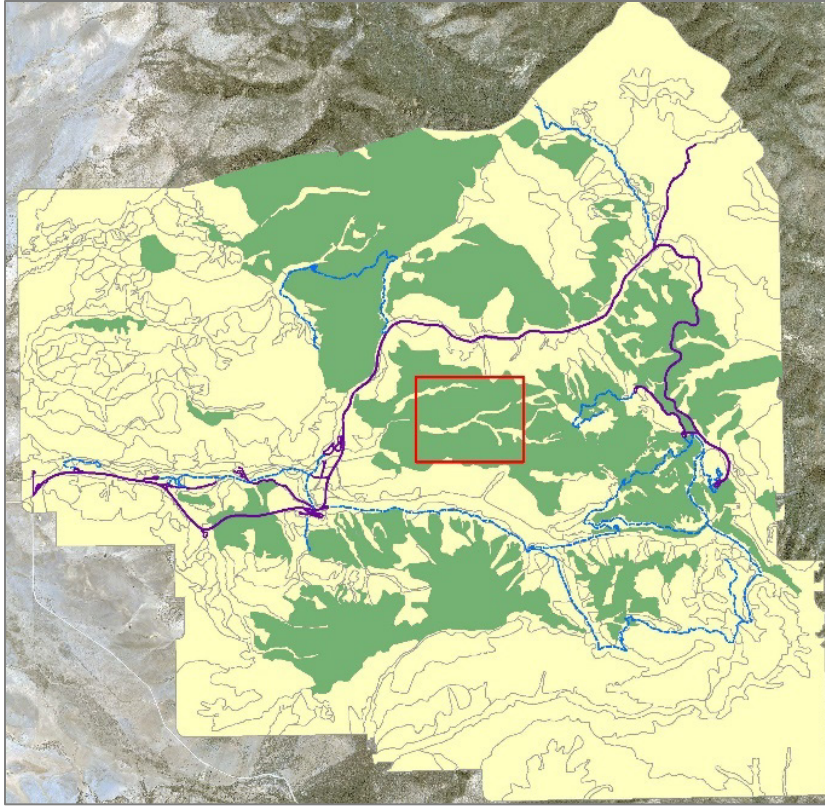


Figure 40. Map of CHIR with all areas mapped as Border Pinyon / Toumey Oak - Pointleaf Manzanita Wooded Shrubland Association showing in green. NPS



Figure 41. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Border Pinyon / Toumey Oak - Pointleaf Manzanita Wooded Shrubland Association. The wooded shrubland appears open-canopied and less dense with patchy clusters of trees, distinctly different from the thick closed-canopy drainage communities seen as linear strips running through it. NPS

8. *Pinus discolor* / *Quercus toumeyi* - *Garrya wrightii* Woodland Association (P)

Border Pinyon / Toumey Oak - Wright's Silktassel Woodland Association

This densely wooded community is characterized by a thick canopy of border pinyon (*Pinus discolor*), a subcanopy dominated by Toumey oak (*Quercus toumeyi*) and/or Wright's silktassel (*Garrya wrightii*) and a sparse field stratum of variable composition. This association is differentiated from others with similar species composition mainly by its woodland form.

Border pinyon is the consistent canopy dominant. On average, this species generates about 40% cover but in the densely wooded examples of this community, it can exceed 80%. Alligator juniper (*Juniperus deppeana*), silverleaf oak (*Quercus hypoleucoides*), Arizona white oak (*Quercus arizonica*), and Arizona cypress (*Hesperocyparis arizonica*) are common associates in this stratum.

In the subcanopy, Toumey oak is consistently dominant or codominant with Wright's silktassel. Both species are present in all examples of this association. Pointleaf manzanita (*Arctostaphylos pungens*) is present in more than half of examples and occasionally approaches the cover of Toumey oak or Wright's silktassel.

The field stratum is open and lacks a consistent dominant. Bullgrass (*Muhlenbergia emersleyi*) and pinyon ricegrass (*Piptochaetium fimbriatum*) are both common and can provide the bulk of the field cover when present. Gumhead (*Gymnosperma glutinosum*) is a common associate.

This association occurs between 1,680 and 2,145 meters (5,512–7,037 ft) elevation on steep, north-trending backslopes above the large drainages of Rhyolite and Bonita canyons. These areas often contain large bedrock outcrops and hoodoos, and the substrate is generally rocky and gravelly with some patches of litter; bare soil is rare.

Common species: *Pinus discolor*, *Quercus toumeyi*, *Garrya wrightii*, *Arctostaphylos pungens*, *Muhlenbergia emersleyi*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 42–44.



Figure 42. An example landscape photo showing a typical view of the Border Pinyon/ Toumey Oak - Wright's Silktassel Woodland Association. NPS

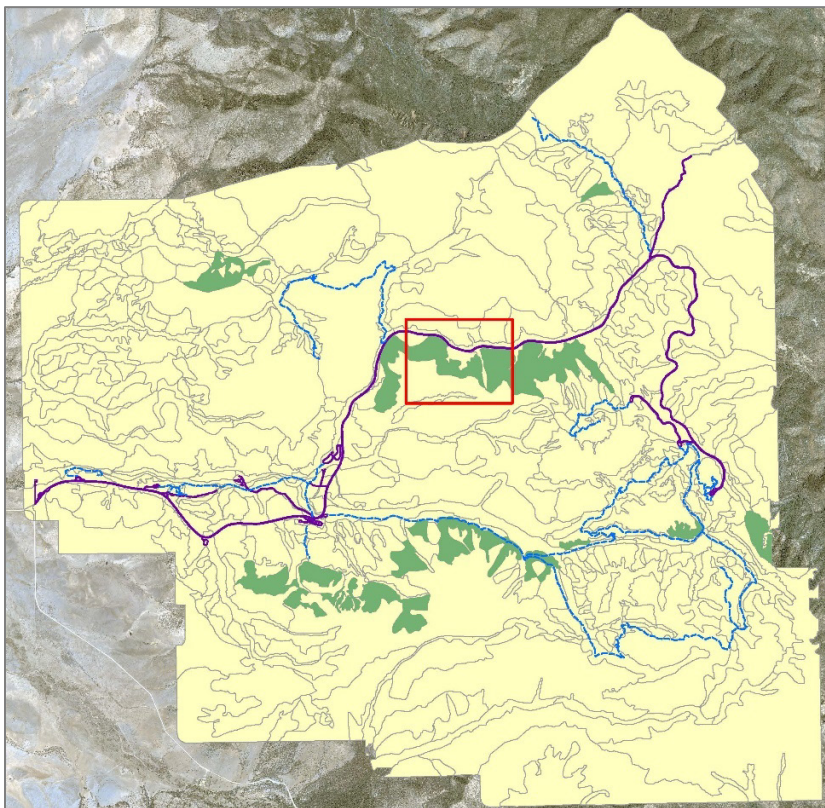


Figure 43. Map of CHIR with all areas mapped as Border Pinyon/ Toumey Oak - Wright's Silktassel Woodland Association showing in green. NPS

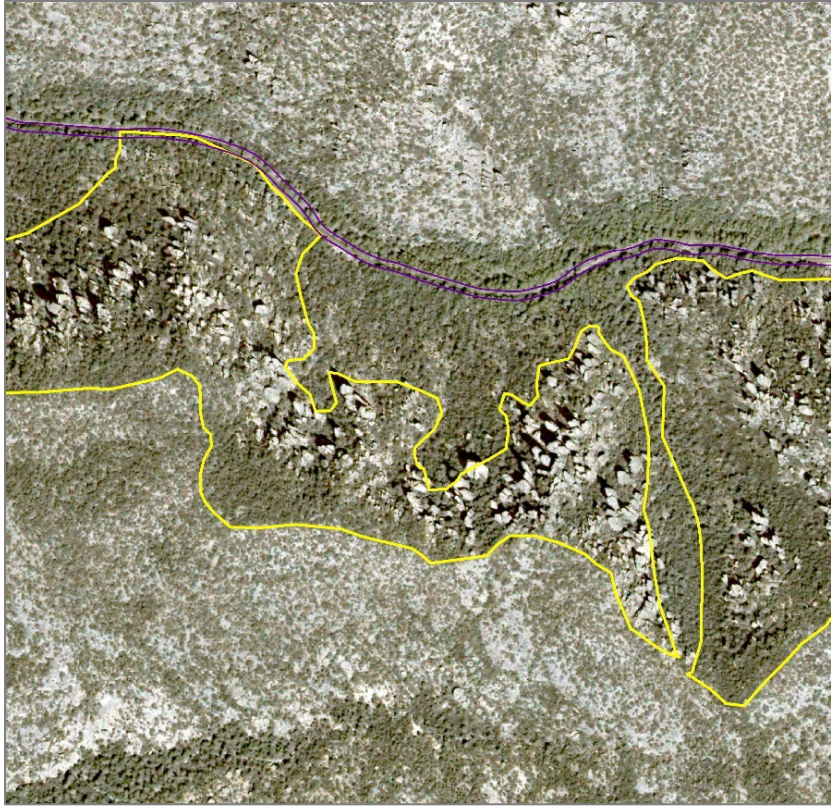


Figure 44. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Border Pinyon/ Toumey Oak - Wright's Silktassel Woodland Association. NPS

9. *Pinus discolor* / *Muhlenbergia emersleyi* Woodland Association

Border Pinyon/ Bullgrass Woodland Association

This woodland association is characterized by a canopy dominated by border pinyon (*Pinus discolor*) with a variable understory in which native perennial grasses, especially bullgrass (*Muhlenbergia emersleyi*), are the primary component. This association varies widely in appearance—examples may be grassy with open canopies or densely wooded with relatively little grass cover.

The canopy stratum (<2 m) may be open or very dense, with total cover values ranging from 15 to 70%. Border pinyon is the most consistently dominant species in this stratum. Alligator juniper (*Juniperus deppeana*) and Arizona white oak (*Quercus arizonica*) are present in all examples and may sometimes be codominant with border pinyon. Silverleaf oak (*Quercus hypoleucoides*) and Emory oak (*Quercus emoryi*) are occasionally present as canopy associates.

The subcanopy stratum (0.5–2 m) consists of an open mix of shrubs and succulents with no clear dominant species. Total cover is again highly variable, though it generally does not exceed about 35%. Common species include mountain yucca (*Yucca madrensis*), beargrass (*Nolina microcarpa*), pointleaf manzanita (*Arctostaphylos pungens*), alderleaf mountain mahogany (*Cercocarpus montanus*), Wright's silktassel (*Garrya wrightii*), Toumey oak (*Quercus toumeyii*), common sotol (*Dasyilirion wheeleri*), and catclaw mimosa (*Mimosa aculeaticarpa*).

The field stratum (<0.5 m) may be sparse or quite dense, with total cover values falling anywhere between 1 and 60%. It is composed mostly of native perennial grasses, with bullgrass the most consistent species. Common associates include sideoats grama (*Bouteloua curtipendula*), pinyon ricegrass (*Piptochaetium fimbriatum*), Texas bluestem (*Schizachyrium cirratum*), single threeawn (*Aristida schiedeana*), hairy grama (*Bouteloua hirsuta*), and cliff muhly (*Muhlenbergia polycaulis*).

This woodland association covers much of the high-elevation northeast corner of the monument, with a few scattered examples elsewhere. It occurs on variable slopes and aspects between 1,610 and 2,390 meters (5,282–7,841 ft) elevation. The substrate consists of a mix of litter, gravel, bare soil, and rock.

Common species: *Pinus discolor*, *Juniperus deppeana*, *Quercus arizonica*, *Muhlenbergia emersleyi*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 45–48.



Figure 45. An example landscape photo showing the more open-woodland variant of the Border Pinyon / Bullgrass Woodland Association. NPS



Figure 46. An example landscape photo showing the grassier variant of the Border Pinyon / Bullgrass Woodland Association. NPS

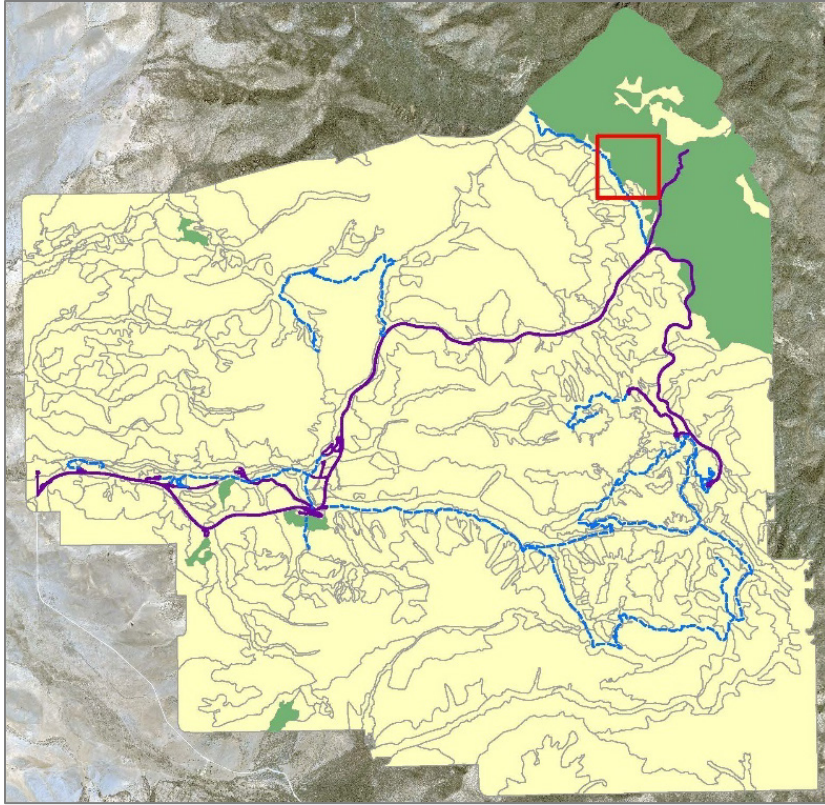


Figure 47. Map of CHIR with all areas mapped as Border Pinyon / Bullgrass Woodland Association showing in green. NPS

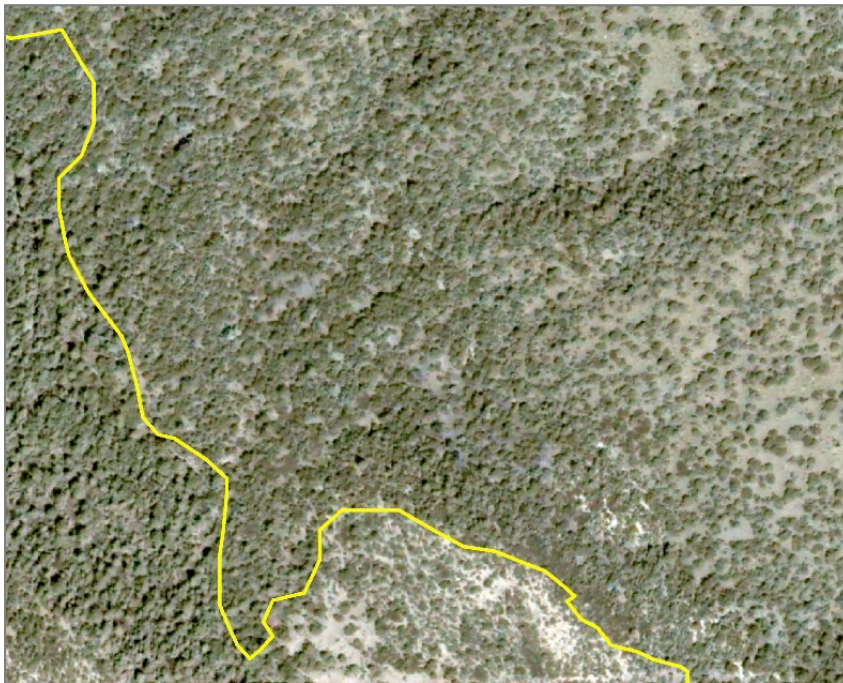


Figure 48. An example area showing the texture and appearance of satellite imagery that was classified and mapped as the Border Pinyon / Bullgrass Woodland Association. NPS

10. *Pinus discolor* / *Piptochaetium fimbriatum* Woodland Association

Border Pinyon / Pinyon Ricegrass Woodland Association

This woodland association consists of a dense canopy of border pinyon (*Pinus discolor*) and a sparse field layer dominated by pinyon ricegrass (*Piptochaetium fimbriatum*).

The canopy stratum (<2 m) is very dense with an average total cover of 70%. The majority of this cover is contributed by border pinyon. Alligator juniper (*Juniperus deppeana*) is a common associate species. Nettleleaf oak (*Quercus rugosa*), canyon live oak (*Q. chrysolepis*), and alderleaf mountain mahogany (*Cercocarpus montanus*) also commonly reach the canopy but contribute only a trace amount of cover.

The subcanopy in this community is very sparse (5%). Wright's silktassel (*Garrya wrightii*) is the dominant species and is joined by a low cover mix of mountain yucca (*Yucca madrensis*), banana yucca (*Y. baccata*), skunkbush sumac (*Rhus trilobata*), beargrass (*Nolina microcarpa*), and Toumey oak (*Quercus toumeyii*).

Pinyon ricegrass contributes between 1 and 5% cover in the field stratum and is the most consistent perennial species. Associate species include twistspine prickly pear (*Opuntia macrorhiza*), cliff muhly (*Muhlenbergia polycaulis*), bullgrass (*M. emersleyi*), hedgehog cactus (*Echinocereus* spp.), and Lemmon's sage (*Salvia lemmonii*). Seasonally, an abundance of annual forbs may contribute significant cover.

This association is found exclusively on the steep (>35%) northwest facing slope of Sugarloaf Mountain between 2,035 and 2,190 meters (6,677–7,185 ft) in elevation. The substrate is predominantly rock, with sparse bare soil, gravel, exposed bedrock, and litter.

Common species: *Pinus discolor*, *Juniperus deppeana*, *Garrya wrightii*, *Piptochaetium fimbriatum*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 49–51.



Figure 49. A photo showing the Border Pinyon / Pinyon Ricegrass Woodland Association, with a springtime flush of annual forbs. NPS

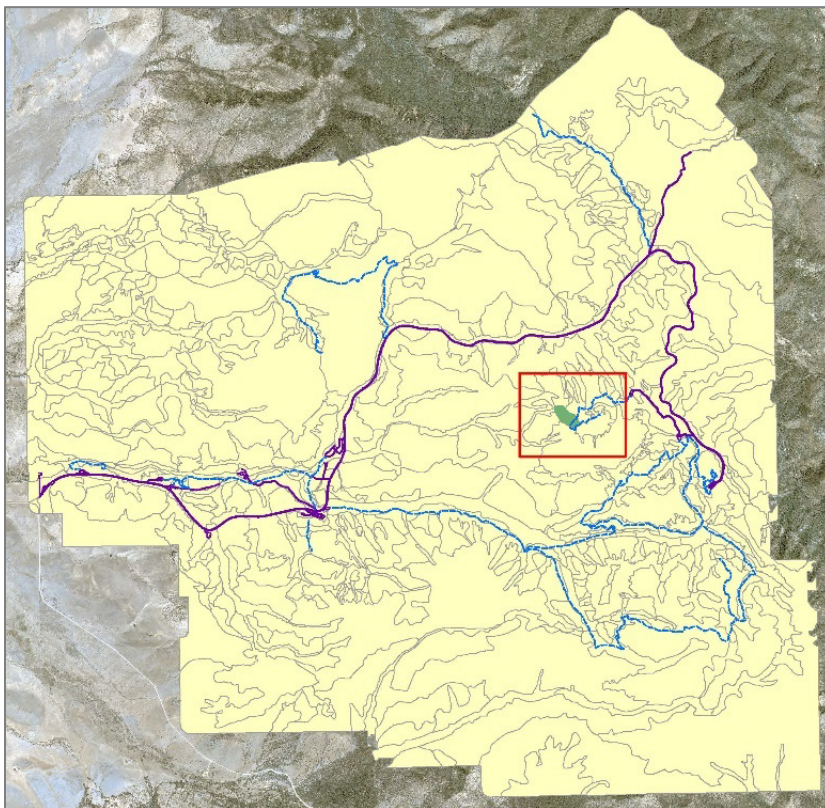


Figure 50. Map of CHIR with all areas mapped as Border Pinyon / Pinyon Ricegrass Woodland Association showing in green. NPS

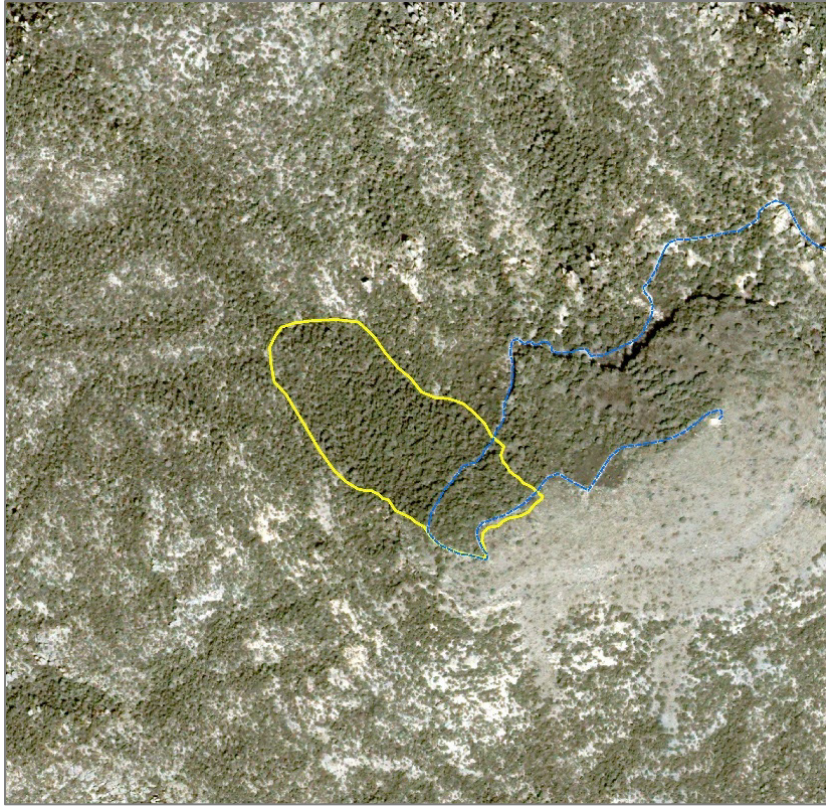


Figure 51. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Border Pinyon / Pinyon Ricegrass Woodland Association. NPS

11. *Quercus emoryi* / *Piptochaetium fimbriatum* Scrub Woodland Association

Emory Oak / Pinyon Ricegrass Scrub Woodland Association

This intermittently flooded woodland community is characterized by stands of codominant Arizona white oak (*Quercus arizonica*) and Emory oak (*Q. emoryi*) with an open understory of various shrubs and perennial grasses.

Total cover in the canopy stratum (> 2 m) averages between 35 and 40%. Arizona white oak and Emory oak are approximately codominant, with Emory oak generally most abundant on the upper terrace and floodplain adjacent to the drainage and white oak more common on banks and lower terraces. Alligator juniper (*Juniperus deppeana*), Arizona juniper (*J. arizonica*), and border pinyon (*Pinus discolor*) are present as low cover associates.

The subcanopy stratum (0.5–2 m) is relatively open, with an average total cover of approximately 20%. Pointleaf manzanita (*Arctostaphylos pungens*) is the consistent dominant species. Wright's silktassel (*Garrya wrightii*), evergreen sumac (*Rhus virens*), and mountain mahogany (*Cercocarpus montanus*) are present in all examples of this association, though always at low cover. Less common subcanopy associates include Toumey oak (*Quercus toumeyii*) and Apache plume (*Fallugia paradoxa*).

The sparse field stratum (<0.5 m) is primarily composed of native perennial grasses and averages about 10% total cover. The two most commonly dominant species are pinyon ricegrass (*Piptochaetium fimbriatum*) and bullgrass (*Muhlenbergia emersleyi*). Common associates include green sprangletop (*Leptochloa dubia*) and plains lovegrass (*Eragrostis intermedia*).

This community is found along ephemeral canyon drainages from approximately 1,550 to 1,650 meters (~5,100–5,400 ft) in Newton, Picket and Little Picket Canyons, as well as a smaller drainage in the northwest corner of the monument. The ground cover is predominantly sand, gravel, and rock, with litter collecting deeply in some areas.

Common species: *Quercus arizonica*, *Quercus emoryi*, *Arctostaphylos pungens*, *Piptochaetium fimbriatum*, *Muhlenbergia emersleyi*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 52–54.



Figure 52. An example landscape photo showing the Emory Oak / Pinyon Ricegrass Scrub Woodland Association. NPS

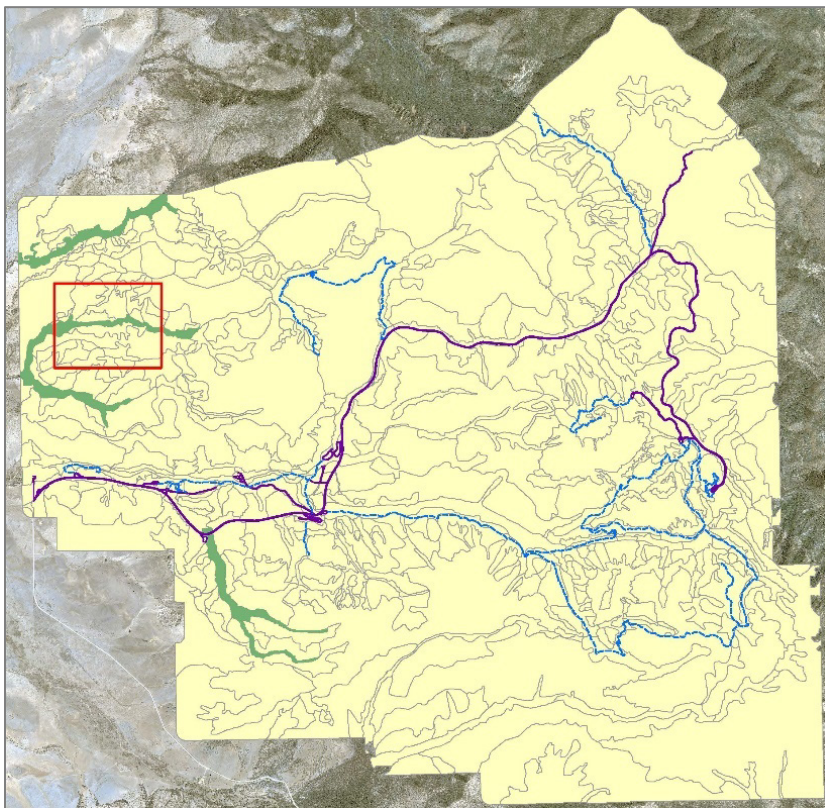


Figure 53. Map of CHIR with all areas mapped as Emory Oak / Pinyon Ricegrass Scrub Woodland Association showing in green. NPS



Figure 54. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Emory Oak / Pinyon Ricegrass Scrub Woodland Association. NPS

12. [*Quercus hypoleucoides* - *Quercus arizonica*] Woodland Association (P)

[Silverleaf Oak - Arizona White Oak] Woodland Association

This woodland community is characterized by a dense canopy dominated by silverleaf oak (*Quercus hypoleucoides*), and to a lesser extent, Arizona white oak (*Quercus arizonica*). Large conifers, when present, contribute minimal cover. The subcanopy and field stratum are generally open and contain no consistent dominants.

The canopy stratum (<2 m) is variably dense with total cover generally falling between 35 and 65%. Silverleaf oak and Arizona white oak are both consistent in this stratum but silverleaf oak is often the more abundant of the two. Border pinyon (*Pinus discolor*) is a consistent canopy associate. Arizona cypress (*Hesperocyparis arizonica*), alligator juniper (*Juniperus deppeana*), Arizona madrone (*Arbutus arizonica*), Emory oak (*Quercus emoryi*), and Chihuahuan pine (*Pinus leiophylla*) may also be present but comprise much less cover than the dominant oak species.

The subcanopy (0.5–2 m) is generally open with a mix of shrubs averaging around 12% total cover. Shrubby oaks, including silverleaf oak, Toumey oak (*Quercus toumeyii*), and netleaf oak (*Q. rugosa*) are common. Other notable associates include pointleaf manzanita (*Arctostaphylos pungens*), Wright's silktassel (*Garrya wrightii*), and evergreen sumac (*Rhus virens*).

The field stratum (<0.5 m) is very sparse, with total cover never surpassing 5%. Cover is provided by an inconsistent mix of subshrubs, graminoids, and forbs, including Canadian horsetail (*Coryza canadensis*), plains lovegrass (*Eragrostis intermedia*), single threeawn (*Aristida schiedeana*), and pinyon ricegrass (*Piptochaetium fimbriatum*).

This association is found in lower elevation drainages, primarily in Picket and Jesse James canyons, as well as a few smaller canyons on the western and southern boundaries of the monument. It generally occurs in low-angle to moderately steep (1–35%), often west-trending, drainages between 1,620–2,020 meters (5,314–6,627 ft). Surface cover is typically dominated by gravel, rock, and litter.

Common species: *Quercus hypoleucoides*, *Quercus arizonica*, *Pinus discolor*, *Quercus toumeyii*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 55–57.



Figure 55. An example landscape photo showing the more open-canopied woodland variant of the Silverleaf Oak - Arizona White Oak Woodland Association. NPS

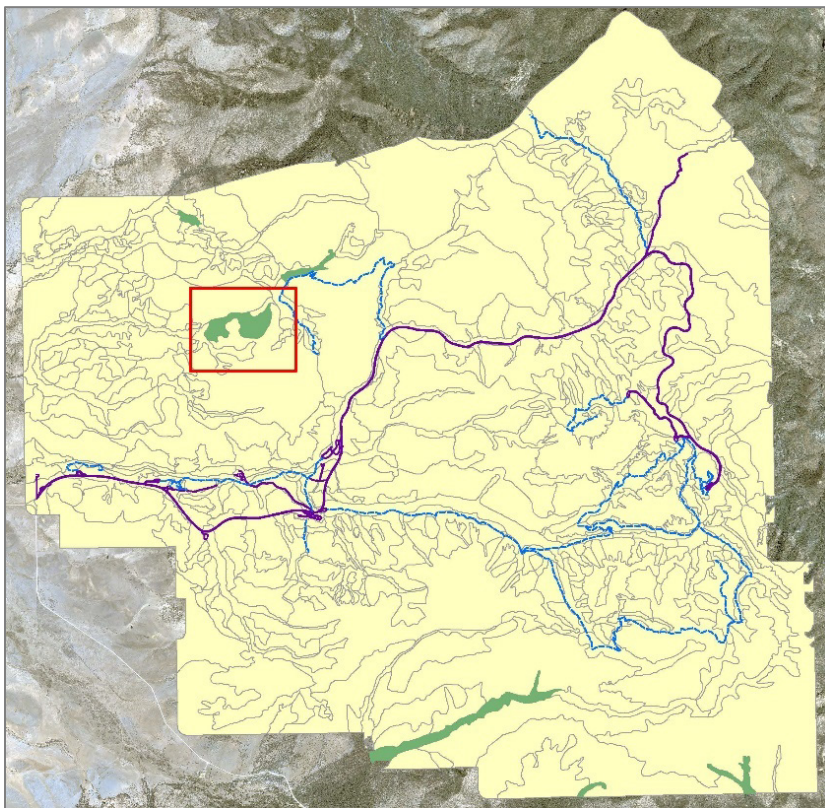


Figure 56. Map of CHIR with all areas mapped as Silverleaf Oak - Arizona White Oak Woodland Association showing in green. NPS



Figure 57. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Silverleaf Oak - Arizona White Oak Woodland Association. NPS

13. (*Juniperus deppeana*) / *Mimosa aculeaticarpa* Wooded Shrubland Association (PS)

(Alligator Juniper) / Catclaw Mimosa Wooded Shrubland Association

This wooded shrubland community is characterized by an open canopy of alligator juniper (*Juniperus deppeana*), a moderately dense subcanopy (0.5–2 m) dominated by catclaw mimosa (*Mimosa aculeaticarpa*), and an open-to-dense field layer dominated by perennial grasses.

In the canopy stratum (>2 m), total cover is generally below 10%. The majority of cover is usually provided by alligator juniper with the remainder from Emory oak (*Quercus emoryi*) and Arizona white oak (*Quercus arizonica*).

The subcanopy (0.5–2 m) is often dense, with total cover averaging around 30% but occasionally reaching as high as 80%. It is strongly dominated by catclaw mimosa, which forms dense thickets, making hiking through this community difficult. Outside of these thickets, common associate species include beargrass (*Nolina microcarpa*), mountain yucca (*Yucca madrensis*), Palmer's century plant (*Agave palmeri*), pointleaf manzanita (*Arctostaphylos pungens*), walkingstick cactus (*Cylindropuntia spinosior*), and common sotol (*Dasylirion wheeleri*).

The field layer (<0.5 m) consists of a diverse mix of perennial grasses which typically generates 25–45% cover. Sideoats grama (*Bouteloua curtipendula*) and slender grama (*Bouteloua repens*) are the most consistent species. The invasive Lehmann lovegrass (*Eragrostis lehmanniana*) is often present at variable cover ranging from less than 1% to 40%. Other noteworthy grasses include bullgrass (*Muhlenbergia emersleyi*), cane bluestem (*Bothriochloa barbinodis*), green sprangletop (*Leptochloa dubia*), hairy grama (*Bouteloua hirsuta*), blue grama (*Bouteloua gracilis*), and Texas bluestem (*Schizachyrium cirratum*).

This association is restricted to the lower slopes of Newton Canyon and a patch just north of the visitor center. It spans moderate grade (15–35%) slopes of variable aspect from 1,620 to 1,745 meters (5,315–5,725 ft). Ground cover tends to be a mix of gravel and rock with exposed bedrock present in all examples.

Common species: *Juniperus deppeana*, *Mimosa aculeaticarpa*, *Bouteloua curtipendula*, *Bouteloua repens*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 58–60.



Figure 58. An example landscape photo showing the Alligator Juniper / Catclaw Mimosa Wooded Shrubland Association. The community is restricted to the hillslope shown on the right side of the image. NPS

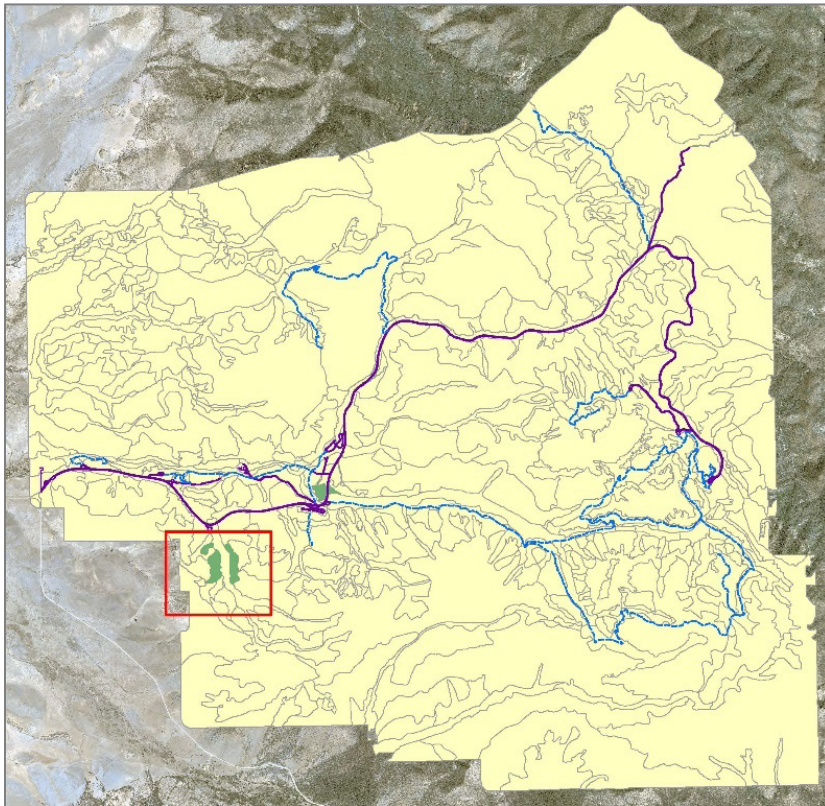


Figure 59. Map of CHIR with all areas mapped as Alligator Juniper / Catclaw Mimosa Wooded Shrubland Association showing in green. NPS



Figure 60. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Alligator Juniper / Catclaw Mimosa Wooded Shrubland Association. NPS

14. *Juniperus deppeana* / *Bouteloua gracilis* Woodland Association

Alligator Juniper / Blue Grama Woodland Association

This woodland association is characterized by an open canopy of alligator juniper (*Juniperus deppeana*) and a grassy, variable field usually dominated by blue grama (*Bouteloua gracilis*).

The canopy stratum (>2 m) ranges between 5 and 35% total cover and is dominated by alligator juniper. This species is present most often as a short-statured tree below 5 meters in height. Arizona white oak (*Quercus arizonica*) is a common associate and may sometimes be codominant with alligator juniper. Arizona juniper (*Juniperus arizonica*) is present in about half of all examples, usually at low cover, but occasionally is codominant with or even exceeds the cover of alligator juniper.

The subcanopy (0.5–2 m) is variable in species composition and total cover, which falls anywhere between 2 and 30%. Turpentine bush (*Ericameria laricifolia*) and catclaw mimosa (*Mimosa aculeaticarpa*) are common and may be locally abundant. Other notable species include beargrass (*Nolina microcarpa*), mountain yucca (*Yucca madrensis*), pointleaf manzanita (*Arctostaphylos pungens*), common sotol (*Dasylirion wheeleri*), Toumey oak (*Quercus toumeyi*), evergreen sumac (*Rhus virens*), Palmer's century plant (*Agave palmeri*), alderleaf mountain mahogany (*Cercocarpus montanus*), and fragrant sumac (*Rhus aromatica*).

The field layer (<0.5 m) is grassy and relatively dense, with cover reaching as high as 75%. Blue grama (*Bouteloua gracilis*) and/or sideoats grama (*B. curtipendula*) are the most common dominants, though blue grama generally contributes higher cover. These species occur with a diverse and variable combination of other perennial grasses, such as pinyon ricegrass (*Piptochaetium fimbriatum*), bullgrass (*Muhlenbergia emersleyi*), hairy grama (*Bouteloua hirsuta*), cane bluestem (*Bothriochloa barbinodis*), and Texas bluestem (*Schizachyrium cirratum*).

Abundant in lower Bonita Canyon, this community occurs in floodplains and north-trending hillslopes between 1,560 and 1,835 meters (5,118–6,020 ft) in elevation. The soil surface cover is dominated by gravel and rock on the hillslopes and litter, gravel, and bare soil in floodplain examples.

Common species: *Juniperus deppeana*, *Quercus arizonica*, *Ericameria laricifolia*, *Mimosa aculeaticarpa*, *Bouteloua gracilis*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 61–63.



Figure 61. An example landscape photo showing a typical stand of the Alligator Juniper / Blue Grama Woodland Association. NPS

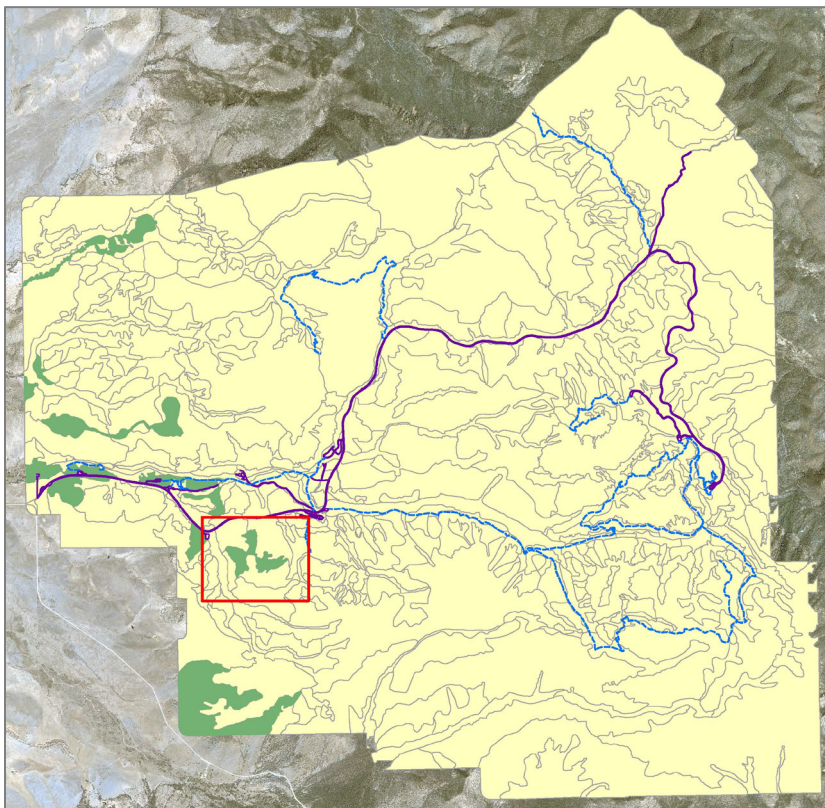


Figure 62. Map of CHIR with all areas mapped as Alligator Juniper / Blue Grama Woodland Association showing in green. NPS

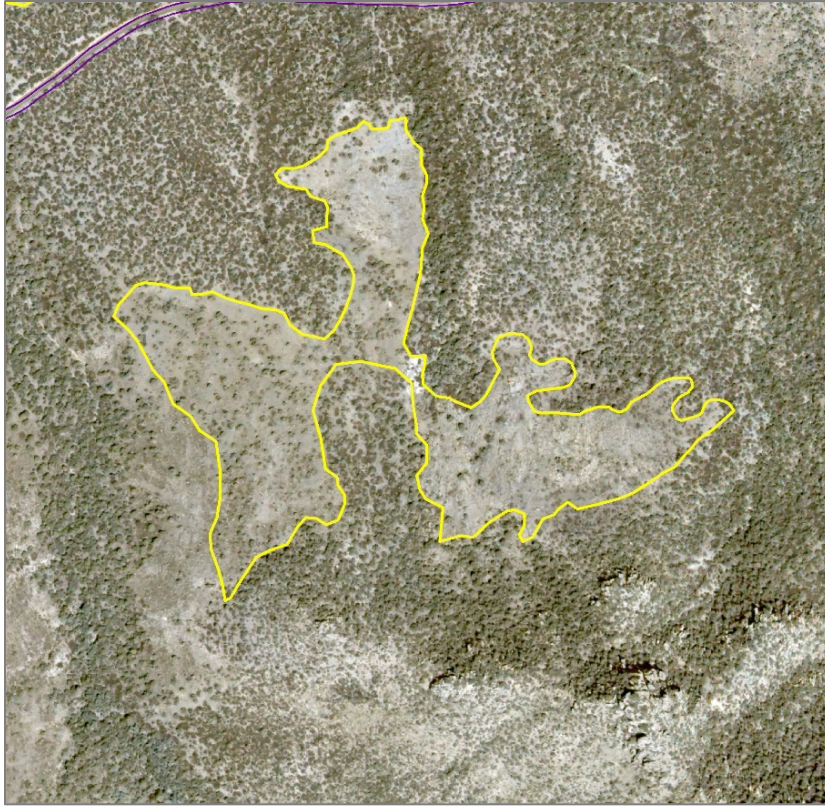


Figure 63. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Alligator Juniper / Blue Grama Woodland Association. NPS

15. *Juniperus deppeana* - *Quercus emoryi* - (*Quercus arizonica*) / *Piptochaetium fimbriatum* Woodland Association (P)

Alligator Juniper - Emory Oak - (Arizona White Oak) / Pinyon Ricegrass Woodland Association

This woodland association is characterized by a dense canopy dominated by alligator juniper (*Juniperus deppeana*) and Emory oak (*Quercus emoryi*) and a variably dense field stratum consistently populated by pinyon ricegrass (*Piptochaetium fimbriatum*).

The canopy stratum of this association is densely vegetated, with total cover averaging approximately 50%. Alligator juniper, Emory oak, and Arizona white oak (*Q. arizonica*) are all consistently present. Of the three, alligator juniper (*J. deppeana*) is the primary dominant. Emory oak (*Q. emoryi*) is the more dominant oak species. Border pinyon (*Pinus discolor*), though a common dominant in woodlands on the monument, may be present but contributes far less cover than alligator juniper and the oaks.

Shrub cover in the subcanopy (0.5–2 m) is low, averaging below 10%. Pointleaf manzanita (*Arctostaphylos pungens*) is consistently present and is the most abundant species in this stratum. Mountain yucca (*Yucca madrensis*), beargrass (*Nolina microcarpa*), Wright's silktassel (*Garrya wrightii*), and catclaw mimosa (*Mimosa aculeaticarpa*) are common low-cover associates.

The field stratum (<0.5 m) is variably dense in respect to the canopy cover. Pinyon ricegrass is generally the dominant species, though it can be missing in some examples of the community. A variable mix of other perennial grass species are also present, including, from most to least common, sideoats grama (*Bouteloua curtipendula*), blue grama (*Bouteloua gracilis*), bullgrass (*Muhlenbergia emersleyi*), hairy grama (*Bouteloua hirsuta*), and spidergrass (*Aristida ternipes*).

This association is found on low-angle mountain slopes and alluvial terraces in lower Bonita Canyon. Slope aspect is variable, and elevation ranges from 1,570–1,725 meters (5150–5659 ft). Surface cover is predominantly gravel and litter.

Common species: *Juniperus deppeana*, *Quercus emoryi*, *Quercus arizonica*, *Arctostaphylos pungens*, *Piptochaetium fimbriatum*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 64–67.



Figure 64. An example landscape photo showing the Alligator Juniper - Emory Oak - (Arizona White Oak) / Pinyon Ricegrass Woodland Association as it occurs in an area adjacent to the Bonita Canyon drainage. NPS



Figure 65. An example landscape photo showing the Alligator Juniper - Emory Oak - (Arizona White Oak) / Pinyon Ricegrass Woodland Association, where an opening in the tree canopy allows for dense grass patches to grow. NPS

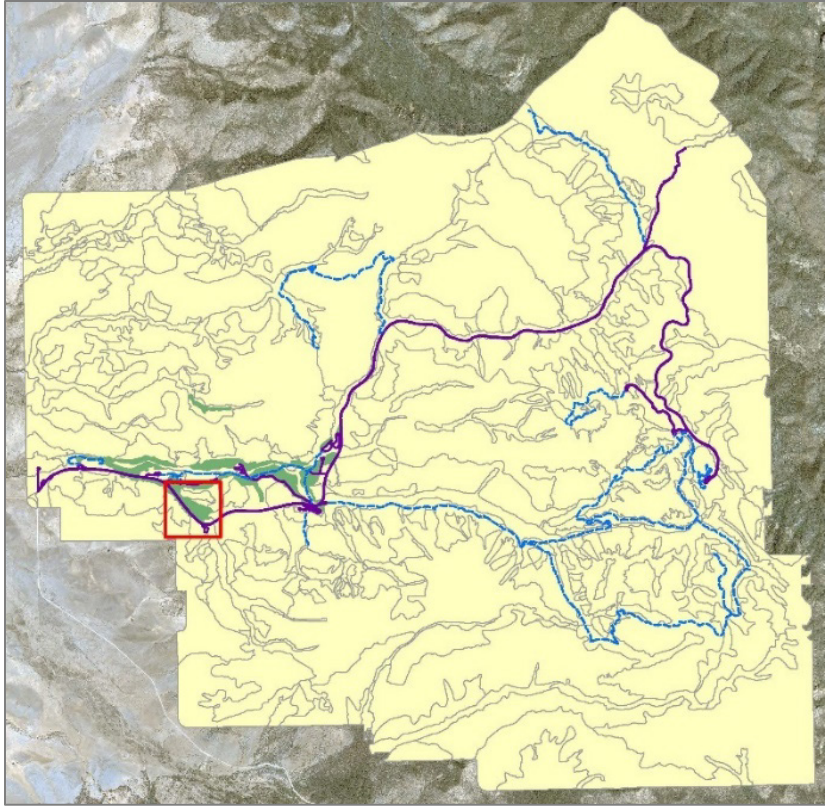


Figure 66. Map of CHIR with all areas mapped as Alligator Juniper - Emory Oak - (Arizona White Oak) / Pinyon Ricegrass Woodland Association showing in green. NPS

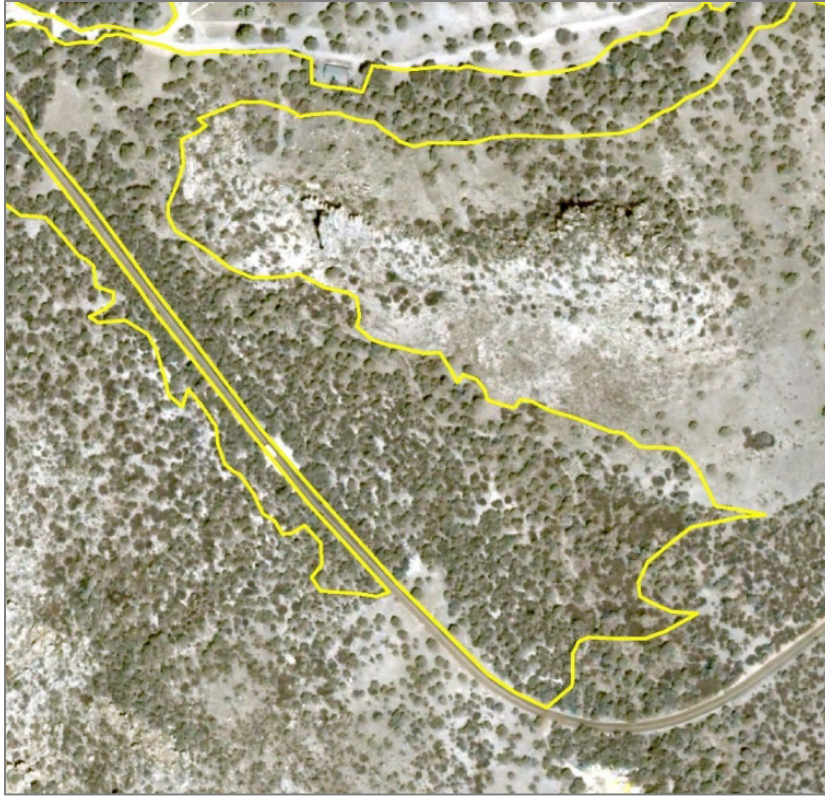


Figure 67. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Alligator Juniper - Emory Oak - (Arizona White Oak) / Pinyon Ricegrass Woodland Association. NPS

16. *Pseudotsuga menziesii* / *Quercus hypoleucoides* Forest Association

Douglas-fir / Silverleaf Oak Forest Association

This community is characterized by a closed canopy of large Douglas-fir (*Pseudotsuga menziesii*), Arizona pine (*Pinus arizonica*) and other large conifers, with a second lower layer of silverleaf oak (*Quercus hypoleucoides*). The understory is primarily occupied by shrubby forms of the tree species and is otherwise sparsely vegetated.

Total cover in the canopy stratum (>2 m) is over 60% in almost all examples of this association. Douglas-fir and Arizona pine usually trade dominance; in most examples the less abundant of the two species still contributes a significant amount of cover. Arizona pine is the weaker dominant of the two, occurring as dominant in fewer of the examples, and occasionally absent. Other common associate species include Arizona cypress (*Hesperocyparis arizonica*), silverleaf oak (*Quercus hypoleucoides*), and Chihuahuan pine (*Pinus leiophylla*). On occasion any of these species may become dominant or co-dominant with Douglas-fir and/or Arizona pine.

As the tall conifers are well-spaced, a second, lower canopy has the opportunity to form. Silverleaf oak is codominant with netleaf oak (*Quercus rugosa*) in this stratum. Together these species generate an average of 25% cover. This stratum is also frequently populated by younger individuals of the upper canopy species.

The subcanopy (0.5–2 m) and field (<0.5 m) strata are largely occupied by the recruits and smaller, shrubby individuals of the canopy dominants. In addition, scattered shrubs and subshrubs, including mountain yucca (*Yucca madrensis*), beargrass (*Nolina microcarpa*), Oregon boxleaf (*Paxistima myrsinites*), and others contribute limited cover. Grasses such as longtongue muhly (*Muhlenbergia longiligula*) and pinyon ricegrass (*Piptochaetium fimbriatum*) are occasional.

This community occupies the upper Rhyolite drainage and steep north-facing slopes between 1,860 and 2,265 meters in elevation (6,102–7,431 ft). Litter is the dominant soil surface cover in most examples creating a cover ranging from 35% to greater than 60%. Rocks and bedrock comprise most of the remaining ground cover. Boulders and larger rocks are more common in the drainages and hoodoos line the minor drainage edges.

Common species: *Pseudotsuga menziesii*, *Pinus arizonica*, *Quercus hypoleucoides*, *Quercus rugosa*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 68–70.



Figure 68. An example landscape photo showing the Douglas-fir / Silverleaf Oak Forest Association within one of the larger upper-elevation drainages at CHIR. NPS

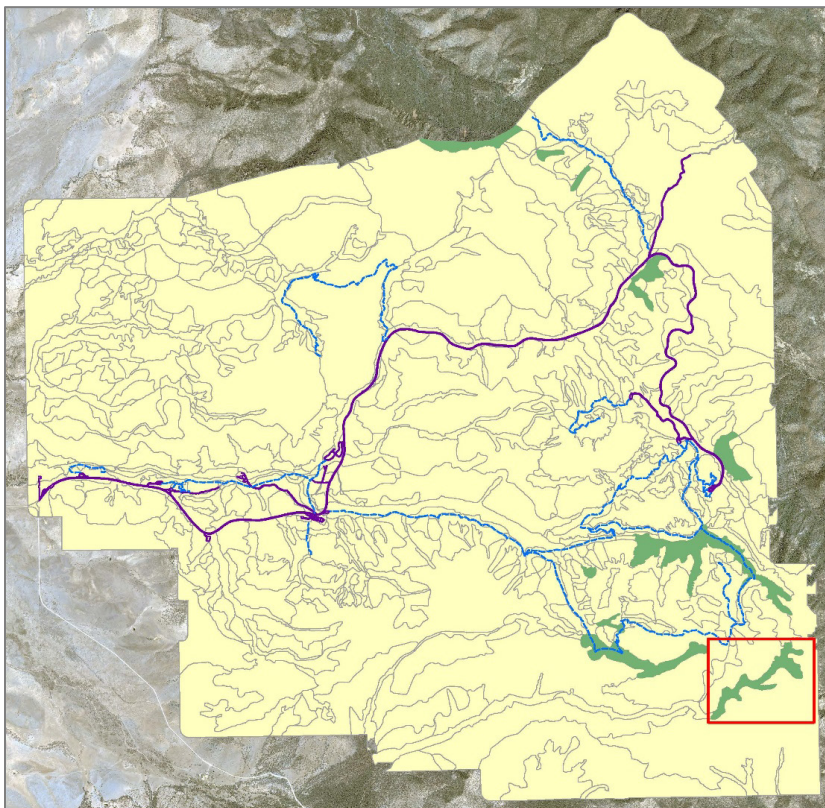


Figure 69. Map of CHIR with all areas mapped as Douglas-fir / Silverleaf Oak Forest Association showing in green. NPS

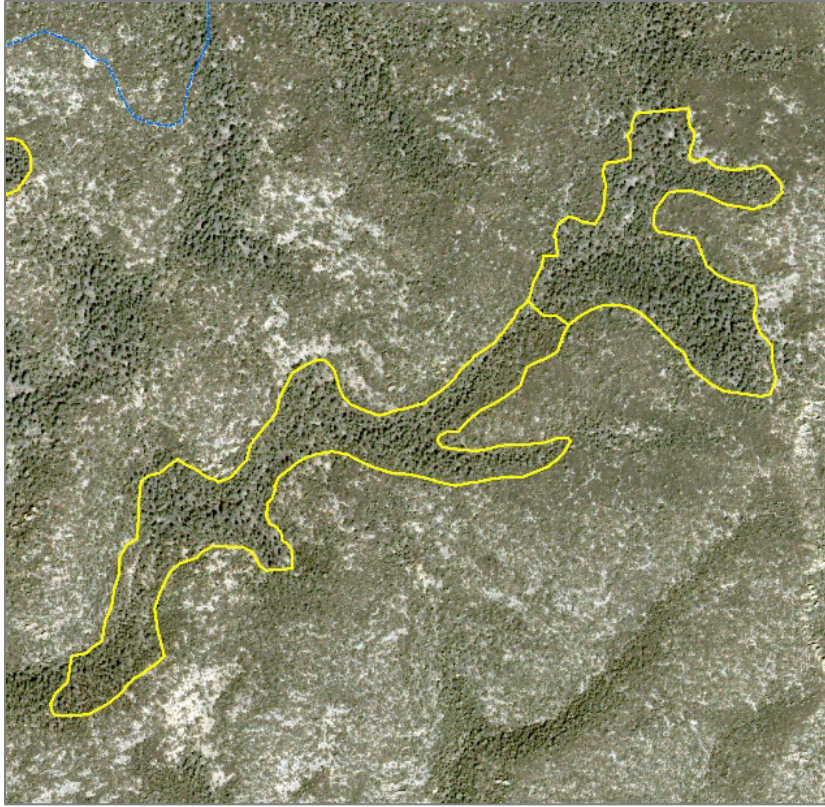


Figure 70. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Douglas-fir / Silverleaf Oak Forest Association. NPS

17. (*Pseudotsuga menziesii* - *Hesperocyparis arizonica*) / *Quercus rugosa* - *Quercus chrysolepis* Forest Association (P)

(Douglas-fir - Arizona Cypress) / Netleaf Oak - Canyon Live Oak Forest Association

This forest association is characterized by a closed canopy dominated by Arizona cypress (*Hesperocyparis arizonica*), Douglas-fir (*Pseudotsuga menziesii*), canyon live oak (*Quercus chrysolepis*), and netleaf oak (*Q. rugosa*).

The upper canopy layer (>5 m) of this association is dominated by tall Douglas-fir and Arizona cypress. These two species can trade dominance with one species the clear dominant while the other may be an associate or missing all together. Total cover for this upper stratum generally ranges between 35 and 50%. Canyon live oak and netleaf oak form a lower canopy (2–5 m), generating between 10 and 25% additional cover.

The subcanopy (0.5–2 m) is generally open and is dominated by short-statured netleaf oak. Common subcanopy associates include, in order from most to least common, Oregon boxleaf (*Paxistima myrsinites*), silverleaf oak (*Quercus hypoleucoides*), mountain yucca (*Yucca madrensis*), Sonoran scrub oak (*Quercus turbinella*), beargrass (*Nolina microcarpa*), mountain ninebark (*Physocarpus monogynus*), and rockspirea (*Holodiscus discolor*).

The field stratum (<0.5 m) ranges from 10–25% cover, though in especially shaded examples it may become quite sparse. Pinyon ricegrass (*Piptochaetium fimbriatum*) is consistently dominant. Notable associate species include longtongue muhly (*Muhlenbergia longiligula*), Fendler's meadow-rue (*Thalictrum fendleri*), and sedges (*Carex* sp.).

This community is scattered in drainages and north-facing slopes near Sugarloaf Mountain and in the upper part of the Rhyolite Canyon watershed between 1,885 and 2,110 meters in elevation (6,184–6,923 ft). Rock, bedrock outcrops, and litter are the dominant soil surface cover.

Common species: *Hesperocyparis arizonica*, *Pseudotsuga menziesii*, *Quercus rugosa*, *Quercus chrysolepis*, *Piptochaetium fimbriatum*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 71–73.



Figure 71. An example landscape photo of the (Douglas-fir - Arizona Cypress) / Netleaf Oak - Canyon Live Oak Forest Association, highlighting the shade created by the closed canopy forest. NPS

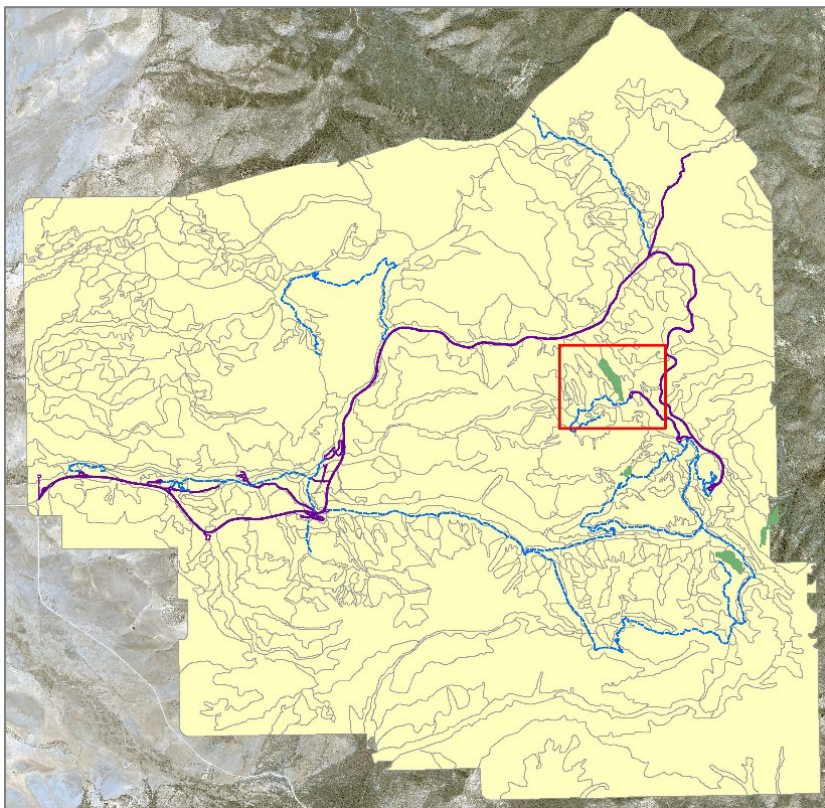


Figure 72. Map of CHIR with all areas mapped as (Douglas-fir - Arizona Cypress) / Netleaf Oak - Canyon Live Oak Forest Association showing in green. NPS

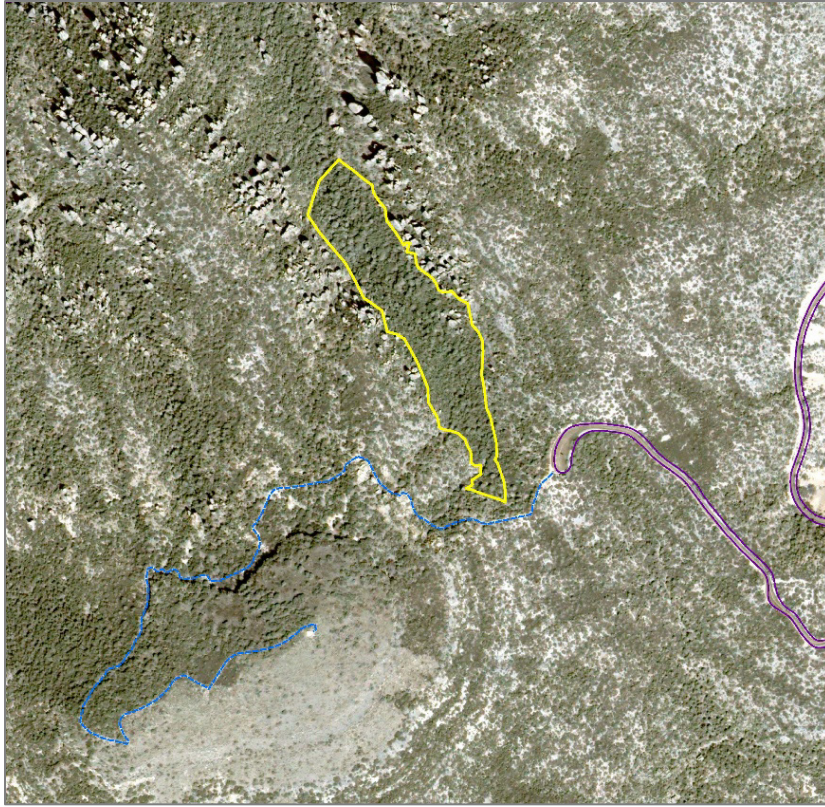


Figure 73. An example area showing the texture and appearance of satellite imagery that was classified and mapped as (Douglas-fir - Arizona Cypress) / Netleaf Oak - Canyon Live Oak Forest Association. NPS

18. *Hesperocyparis arizonica* / *Quercus hypoleuroides* Forest Association

Arizona Cypress / Silverleaf Oak Forest Association

This woodland association is characterized by a dense canopy dominated by Arizona cypress (*Hesperocyparis arizonica*) and border pinyon (*Pinus discolor*) and an open subcanopy dominated by shrubby netleaf oak (*Quercus rugosa*) and silverleaf oak (*Q. hypoleuroides*).

Total cover in the canopy stratum (>2 m) averages approximately 50%. Arizona cypress and border pinyon are both consistent dominants in this stratum. Netleaf oak and silverleaf oak provide substantial canopy across both the canopy and subcanopy (0.5–2 m) strata. Silverleaf oak typically grows as a tree and contributes more to the canopy whereas the netleaf oak grows more as shrub and contributes evenly across the canopy and subcanopy. Toumey oak (*Quercus toumeyi*) and pointleaf manzanita (*Arctostaphylos pungens*) are common associates in the subcanopy stratum and often form dense patches. Wright's silktassel (*Garrya wrightii*) is commonly present but usually generates less cover than Toumey oak or pointleaf manzanita.

The field stratum (<0.5 m) is very open with less than 10% total cover and no clear dominants. Pinyon ricegrass (*Piptochaetium fimbriatum*) and, to a lesser extent, longtongue muhly (*Muhlenbergia longiligula*) are common but contribute little cover.

This community is found on north-trending mountain backslopes and in small drainages throughout the monument from 1,630 to 2,150 meters (5,347–7,054 ft) in elevation. Surface cover consists of bedrock outcrops, rock, and gravel.

Common species: *Hesperocyparis arizonica*, *Pinus discolor*, *Quercus rugosa*, *Quercus hypoleuroides*, *Quercus toumeyi*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 74–76.



Figure 74. An example landscape photo of the Arizona cypress / Silverleaf Oak Forest Association, looking upslope near a small drainage. NPS

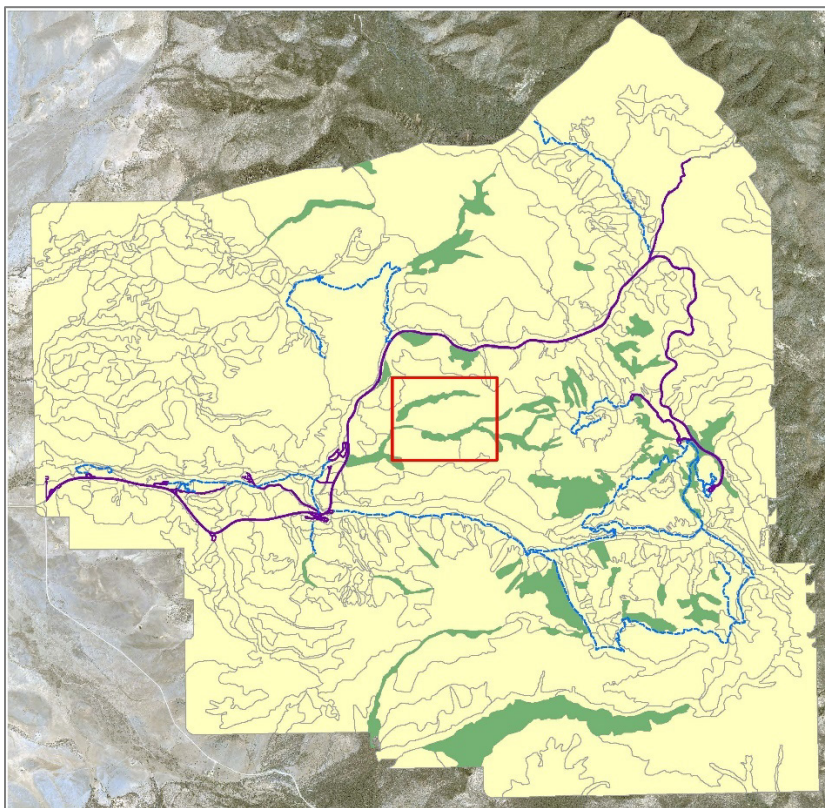


Figure 75. Map of CHIR with all areas mapped as Arizona Cypress / Silverleaf Oak Forest Association showing in green. NPS



Figure 76. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Arizona Cypress / Silverleaf Oak Forest Association. NPS

19. *Hesperocyparis arizonica* - (*Platanus wrightii*) / *Quercus* spp. Intermittently Flooded Forest Association (P)

Arizona Cypress - (Arizona Sycamore) / Oak Species Intermittently Flooded Forest Association

This association is characterized by a dense canopy dominated by Arizona cypress (*Hesperocyparis arizonica*) and silverleaf oak (*Quercus hypoleuroides*) with scattered Arizona sycamore (*Platanus wrightii*). The understory is very open, with no consistent dominants.

The canopy stratum (>2 m) is dense, averaging about 45% total cover, and dominated by large, 10–20 meters tall Arizona cypress. Silverleaf oak is a consistent secondary dominant and while the bulk of its cover occurs in the upper canopy, this species is present in multiple strata. Because this community spans a wide elevational gradient, a variety of associate species trade dominance. From low elevation to high, these species include Emory oak (*Quercus emoryi*), Arizona white oak (*Quercus arizonica*), netleaf oak (*Quercus rugosa*), canyon live oak (*Quercus chrysolepis*). Of these, Arizona white oak (*Q. arizonica*) is most consistently present.

The subcanopy (0.5–2 m) is typically sparse, generally totaling less than 10% cover, and has no clear dominant species. Close to the water course, Wright's silktassel (*Garrya wrightii*), shrubby silverleaf oak (*Q. hypoleuroides*), and mountain yucca (*Yucca madrensis*) occur. In drier areas pointleaf manzanita (*Arctostaphylos pungens*) is more common. The field layer (<0.5m) is similarly sparse, consisting of a low cover mix of perennial graminoids. The most common species include pinyon ricegrass (*Piptochaetium fimbriatum*), longtongue muhly (*Muhlenbergia longiligula*), sideoats grama (*Bouteloua curtipendula*), Texas bluestem (*Schizachyrium cirratum*), and sedges (*Carex* spp.).

This community spans the Bonita Creek drainage from the western boundary to the King of Lead Mine Road, including North Bonita Canyon. It occurs between 1,565 and 2,110 meters (5,134–6,922 ft) in elevation. Soil surface cover reflects the influence of the dense tree canopies with leaf litter comprising much of the ground cover, especially where it gathers on islands of accumulated gravel and rock. Rocks of volcanic tuff and rhyolite create the most common ground cover with large rocks and boulders deposited along the drainage channels.

Common species: *Hesperocyparis arizonica*, *Platanus wrightii*, *Quercus hypoleuroides*, *Quercus arizonica*, *Piptochaetium fimbriatum*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 77–79.



Figure 77. An example landscape photo showing the Arizona Cypress - (Arizona Sycamore) / Oak Intermittently Flooded Forest Association. The view is from a high elevation vantage, looking out across the valley and downwards along a canyon drainage system. NPS

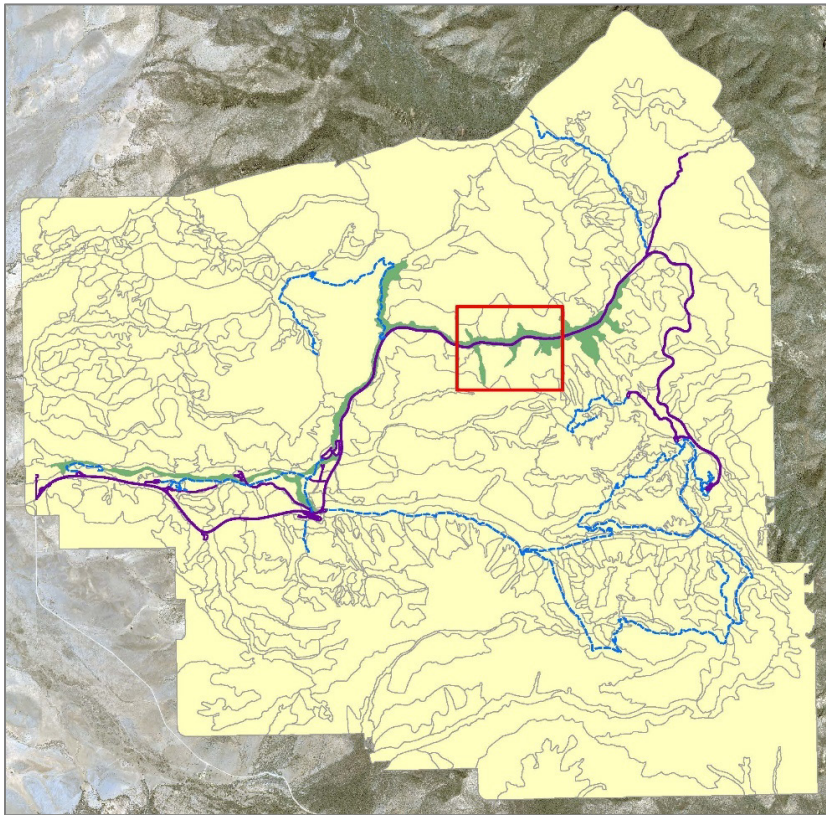


Figure 78. Map of CHIR with all areas mapped as Arizona Cypress - (Arizona Sycamore) / Oak Intermittently Flooded Forest Association shown in green. NPS



Figure 79. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Arizona Cypress - (Arizona Sycamore) / Oak Intermittently Flooded Forest Association. This area is on either side of the main road at CHIR along Bonita Canyon. NPS

20. [*Pinus engelmannii* - *Hesperocyparis arizonica* - *Quercus hypoleucoides*] Intermittently Flooded Forest Association (P)

[Apache Pine - Arizona Cypress - Silverleaf Oak] Intermittently Flooded Forest Association

This intermittently flooded forest community is characterized by a tall, dense canopy stratum dominated by a mixture of Apache pine (*Pinus engelmannii*), Arizona cypress (*Hesperocyparis arizonica*) and silverleaf oak (*Quercus hypoleucoides*) with associate to co-dominant Arizona pine (*Pinus arizonica*). The lower strata are generally open with no consistently dominant species.

Total cover for the canopy stratum (>2 m) in this association usually falls between 60 and 70%. The upper reaches of this stratum are dominated by Apache pine and Arizona cypress; the latter is concentrated primarily near drainage channels. Silverleaf oak forms a lower-stature layer below the taller conifers, often generating significant cover in both the canopy and the lower strata. Arizona pine is a consistent associate commonly that occasionally occurs as a co-dominant with the other conifers. Other common associates include Arizona madrone (*Arbutus arizonica*), border pinyon (*Pinus discolor*), and Arizona white oak (*Quercus arizonica*). Douglas-fir (*Pseudotsuga menziesii*), Chihuahua pine (*Pinus leiophylla*), and Emory oak (*Quercus emoryi*), when present, generate very little cover.

The subcanopy (0.5–2 m) stratum is generally very open in this community, with the majority of examples having less than 5% total cover, though shrubby oaks, including netleaf oak (*Quercus rugosa*), can very occasionally form a moderately dense layer. Common, but low cover, subcanopy associates include mountain yucca (*Yucca madrensis*), beechleaf frangula (*Frangula betulifolia*), and western white honeysuckle (*Lonicera albiflora*).

The field stratum (<0.5 m) is similarly sparse, rarely, if ever, generating above 5% total cover. Again, there are no consistent dominant species for this stratum, though brackenfern (*Pteridium aquilinum*), nodding brome (*Bromus anomalus*), and *Muhlenbergia* spp. are commonly observed.

This community occurs in wide (to 100 m), west- or northwest-trending drainages between 1,635 and 2,005 meters (5,364–6,578 ft) in elevation in Rhyolite and Sarah Deming canyons. Slope and aspect are variable. Soil surface cover consists primarily of rock and gravel in the active channels of the drainage and litter elsewhere. Exposed bare soil is recent alluvium.

Common species: *Hesperocyparis arizonica*, *Pinus engelmannii*, *Pinus arizonica*, *Quercus hypoleucoides*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 80–82.



Figure 80. An example landscape photo showing the [Apache Pine - Arizona Cypress - Silverleaf Oak] Intermittently Flooded Forest Association, as it occurs in Rhyolite Canyon at CHIR. NPS

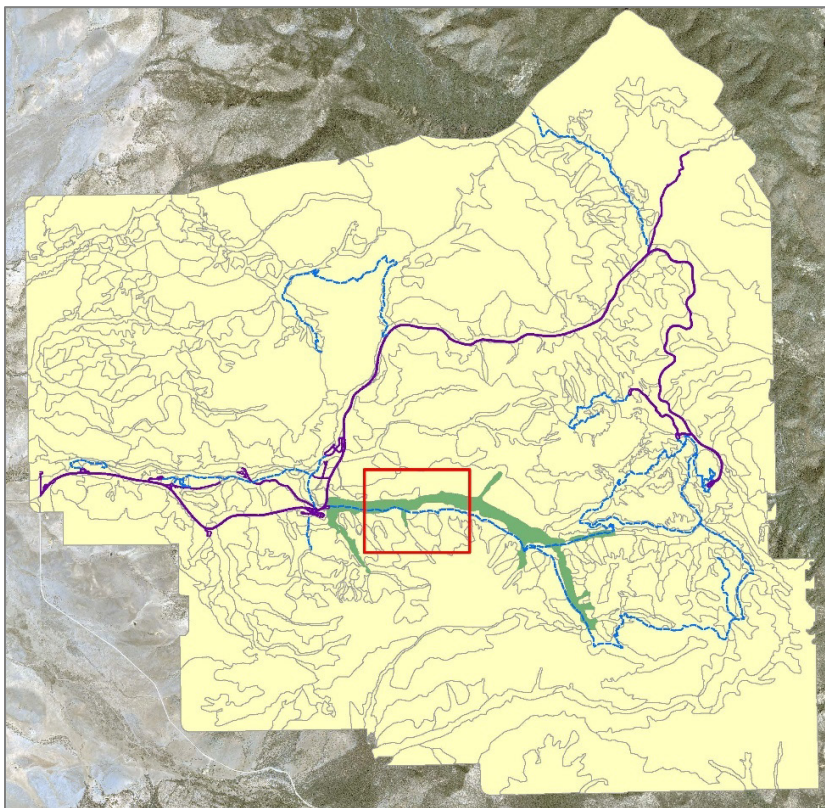


Figure 81. Map of CHIR with all areas mapped as [Apache Pine - Arizona Cypress - Silverleaf Oak] Intermittently Flooded Forest Association showing in green. NPS



Figure 82. An example area showing the texture and appearance of satellite imagery that was classified and mapped as [Apache Pine - Arizona Cypress - Silverleaf Oak] Intermittently Flooded Forest Association. NPS

21. *Pinus engelmannii* / *Quercus hypoleuroides* Woodland Association

Apache Pine / Silverleaf Oak Woodland Association

This woodland association is characterized by a dense canopy dominated by silverleaf oak (*Quercus hypoleuroides*) and Apache pine (*Pinus engelmannii*). The understory varies in both cover and species composition but typically features a mix of shrubby oaks and perennial grasses.

Silverleaf oak is a consistent dominant throughout this community, contributing an average of 25% cover across all height strata, but primarily in the form of canopy-height (>2 m) trees. Apache pine is consistently present, emerging from the canopy of the oak. Chihuahuan pine (*Pinus leiophylla*) and Arizona white oak (*Quercus arizonica*) are common associate trees. Total canopy cover averages about 50%.

The subcanopy (0.5–2 m) is characterized by a mix of shrubby oaks, typically silverleaf oak (*Q. hypoleuroides*) and netleaf oak (*Q. rugosa*). The oaks are accompanied by a mix of shrubs and succulents including pointleaf manzanita (*Arctostaphylos pungens*), beargrass (*Nolina microcarpa*), mountain yucca (*Yucca madrensis*), and Wright's silktassel (*Garrya wrightii*). Total cover in this stratum averages about 10% but may occasionally reach 50%.

The field stratum (<0.5 m) is generally sparse, averaging below 10% cover, though in particularly grassy examples of this association it may reach 50%. Species composition is variable: in the most densely wooded examples, the most abundant grasses are longtongue muhly (*Muhlenbergia longiligula*) and pinyon ricegrass (*Piptochaetium fimbriatum*), while bullgrass (*Muhlenbergia emersleyi*) appears more commonly in steep, rocky, and open versions of this association.

This association is scattered across the monument with the most prominent examples occurring on the slopes west of Bonita Park, near Picket Park, and the northeast-trending slopes to the north of Massai Point. It occurs on moderate, north-trending mountain backslopes and drainages from 1,715 to 2,095 meters (5,626–6,873 ft). Soil surface cover consists mostly of rock, gravel, and litter, with the litter occurring most frequently on drainage banks.

Common species: *Quercus hypoleuroides*, *Pinus engelmannii*, *Pinus leiophylla*, *Quercus rugosa*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 83–85.



Figure 83. An example landscape photo showing the Apache Pine / Silverleaf Oak Forest Association. NPS

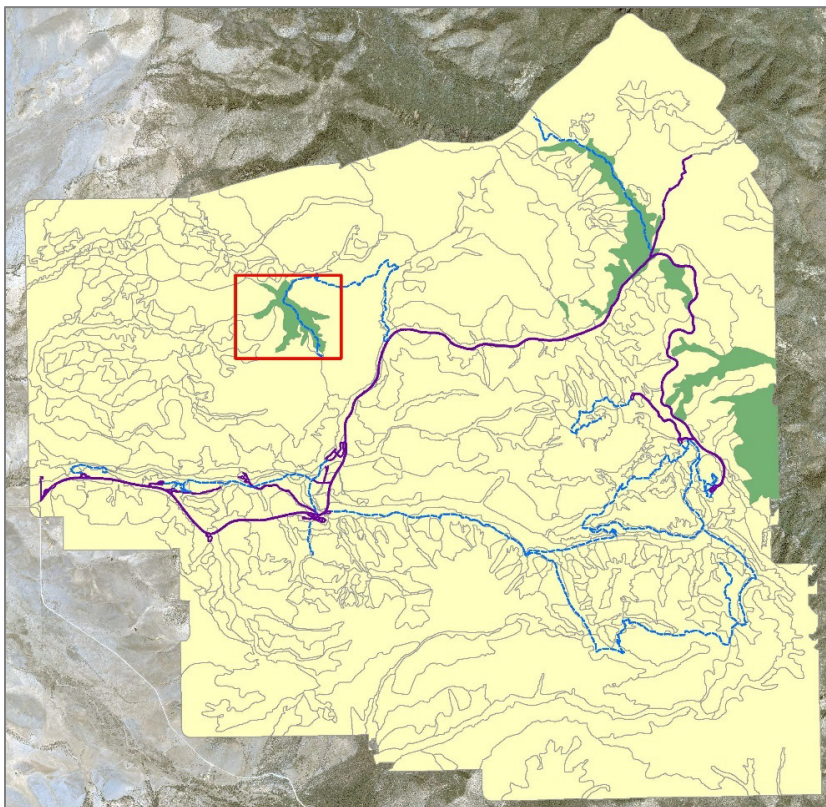


Figure 84. Map of CHIR with all areas mapped as Apache Pine / Silverleaf Oak Forest Association showing in green. NPS



Figure 85. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Apache Pine / Silverleaf Oak Forest Association. NPS

22. [*Pinus arizonica* - *Pinus leiophylla*] / *Quercus hypoleucoides* Forest Association (P)

[Arizona Pine - Chihuahuan Pine] / Silverleaf Oak Forest Association

This community is characterized by a dense canopy stratum dominated by silverleaf oak (*Quercus hypoleucoides*), Arizona pine (*Pinus arizonica*), and/or Chihuahuan pine (*Pinus leiophylla*) with a generally open understory of variable species composition.

Silverleaf oak is a consistent dominant throughout all height strata of this association. In the canopy stratum (>2 m), this species is typically codominant with Arizona pine, Chihuahuan pine, or a combination of both species. Though more abundant in lower strata, shrubby netleaf oak (*Quercus rugosa*) often reaches into the canopy. Arizona cypress (*Hesperocyparis arizonica*), border pinyon (*Pinus discolor*), and Douglas-fir (*Pseudotsuga menziesii*) are often present but typically at lower cover than Arizona and Chihuahuan pine.

The subcanopy stratum (0.5–2 m) is relatively open, ranging between 5 and 25% total cover. It is generally composed of shrubby oaks, especially netleaf oak (*Quercus rugosa*). Shorter stature silverleaf oak individuals also contribute significant cover. Other shrubs such as pointleaf manzanita (*Arctostaphylos pungens*) and Wright's silktassel (*Garrya wrightii*) may be present.

The field layer (<0.5 m) is sparse, never generating more than 10% total cover. Typically, it consists of scattered graminoids such as longtongue muhly (*Muhlenbergia longiligula*) and pinyon ricegrass (*Piptochaetium fimbriatum*).

This community occurs primarily in association with drainages from 1,780–2,235 meters (5,839–7,332 ft) elevation. It is concentrated in the high-elevation southeast corner of the monument, in the upper portions of the Rhyolite and Jesse James watersheds, though an isolated example occurs on the upper slopes of Whitetail Canyon in the northeast corner of the monument. Slope and aspect are highly variable. Litter is almost always the dominant soil surface cover and is often interspersed with rock, bedrock, and occasional gravelly areas.

Common species: *Quercus hypoleucoides*, *Pinus arizonica*, *Pinus leiophylla*, *Quercus rugosa*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 86–88.



Figure 86. An example landscape photo showing the [Arizona Pine - Chihuahuan Pine] / Silverleaf Oak Forest Association. NPS

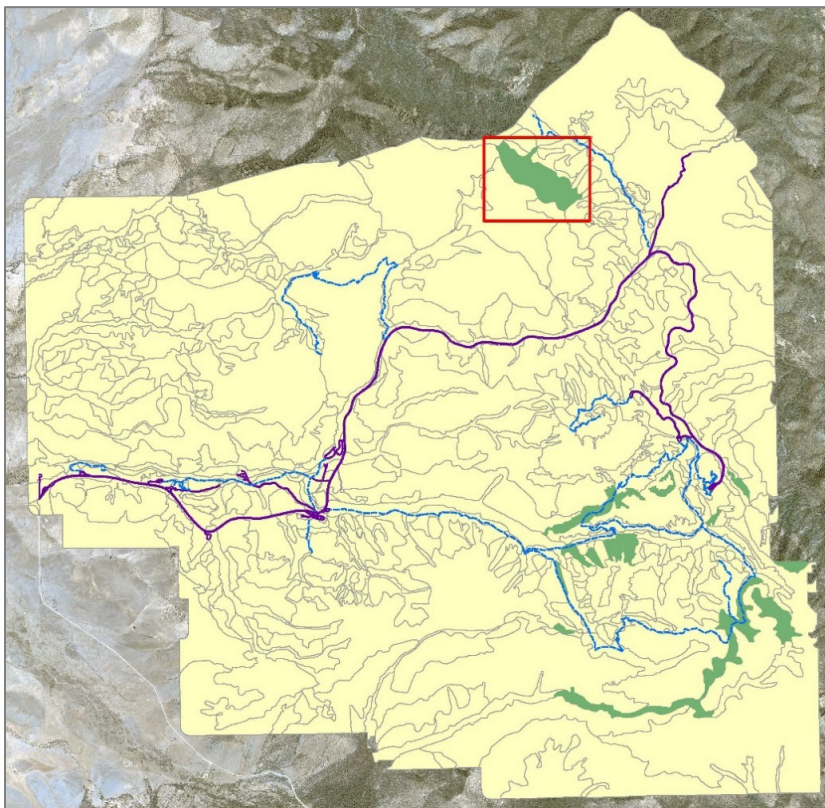


Figure 87. Map of CHIR with all areas mapped as [Arizona Pine - Chihuahuan Pine] / Silverleaf Oak Forest Association showing in green. NPS

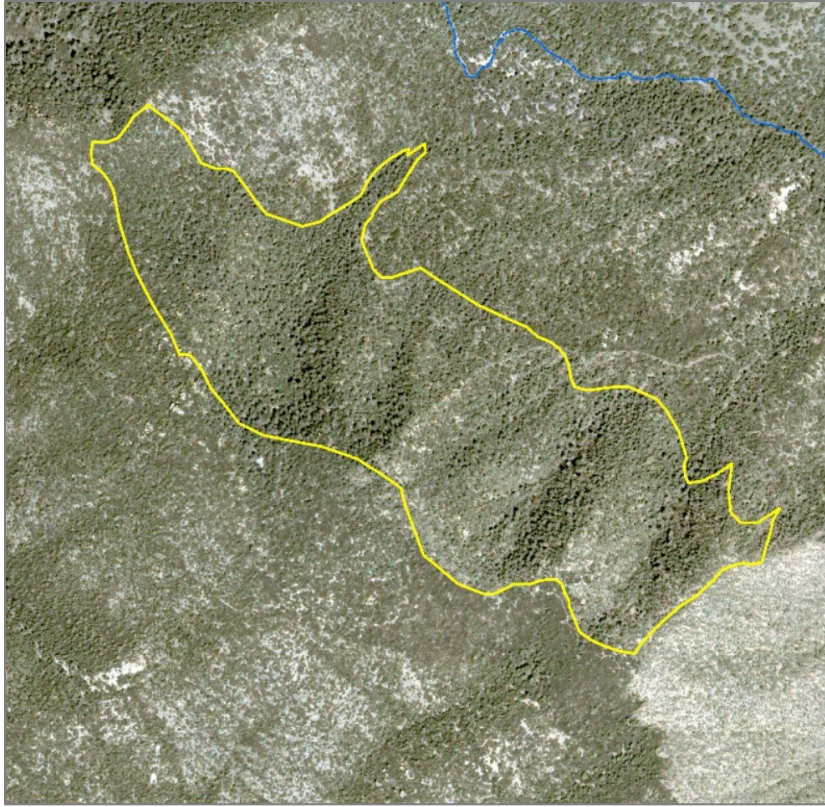


Figure 88. An example area showing the texture and appearance of satellite imagery that was classified and mapped as [Arizona Pine - Chihuahuan Pine] / Silverleaf Oak Forest Association. NPS

23. *Quercus hypoleucoides* Shrubland Association (P)

Silverleaf Oak Shrubland Association

This shrubland association is characterized by a sparse to absent canopy with a dense subcanopy dominated by silverleaf oak (*Quercus hypoleucoides*).

When present, the canopy (>2 m) is sparse—usually less than 10% total cover—and consists of scattered conifers from surrounding communities. Most typically, these include alligator juniper (*Juniperus deppeana*) and Chihuahuan pine (*Pinus leiophylla*), though Apache pine (*Pinus engelmannii*) and Douglas-fir (*Pseudotsuga menziesii*) may occasionally appear.

Subcanopy height (0.5–2 m) silverleaf oak contributes the bulk of cover in this association. Total cover in this densely vegetated stratum averages 40%, but occasionally exceeds 80%. Beargrass (*Nolina microcarpa*) is consistently present but generates little overall cover. Other common shrubs include pointleaf manzanita (*Arctostaphylos pungens*), Toumey oak (*Quercus toumeyii*), and Fendler’s ceanothus (*Ceanothus fendleri*).

Like the canopy the field stratum (<0.5 m) is very sparse, with total cover generally below 5%. Bullgrass (*Muhlenbergia emersleyi*) is the consistent dominant; oakwoods prairie clover (*Dalea versicolor*) and Bigelow’s bristlehead (*Carphochaete bigelovii*) are common low-cover associates.

This association is limited to the slopes of Whitetail Canyon from 1,910 to 2,185 meters (6,266–7168 ft) elevation. The soil surface consists mostly of gravel, rock, and bedrock.

Common species: *Quercus hypoleucoides*, *Juniperus deppeana*, *Pinus leiophylla*, *Muhlenbergia emersleyi*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 89–92.



Figure 89. An example landscape photo showing the Silverleaf Oak Shrubland Association as it occurs at the crest of a hill, at CHIR. NPS



Figure 90. An example landscape photo showing the Silverleaf Oak Shrubland Association looking across one of the mapped areas. NPS

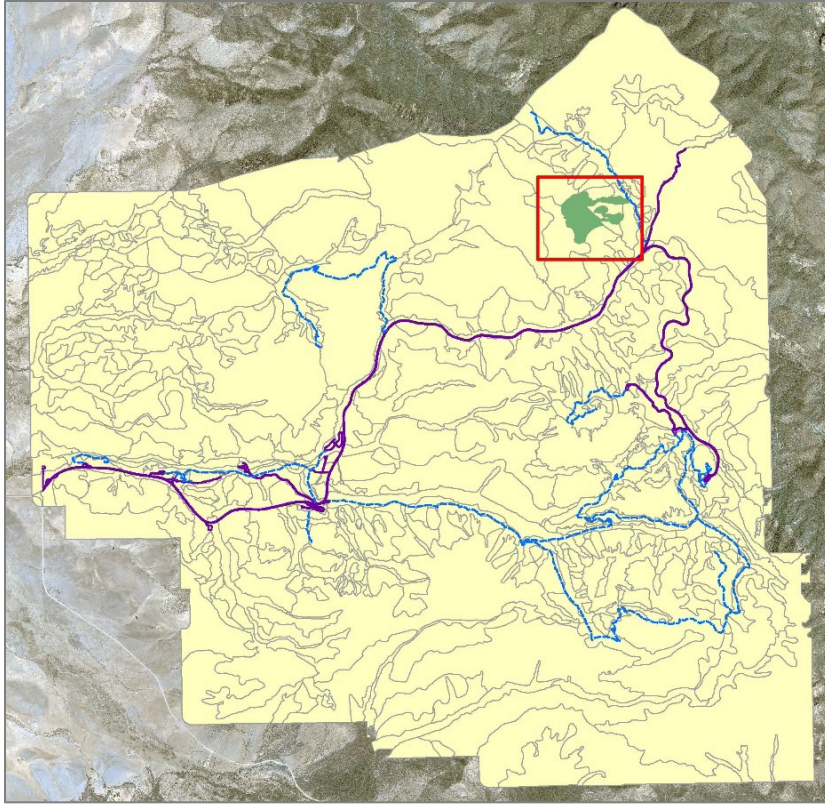


Figure 91. Map of CHIR with all areas mapped as Silverleaf Oak Shrubland Association showing in green. NPS

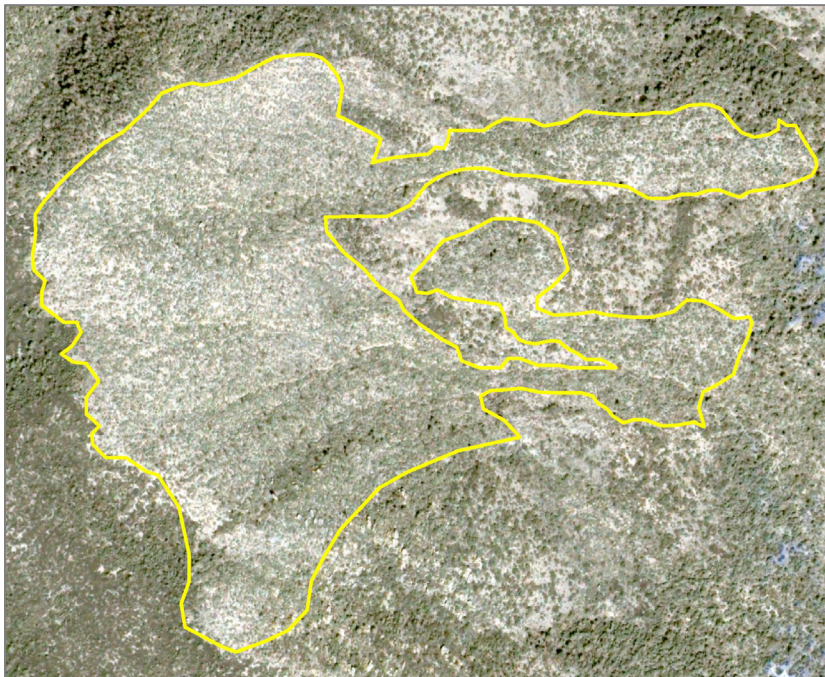


Figure 92. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Silverleaf Oak Shrubland Association. NPS

24. [*Cercocarpus montanus* - *Garrya wrightii*] / Mixed Perennial Grass Wooded Shrub Savanna Association (P)

[Alderleaf Mountain Mahogany - Wright's Silktassel] / Mixed Perennial Grass Wooded Shrub Savanna Association

This shrub savanna is characterized by an open subcanopy stratum dominated by alderleaf mountain mahogany (*Cercocarpus montanus*) and Wright's silktassel (*Garrya wrightii*). The field stratum is dense and grassy.

The canopy (>2 m) in this association is highly variable, ranging in cover from 0–25%. Common tree species include Arizona white oak (*Quercus arizonica*), alligator juniper (*Juniperus deppeana*), border pinyon (*Pinus discolor*), and Arizona juniper (*J. arizonica*).

Alderleaf mountain mahogany is the diagnostic species for this association and is generally codominant with Wright's silktassel (*Garrya wrightii*) in the subcanopy stratum (0.5–2 m). Beargrass (*Nolina microcarpa*) is a consistent low-cover associate. The total cover for this stratum averages about 20%.

The field stratum (<0.5 m) is moderately dense, with total cover ranging between 12 and 45%. The vegetation in this stratum consists of a diverse mix of perennial grasses. Sideoats grama (*Bouteloua curtipendula*) is almost always present and is generally the most abundant species. Bullgrass (*Muhlenbergia emersleyi*) is a very common associate. The invasive rangeland grass Lehmann lovegrass (*Eragrostis lehmanniana*) is present in some examples.

This association is found on moderately steep, north-trending slopes hillslopes between 1,600 and 1,930 meters (5,249–6,332 ft) elevation in the western half of the monument. The soil surface is rocky, with rock, gravel, and bedrock accounting for a majority of ground cover.

Common species: *Quercus arizonica*, *Cercocarpus montanus*, *Garrya wrightii*, *Bouteloua curtipendula*, *Muhlenbergia emersleyi*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 93–96.



Figure 93. The image shows an example of an area mapped as [Alderleaf Mountain Mahogany - Wright's Silktassel] / Mixed Perennial Grass Wooded Shrub Savanna Association. This is a grass-dominated community with scraggly mountain mahogany shrubs mixed with other succulents occurring throughout. NPS



Figure 94. A second example of the [Alderleaf Mountain Mahogany - Wright's Silktassel]/ Mixed Perennial Grass Wooded Shrub Savanna Association, showing a rockier site. Lichen-covered exposed bedrock is common in this community. NPS

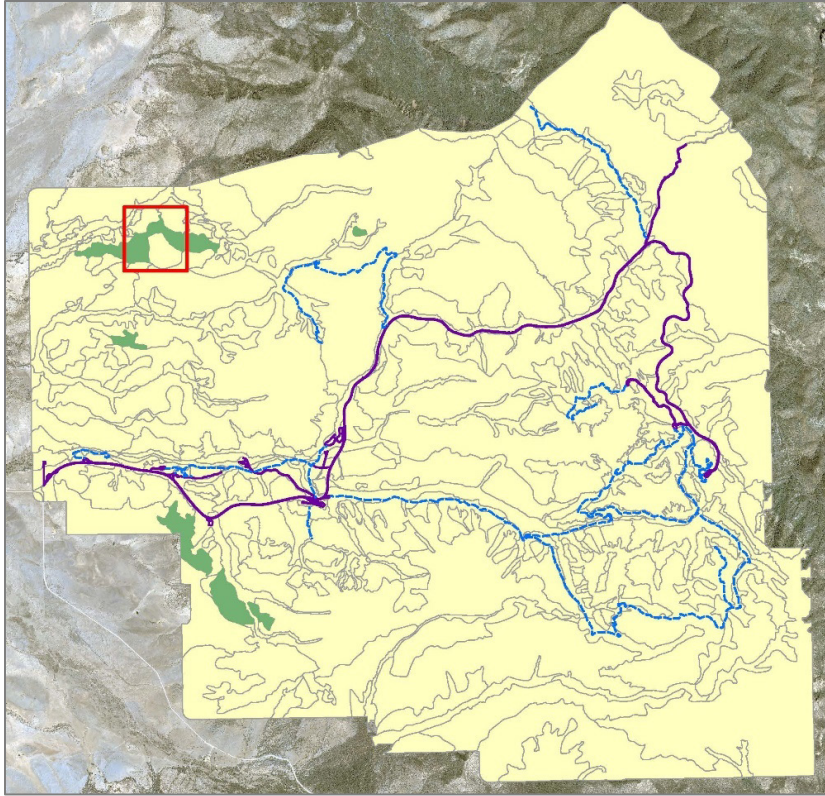


Figure 95. Map of CHIR with all areas mapped as [Alderleaf Mountain Mahogany - Wright's Silktassel]/ Mixed Perennial Grass Wooded Shrub Savanna Association showing in green. NPS

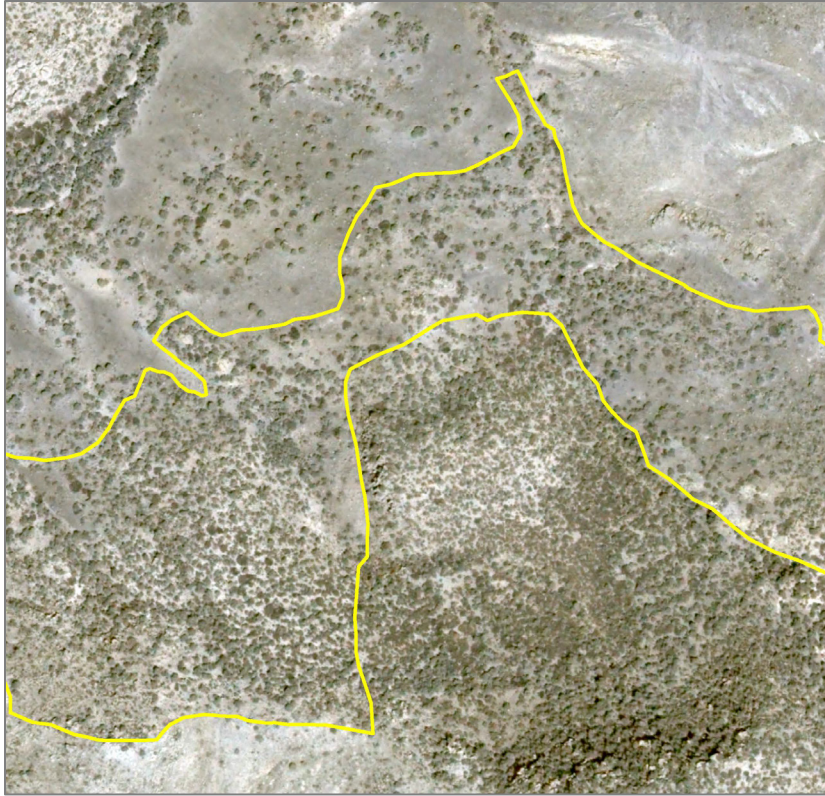


Figure 96. An example area showing the texture and appearance of satellite imagery that was classified and mapped as [Alderleaf Mountain Mahogany - Wright's Silktassel] / Mixed Perennial Grass Wooded Shrub Savanna Association. NPS

25. *Parthenium incanum* / *Eragrostis lehmanniana* Shrub Savanna Association (P)

Mariola / Lehmann Lovegrass Shrub Savanna Association

This community is characterized by an open subcanopy stratum dominated by mariola (*Parthenium incanum*) with a field stratum heavily invaded by Lehmann lovegrass (*Eragrostis lehmanniana*).

Canopy cover is sparse in this association, usually well under 10% total cover. Documented species in this stratum include alligator juniper (*Juniperus deppeana*), Arizona white oak (*Quercus arizonica*), Emory oak (*Quercus emoryi*), and ocotillo (*Fouquieria splendens*).

The subcanopy stratum (0.5–2 m) is open, with total cover values falling between 10 and 35%, and is characterized by the dominance of mariola. This species may occur with a diverse suite of associates, including evergreen sumac (*Rhus virens*), common sotol (*Dasylirion wheeleri*), Wright's beebush (*Aloysia wrightii*), beargrass (*Nolina microcarpa*), catclaw mimosa (*Mimosa aculeaticarpa*), turpentine bush (*Ericameria laricifolia*), pointleaf manzanita (*Arctostaphylos pungens*), Palmer's century plant (*Agave palmeri*), California brickellbush (*Brickellia californica*), Wright's silktassel (*Garrya wrightii*), and mountain mahogany (*Cercocarpus montanus*).

The field layer (<0.5 m) is in most cases dominated by the rangeland invasive Lehmann lovegrass. Native grasses are present throughout this community, with combined cover at times exceeding that of Lehmann lovegrass. The three most common native grasses are Texas bluestem (*Schizachyrium cirratum*), bullgrass (*Muhlenbergia emersleyi*), and sideoats grama (*Bouteloua curtipendula*). Other noteworthy field species include Arizona bluecurls (*Trichostema arizonicum*), tanglehead (*Heteropogon contortus*), and plains lovegrass (*Eragrostis intermedia*).

This community occupies south-trending mountain slopes from 1,570 to 1,930 meters (5,151–6,332 ft), mostly in the western portion of the monument near the rangelands of Sulphur Springs Valley. The soil surface cover is characterized by loose rocks and irregularly sized gravel overlying well-drained soils.

Common species: *Parthenium incanum*, *Eragrostis lehmanniana*, *Schizachyrium cirratum*, *Muhlenbergia emersleyi*, *Bouteloua curtipendula*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 97–99.



Figure 97. An example landscape photo showing the Mariola / Lehmann Lovegrass Shrub Savanna Association at CHIR. NPS

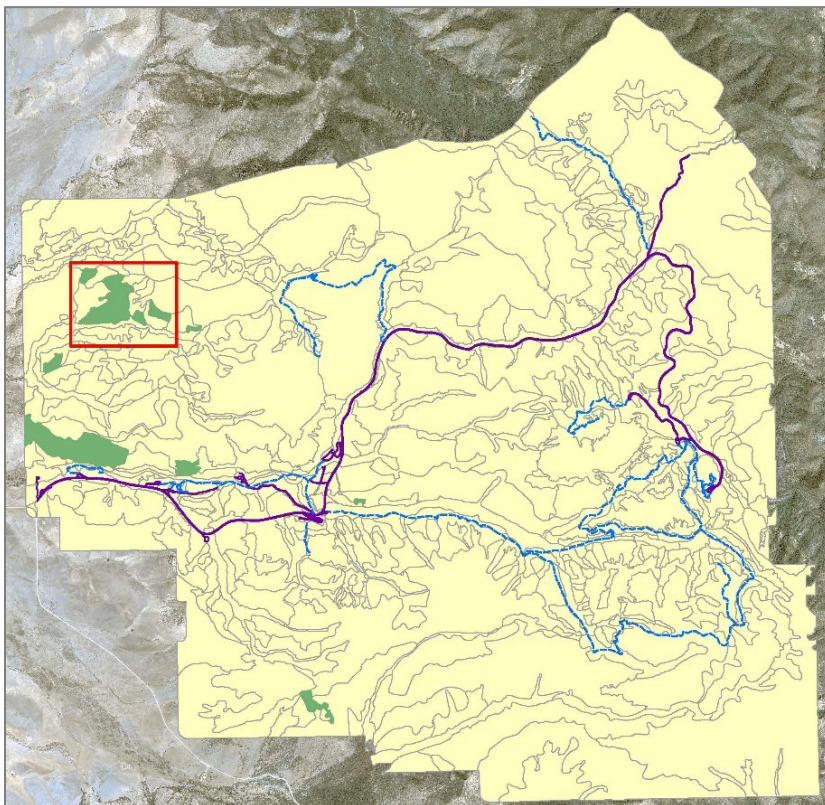


Figure 98. Map of CHIR with all areas mapped as Mariola / Lehmann Lovegrass Shrub Savanna Association showing in green. NPS



Figure 99. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Mariola / Lehmann Lovegrass Shrub Savanna Association. NPS

26. *Prosopis glandulosa* / Mixed Grasses Ruderal Shrubland Association

Honey Mesquite / Mixed Grasses Ruderal Shrubland Association

This highly variable shrub savanna association is dominated by shrubby honey mesquite (*Prosopis glandulosa*). The field stratum can be open to dense and features a variety of native perennial grasses and subshrubs and is commonly invaded by Lehmann lovegrass (*Eragrostis lehmanniana*).

Honey mesquite is present in almost all examples as a shrub and/or a short-statured tree. When present it generates up to of 25% cover split between canopy (>2 m) and subcanopy (0.5–2 m) strata. Alligator juniper (*Juniperus deppeana*) is an occasional canopy associate.

The field stratum (<0.5 m) produces most of the vegetative cover in this association, with up to 65% total cover. Blue grama (*Bouteloua gracilis*) is the most common dominant species. The rangeland invasive Lehmann lovegrass is present in most examples though cover is typically below 5%. Sideoats grama (*Bouteloua curtipendula*) is regularly present and sometimes becomes the dominant species. Other common associates in the field stratum include native grasses such as cane bluestem (*Bothriochloa barbinodis*), tobosa grass (*Hilaria mutica*), bush muhly (*Muhlenbergia porteri*), spider grass (*Aristida ternipes*), and small shrubs and subshrubs such as broom snakeweed (*Gutierrezia sarothrae*), burroweed (*Isocoma tenuisecta*), and yerba de pasmo (*Baccharis pteronioides*).

This association typically occurs on low-angle hill toeslopes, floodplains, and alluvial terraces between 1,560 and 1,635 meters (5,118–5,364 ft) in elevation. It is restricted to the mouths of canyons on the far west side of the monument. Soil surface cover is typically a mixture of bare soil and gravel with occasional dense litter cover.

Common species: *Prosopis glandulosa*, *Juniperus deppeana*, *Bouteloua gracilis*, *Eragrostis lehmanniana*, *Bouteloua curtipendula*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 100–103.



Figure 100. An example landscape photo showing the Honey Mesquite / Mixed Grass Ruderal Shrubland Association during a post-monsoon season when grasses and forbs are flowering. NPS



Figure 101. An example landscape photo showing the Honey Mesquite / Mixed Grass Ruderal Shrubland Association at the end of the pre-summer warm season. Grasses are dry. The mesquites are low-growing and occur in clusters here. NPS

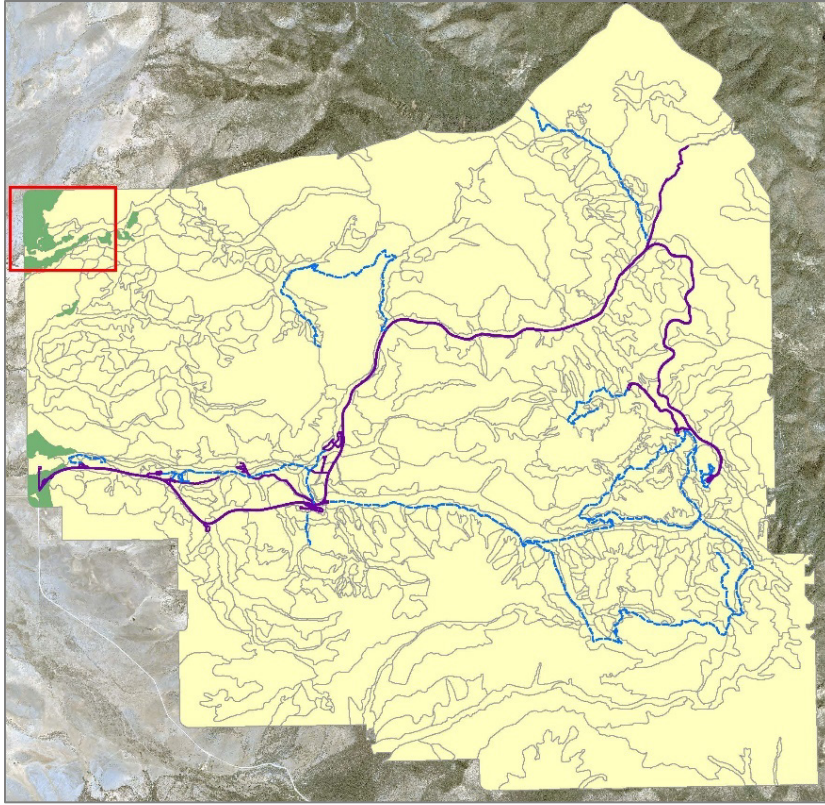


Figure 102. Map of CHIR with all areas mapped as Honey Mesquite / Mixed Grass Ruderal Shrubland showing in green. NPS



Figure 103. An example area showing the texture and appearance of satellite imagery that was classified and mapped as Honey Mesquite / Mixed Grass Ruderal Shrubland. NPS

27. (*Carex ultra*) / *Juncus balticus* - *Solidago canadensis* Herbaceous Association (PS)

(Cochise Sedge) / Mountain Rush - Canada Goldenrod Herbaceous Association

This association, which occurs only at the marshy, spring-fed Silver Spur meadow, is defined by a dense field layer dominated by graminoids and herbaceous perennials, especially mountain rush (*Juncus balticus*) and Canada goldenrod (*Solidago canadensis*). The sparse canopy and subcanopy layers are only populated by scattered alligator juniper (*Juniperus deppeana*) and Cochise sedge (*Carex ultra*), respectively.

The canopy stratum (> 2 m) contains scattered large individuals of alligator juniper, typically along the drier margins of the community. The subcanopy stratum (0.5–2 m) is largely empty, with approximately 1% total cover. The most abundant species in this stratum is Cochise sedge (*Carex ultra*).

This association is defined by a dense field layer with approximately 90% total cover, dominated by graminoids and herbaceous perennials. Mountain rush is the overall dominant species, though it is restricted to the lowest, wettest areas. Canada goldenrod is more widely distributed throughout the meadow. Indiangrass (*Sorghastrum nutans*) and bermudagrass (*Cynodon dactylon*) are common associate grasses. The non-native perennial herb horehound (*Marrubium vulgare*) occurs in patches in shaded areas. Other documented field stratum species include horsetail (*Equisetum* sp.), pinyon ricegrass (*Piptochaetium fimbriatum*), common mullein (*Verbascum thapsus*), muttongrass (*Poa fendleriana*), squirreltail grass (*Elymus elymoides*), and blue grama (*Bouteloua gracilis*).

This unique herbaceous association is restricted to the Silver Spur meadow at 1,620 meters (5,315 ft). The area ranges from a marshy wetland at the north-west end to a drier area with increased species diversity at the south-east end. The meadow itself is situated on a floodplain adjacent to Bonita Creek and Silver Spur Spring, one of the largest perennial springs in the monument. The soil surface and parent material here is recent alluvium.

Common Species: *Carex ultra*, *Juncus balticus*, *Solidago canadensis*, *Sorghastrum nutans*, *Cynodon dactylon*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 104–106.



Figure 104. Photo showing the (Cochise Sedge) / Mountain Rush - Canada Goldenrod Herbaceous Association in Silver Spur Meadow at CHIR. NPS

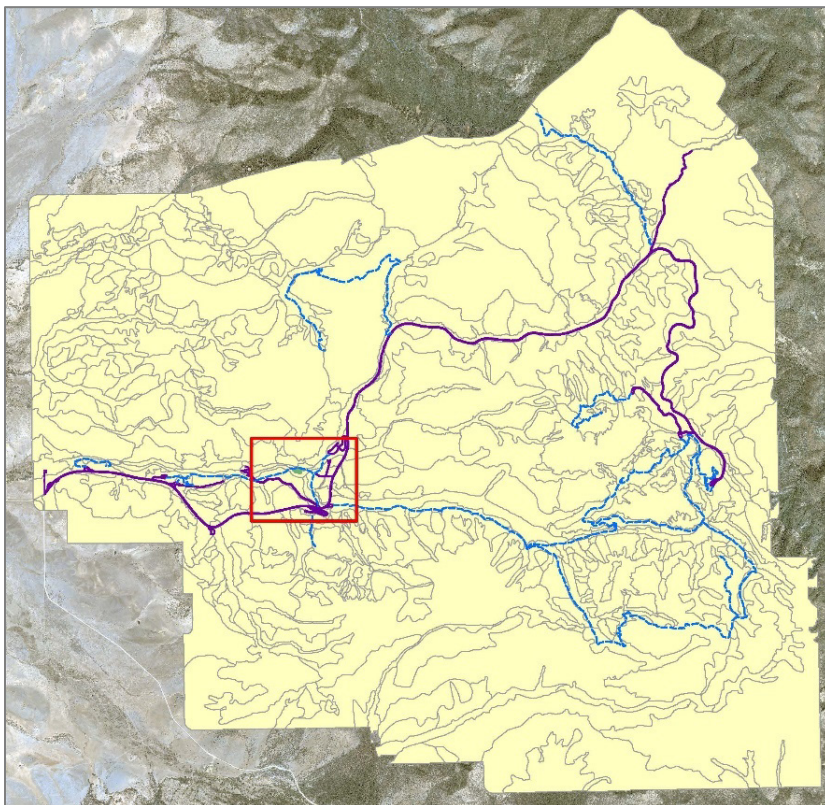


Figure 105. Map of CHIR with all areas mapped as (Cochise Sedge) / Mountain Rush - Canada Goldenrod Herbaceous Association showing in green. NPS



Figure 106. An example area showing the texture and appearance of satellite imagery that was classified and mapped as (Cochise Sedge) / Mountain Rush - Canada Goldenrod Herbaceous Association. The meadow is in stark contrast to the surrounding communities. NPS

28. (*Dasyilirion wheeleri* - *Agave palmeri*) / *Eragrostis lehmanniana* - *Muhlenbergia emersleyi* Shrub Herbaceous Association (P)

(Common Sotol - Palmer's Century Plant) / Lehmann Lovegrass - Bullgrass Shrub Herbaceous Association

This shrub herbaceous community is characterized by a variably open subcanopy of common sotol (*Dasyilirion wheeleri*) and Palmer's century plant (*Agave palmeri*) with a dense field layer dominated by Lehmann lovegrass (*Eragrostis lehmanniana*) and bullgrass (*Muhlenbergia emersleyi*).

The canopy stratum (>2 m) is very sparse, with overall cover of less than 5%. The most common species is alligator juniper (*Juniperus deppeana*). Ocotillo (*Fouquieria splendens*) occurs in areas of high bedrock cover.

The subcanopy (0.5–2 m) is open, with total cover mostly falling between 10 and 15%, though it may be higher in rare examples. It is defined by a mix of two common succulents, common sotol and Palmer's century plant. Turpentine bush (*Ericameria laricifolia*) is an occasional associate. At times this species can provide cover similar to Palmer's century plant and common sotol.

The field layer (<0.5 m) is frequently dominated by invasive Lehmann lovegrass, which occurs with a suite of native perennial grasses, most notably bullgrass. At times, this species maintains higher cover than Lehmann lovegrass and is the sole field dominant. Other common native grasses include sideoats grama (*Bouteloua curtipendula*), cane bluestem (*Bothriochloa barbinodis*), Texas bluestem (*Schizachyrium cirratum*), hairy grama (*Bouteloua hirsuta*), slender grama (*Bouteloua repens*), blue grama (*Bouteloua gracilis*), and tanglehead (*Heteropogon contortus*).

This community spans moderately steep slopes from 1,580 to 1,880 meters (5,183–6,167 ft) in elevation. It is widespread along the southwest boundary of the monument, below Erickson Ridge, and also occurs in scattered patches throughout the low hills adjacent to Picket and Little Picket Canyons. Soil surface cover is comprised mostly of a mix of rock, bedrock, and gravel.

Common species: *Juniperus deppeana*, *Fouquieria splendens*, *Dasyilirion wheeleri*, *Agave palmeri*, *Eragrostis lehmanniana*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 107–109.



Figure 107. A photo showing a typically landscape view of the (Common Sotol - Palmer's Century Plant) / Lehmann Lovegrass - Bullgrass Shrub Herbaceous Association. NPS

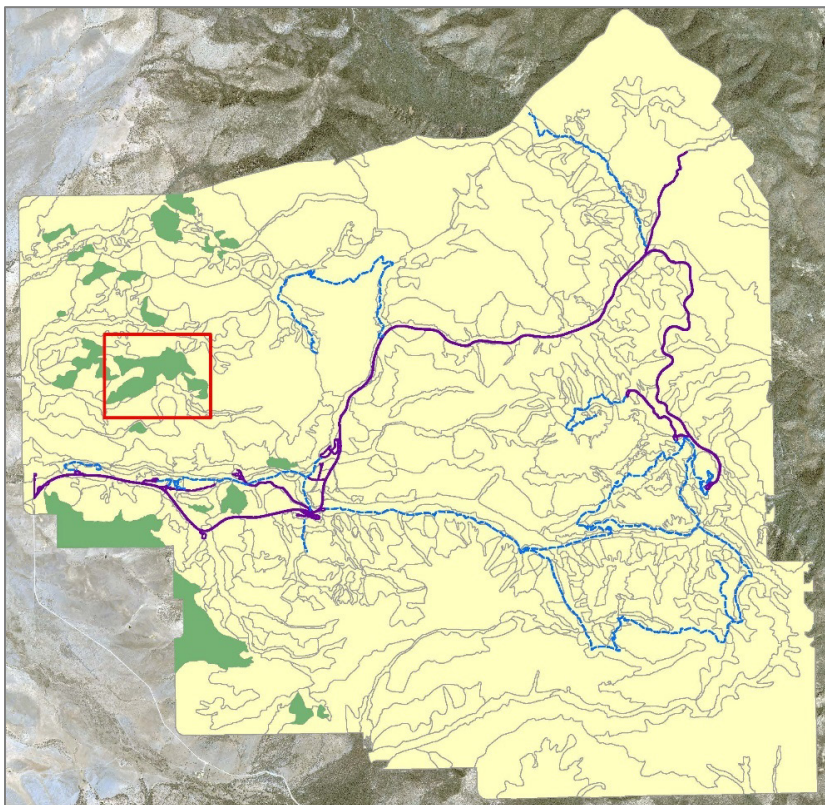


Figure 108. Map of CHIR with all areas mapped as (Common Sotol - Palmer's Century Plant) / Lehmann Lovegrass - Bullgrass Shrub Herbaceous Association showing in green. NPS



Figure 109. An example area showing the texture and appearance of satellite imagery that was classified and mapped as (Common Sotol - Palmer's Century Plant) / Lehmann Lovegrass - Bullgrass Shrub Herbaceous Association. NPS

29. *Nolina microcarpa* / *Muhlenbergia emersleyi* Shrub Savanna Association (PS)

Beargrass / Bullgrass Shrub Savanna Association

This shrub savanna is characterized by a very sparse canopy, an open subcanopy dominated by beargrass (*Nolina microcarpa*), and a dense field layer dominated by bullgrass (*Muhlenbergia emersleyi*).

The sparse canopy stratum (>2 m) is characterized by a low-cover mix of short-statured trees dominated by Arizona white oak (*Quercus arizonica*). Alligator juniper (*Juniperus deppeana*) and border pinyon (*Pinus discolor*) are also present as low-cover associates. In all, the total cover for this stratum does not exceed 5%.

The subcanopy stratum (0.5–2 m) is characterized by the consistent dominance of beargrass which occurs with a sparse mix of shrubs and succulents. Notable associates in this stratum include mountain mahogany (*Cercocarpus montanus*), mountain yucca (*Yucca madrensis*), dollarjoint pricklypear (*Opuntia chlorotica*), catclaw mimosa (*Mimosa aculeaticarpa*), gumhead (*Gymnosperma glutinosum*), Toumey oak (*Quercus toumeyii*), and cactus apple (*Opuntia engelmannii*). Total cover for this stratum ranges from 10 to 30%.

The field stratum (<0.5 m) is densely vegetated with a diverse suite of perennial grasses, subshrubs, and forbs, with total cover averaging 50%. Bullgrass is generally the overwhelming dominant. Other noteworthy field species include sideoats grama (*Bouteloua curtipendula*), blue grama (*Bouteloua gracilis*), plains lovegrass (*Eragrostis intermedia*), bristly wolfstail (*Muhlenbergia alopecuroides*), Texas bluestem (*Schizachyrium cirratum*), and bastardsage (*Eriogonum wrightii*).

This community is found only on the steep, southeast-trending backslope of Sugarloaf Mountain, from 2,080 to 2,225 meters (6,824–7,300 ft). The soil surface cover is characterized by loose, unstable rocks overlaying dry, silty loam.

Common species: *Quercus arizonica*, *Nolina macrocarpa*, *Muhlenbergia emersleyi*

Representative images of the association, its distribution across the park, and satellite imagery for a representative polygon follow in Figures 110–113.



Figure 110. The photo shows a view across the single polygon that was mapped as Beargrass / Bullgrass Shrub Savanna Association. Slope is steep and the primary shrub cover is Beargrass with little else growing in the canopy. NPS



Figure 111. Another view of the Beargrass / Bullgrass Shrub Savanna Association showing a slightly more diverse patch, having some prickly pear cactus (*Opuntia* spp.) and scrubby short trees here and there. NPS

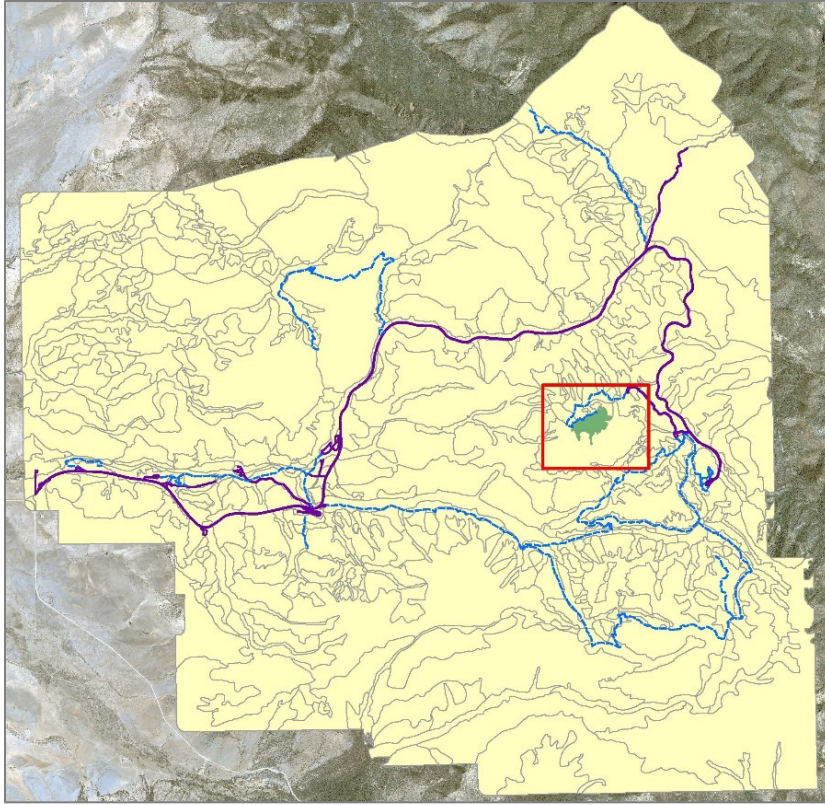


Figure 112. Map of CHIR with all areas mapped as Beargrass / Bullgrass Shrub Savanna Association showing in green. NPS

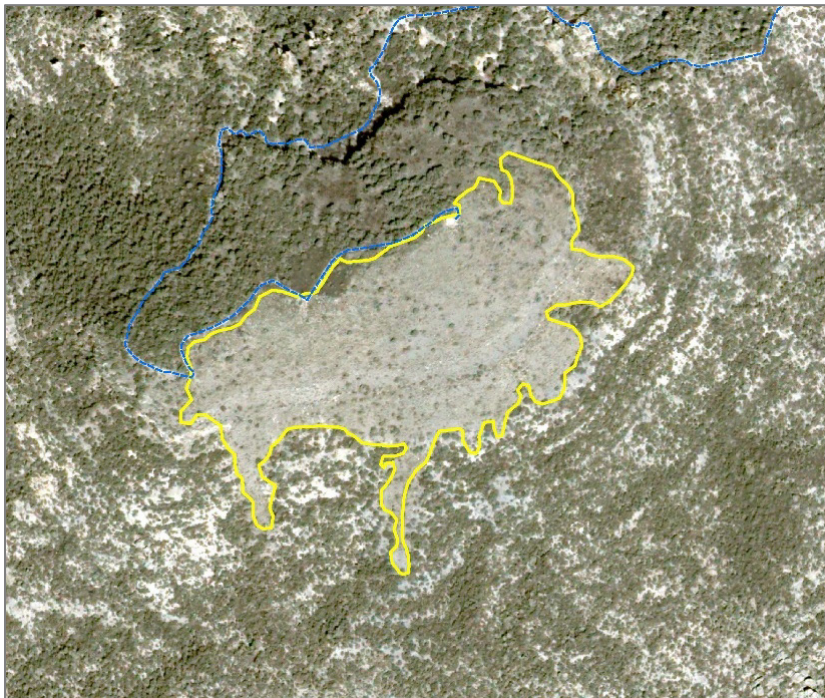


Figure 113. An example area showing the texture and appearance of the satellite imagery that was classified and mapped as Beargrass / Bullgrass Shrub Savanna Association. NPS

Chapter 6: Discussion

Role of Fire, Fire History, and Horseshoe Two Effects and Recovery

Post-Fire Plant Community Changes

Fire severity patterns during the 2011 Horseshoe Two Fire have heavily impacted the spatial distribution and abundance of vegetation types in Chiricahua National Monument. Across most vegetation types, woody cover decreased significantly following moderate- and high-severity fire, reversing the trend of increasing woody canopy cover that prevailed in the previous century (Taylor et al. 2021). By the early 21st century, the long-term lack of fire in most of the monument had led to an increase in woody vegetation cover across most vegetation types and allowed for the establishment of fire-sensitive species, especially border pinyon, in areas that had previously been subject to frequent fire (Baisan and Morino 2000; Taylor et al. 2021). As noted in Taylor et al., pre-fire exclusion of the Ponderosa pine and Madrean mixed pine-oak woodlands and forests would have seen fire on a 5 to 15-year return interval, which would have maintained open canopies by killing off seedlings and saplings.

In the Madrean pine-oak woodlands, regeneration of rapidly resprouting oaks (*Quercus* spp.) and other shrub species such as catclaw mimosa (*Mimosa aculeaticarpa*) has far outpaced that of Chihuahuahua and Apache pines (*Pinus leiophylla* and *P. engelmannii*), which rely primarily on seedling germination to re-establish after fire events, though Chihuahuahua pine occasionally resprouts (Barton and Poulos 2018; Taylor et al. 2021). As a result, these landscapes are increasingly dominated by oak species (Figure 114).

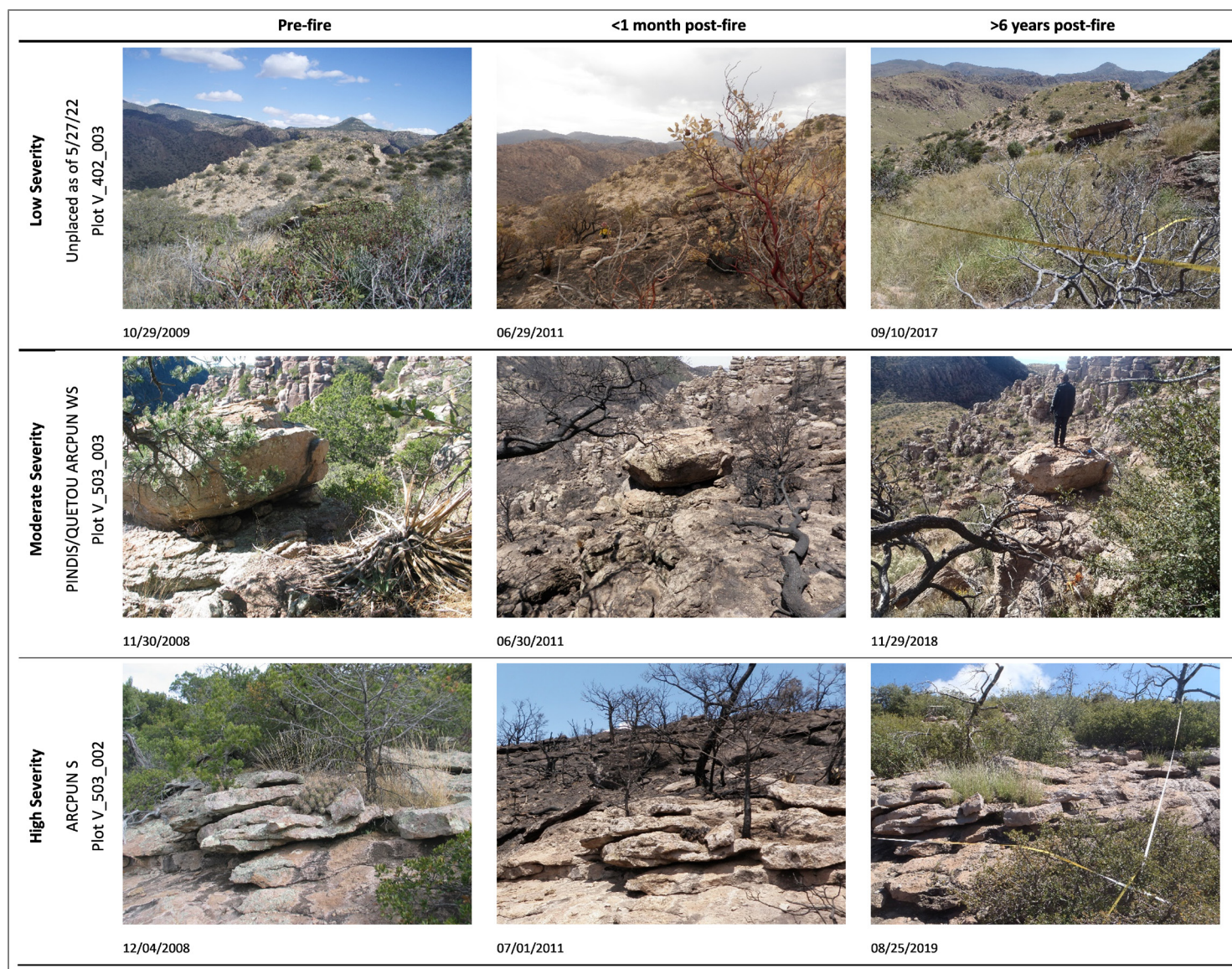


Figure 114. Photo comparison of three SODN monitoring sites pre-fire (left column), immediately post-fire (middle column) and >6 years post-fire (right column), highlighting the loss of plant cover and eventual regrowth especially of sprouting oak species (*Quercus* spp.). NPS

Cover of Border pinyon (*Pinus discolor*)
across height categories (plot-level)

Stratum

- V402
- V501
- V502
- V503

Visit 1 (2007-2010)

Visit 3 (2017-2021)

Cover (%; hits/240)

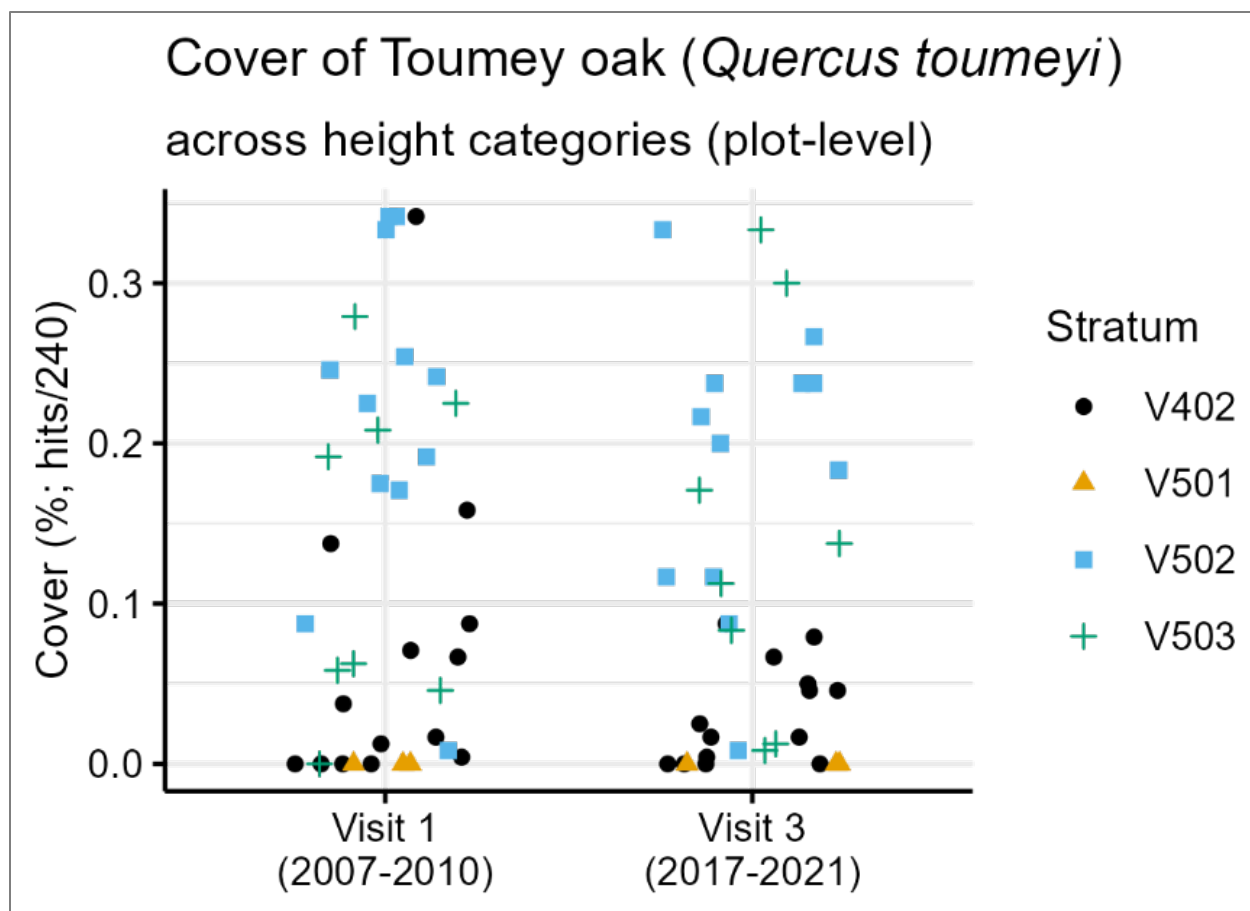


Figure 116. Data from SODN monitoring plots across all elevation/soil strata at CHIR, showing percent cover of Toumey oak (*Quercus toumeyi*) from 2007 to 2010 vs. from 2017 to 2021 (across height categories). Rapid recovery in cover is apparent for most strata, with the lowest elevation (V402) showing less recovery. NPS

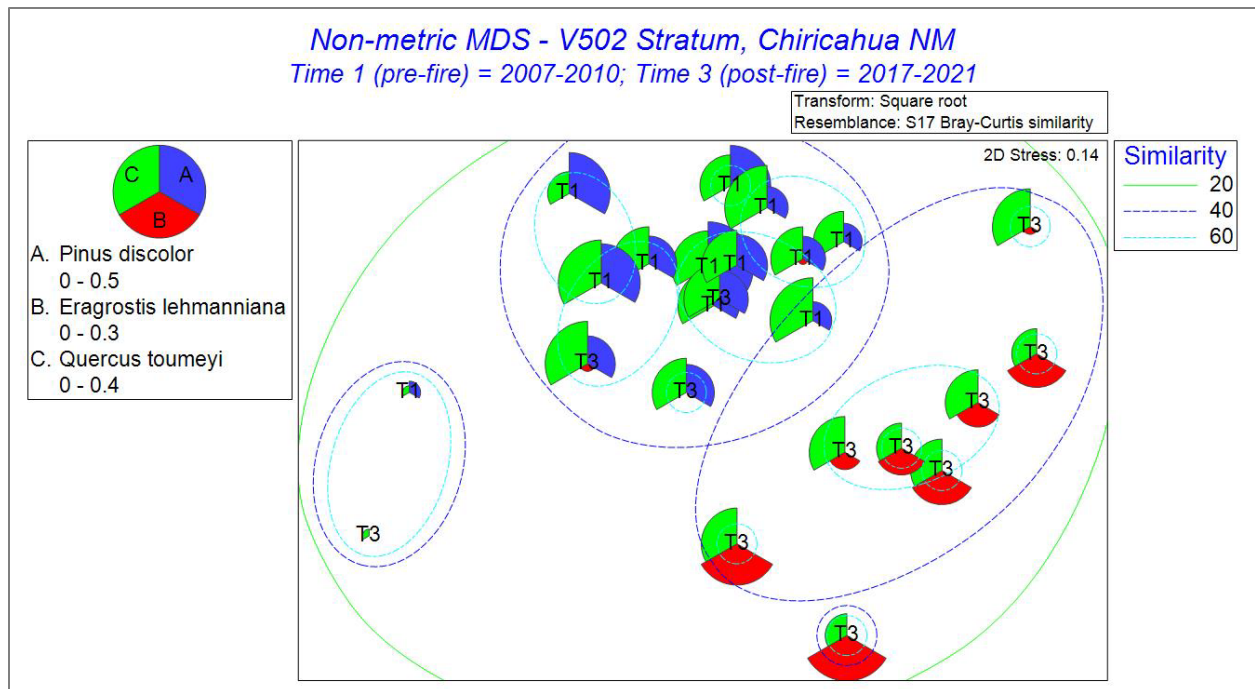


Figure 117. Segmented bubble plot graph showing the relative abundance of three key species in monitoring plots within the 502 stratum at CHIR (n=12), both pre-fire (T1 = 2007–2010) and post-fire (T3 = 2017–2021). Time 2 was one year post fire and is not shown. The 502 stratum is defined by elevation over 6,000 feet and soil rock fragment between 35 and 90%. The 502 stratum was chosen to illustrate the abundance of these three species as it had the greatest abundance and consistent presence of border pinyon in the monitoring plots pre-fire. Size of the pie piece indicates relative abundance. Border pinyon (*Pinus discolor*) is consistently present and abundant in T1 but seen to be absent in T3 and in contrast Lehmann's lovegrass (*E. lehmanniana*) has become present and abundant in T3, whereas pre-fire it was only present in 1 plot. Also notable is the rapid regrowth of Toumey's oak to approximately half pre-fire levels. NPS

Arizona cypress (*Hesperocyparis arizonica*) suffered high mortality rates with severe fire, but post-fire seedling establishment has been abundant in these areas (Barton and Poulos 2019). Similarly, pointleaf manzanita (*Arctostaphylos pungens*) has rebounded quickly following severe fire as is typical of this fire-adapted species (Poulos et al. 2021; Taylor et al. 2021).

In summary, areas that experienced high burn severity during the Horseshoe Two Fire, especially the high-elevation, relatively dry slopes previously occupied by pine-oak woodland vegetation types, are expected to shift towards oak- and manzanita-dominated shrubland or shrub savanna communities. Conifer-dominated communities will likely become increasingly restricted to relatively cool and wet drainages that typically experience low burn severity. Whether these changes persist over the long term or historic vegetation types re-establish to some extent will depend on future changes to the climate and fire regime of the region. Repeated high severity fires could have the potential to cause long-term type conversion. Continued long-term vegetation and soils monitoring combined with repeating the mapping effort will allow us to track these changes and better inform resource management actions at the monument.

Fire and Invasive Grasses

Fire also appears to have facilitated or amplified invasion by Lehmann lovegrass (*Eragrostis lehmanniana*) at high elevations in CHIR (Figure 118, stratum 502 and 503). In these long-term monitoring plots, our data shows a rapid and sustained (over ~10+ years) increase in the number of plots that had this invasive non-native perennial bunchgrass present.

Two sections of the Natural Bridge Trail which burned at high severity are now dominated by Lehmann lovegrass (SODN 2022; Figure 119). Lehmann lovegrass has been well documented as tolerant of fire and even benefitting from fire (McGlone and Huenneke 2004) and due to its larger biomass over most native grasses, an invaded landscape can also carry heavier fuel loads potentially increasing fire intensity and/or fire frequency and thereby often loss of native grasses and shrubs and fire intolerant succulents such as agave and cacti (Fusco et. al. 2019).

Another factor affecting both native and non-native grass diversity and abundance is drought, which could be compounding the increases in lovegrass seen at CHIR. A study using 14 years of data from nearby grasslands elsewhere in southern Arizona (Bodner et al. 2016), showed that the timing of winter rains (January to June), grazing rotations and soil type had complex interactions affecting production but that overall, reduced precipitation during this period correlated to reduced mean basal area of perennial grasses. They also observed that canopy dominance of Lehmann lovegrass was strongly associated with native grass cover declines, in addition to the effects of precipitation, however it cannot be said decisively that Lehmann lovegrass is causing this or merely taking advantage of the open niche space (Bodner et al. 2016).

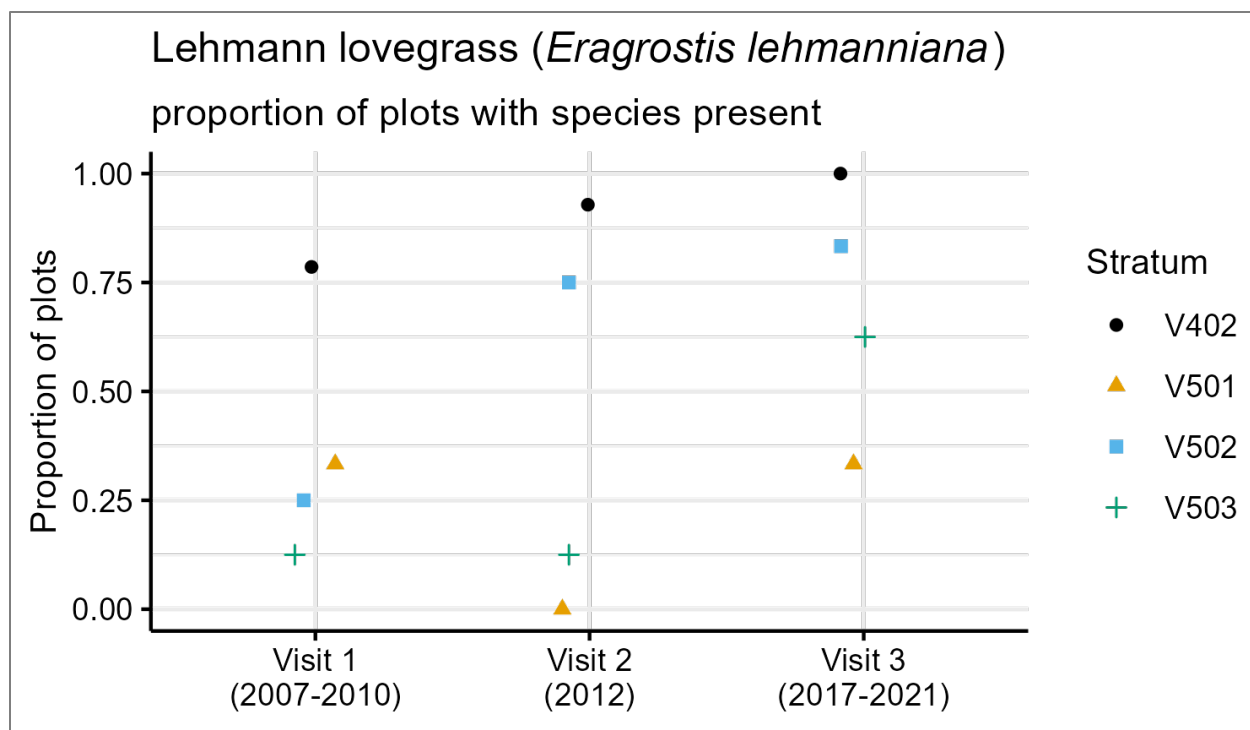


Figure 118. Graph showing the proportion of SODN long-term monitoring plots with Lehmann's lovegrass present, shown by elevation stratum and time visited. Visit 1 = pre-Horseshoe Two Fire (2007–2010), Visit 2 = one-year post-fire (2012) and Visit 3 = 5+ years post-fire (2017–2021). Data for visit 4= 10+ years post-fire (2022–2026) not shown because data collection is ongoing). NPS

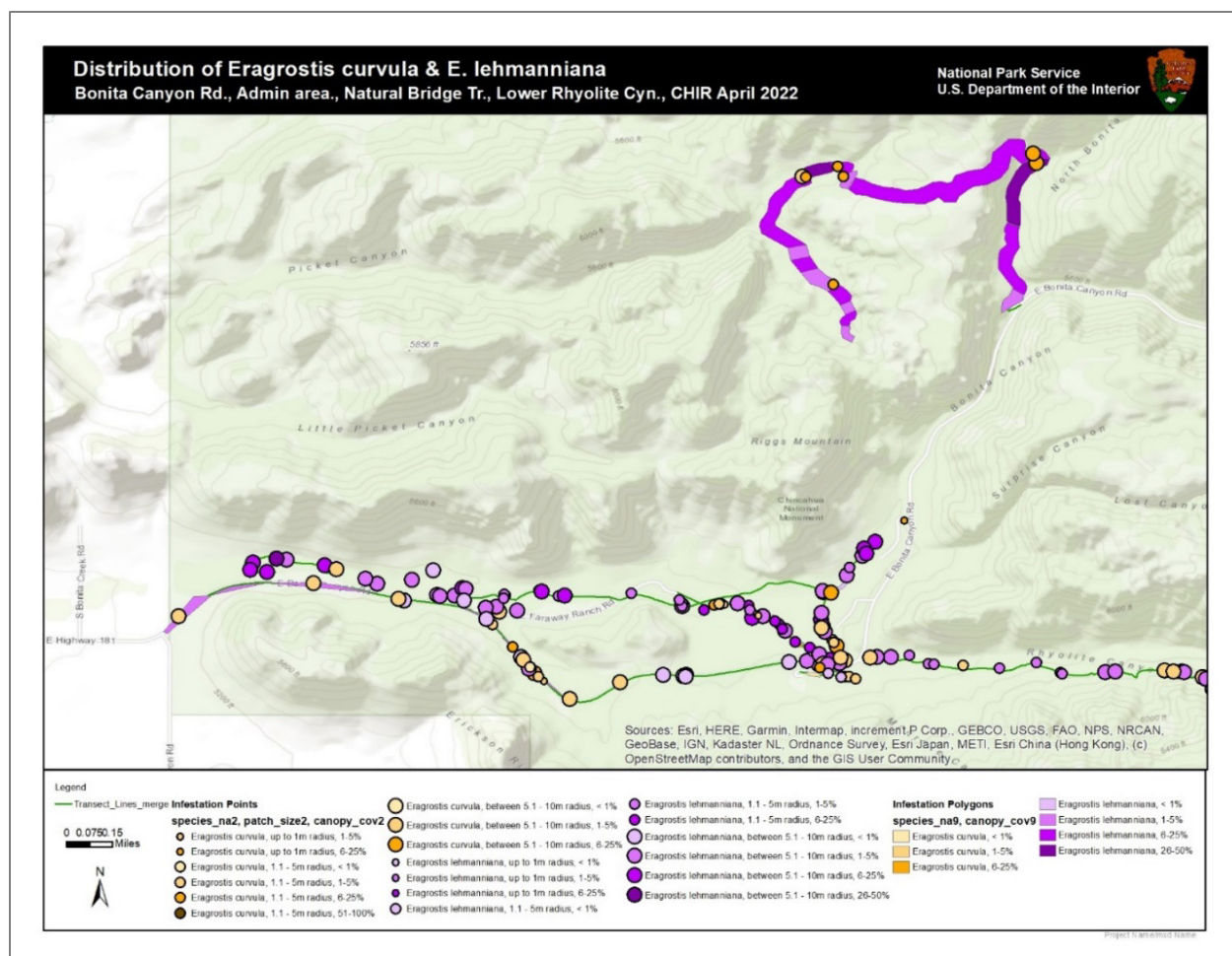


Figure 119. The results of the 2022 exotic plant early detection surveys, along roads and trails in the western side of CHIR. Shown here are Bonita Canyon Road, the park administrative areas and lower Rhyolite Canyon running from left to right along the lower part of the map, and Natural Bridge Trail in the upper right. The locations of two non-native lovegrass species, *Eragrostis curvula* and *E. lehmanniana* are shown as either points or buffered lines (infestation points or polygons respectively), with the size of the point and color indicating abundance (percent cover). As noted elsewhere in the text, the Natural Bridge Trail was observed to be heavily infested with Lehmann lovegrass during these surveys. NPS

Summary

Final Products and Geodatabase Delivery

This map and associated classification represent the most detailed descriptions of the vegetation communities and highest resolution mapping that the monument has had to date. While the wildfire in 2011 surely impacted the vegetation communities at CHIR, the mapping of the pre-fire boundaries should remain of use to management for decades to come and serve as an important baseline against which recovery from the fire can be assessed and used to guide management actions. Vegetation community boundaries are often strongly tied to landscape-scale environmental factors such as aspect, slope, soil type, distance from water–topoedaphic factors that are very heterogenous at Chiricahua National Monument, and factors which remain relatively static over time. These landscape features will continue to influence what species thrive in particular locations within the monument. Vegetation impacts from the fire will continue to change over decades and will be influenced on many occasions by factors such as drought, wet years, and eventually more wildfires. The pre-fire environment itself represented a landscape shaped by nearly a century of wildfire suppression, woody encroachment, and human activities such as livestock grazing and present-day visitor use, all occurring against the fixed backdrop of steep topography and natural fuel breaks created by rock outcrops and hoodoos, (Baisan and Morino 2000). This map and associated products can serve as the basis for future map updates and as an essential complement to long-term monitoring, research, and resource management activities. The classification will contribute to the ongoing development of the comprehensive USNVC across the desert southwest and permit us to place the vegetation of Chiricahua National Monument in a regional context.

Both spatial and tabular data collected during this project were input into a file geodatabase⁷ designed to support relationships between the different data sources. This geodatabase contains all final map data, including photographs from plots and polygon photo point locations. Each spatial feature in the database (points and polygons) can be selected and will show their associated vegetation community type. Searches can be performed both forwards and backwards in this format, so the user can browse data by community and see all the locations, or by location and see all the types.

All final products, including this report, Volume II of this report, keys to vegetation formations and the dichotomous key, and the geodatabase, are available for download and viewing in [NPS' IRMA DataStore](#) and [NPS' Inventory & Monitoring \(I&M\) Vegetation Inventory Products](#) Data can also be requested directly from SODN offices or accessed in [SODN's Reports & Publications](#) under the inventory reports tab.

⁷ Supplemental materials for this report, including the geodatabase, are available in NPS' IRMA DataStore: [Vegetation Mapping Inventory Project for Chiricahua National Monument](#).

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