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El Malpais National Monument

Natural Resource Condition Assessment

Natural Resource Report NPS/SCPN/NRR—2016/1301



ON THE COVER

View of the El Malpais NM landscape from the Sandstone Bluffs Overlook. Photo Credit: Patty Valentine-Darby

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Contents

Page

Executive Summary xix

Acknowledgements xxi

Chapter 1: NRCA Background Information 1

Chapter 2: Introduction and Resource Setting 5
2.1. Introduction 5
2.1.1. Enabling Legislation/Executive Orders 5
2.1.2. Geographic Setting 7
2.1.3. Visitation Statistics 10
2.2. Natural Resources 10
2.2.1. Ecological Units, Watersheds, and NPScape Landscape-scale 10
2.2.2. Resource Descriptions 12
2.2.3. Resource Issues Overview 25
2.3. Resource Stewardship 29
2.3.1. Management Directives and Planning Guidance 29
2.3.2. Status of Supporting Science 30
2.3.3. Literature Cited 31

Chapter 3: Study Scoping and Design 39
3.1. Preliminary Scoping 39
3.2. Study Design 40
3.2.1. Indicator Framework, Focal Study Resources and Indicators 40
3.2.2. Reporting Areas 42
3.2.3. General Approach and Methods 42
3.3. Literature Cited 44

Chapter 4: Natural Resource Conditions 45
4.1. Viewshed 47
4.1.1. Background and Importance 47
4.1.2. Data and Methods 48
4.1.3. Reference Conditions 54
4.1.4. Condition and Trend 54
4.1.5. Sources of Expertise 61
4.1.6. Literature Cited 62
4.2. Night Sky 65
4.2.1. Background and Importance 65
4.2.2. Data and Methods 66
4.2.3. Reference Conditions 68
4.2.4. Condition and Trend 71
4.2.5. Sources of Expertise 75
4.2.6. Literature Cited 75
4.3. Soundscape 77
4.3.1. Background and Importance 77
4.3.2. Data and Methods 78
4.3.3. Reference Conditions 80
4.3.4. Condition and Trend 81

Contents (continued)

Page

4.3.5. Sources of Expertise 83
4.3.6. Literature Cited 84
4.4. Air Quality 87
4.4.1. Background and Importance 87
4.4.2. Data and Methods 89
4.4.3. Reference Conditions 92
4.4.4. Condition and Trend 93
4.4.5. Sources of Expertise 98
4.4.6. Literature Cited 99
4.5. Surface Geology 103
4.5.1. Background and Importance 103
4.5.2. Data and Methods 107
4.5.3. Reference Conditions 111
4.5.4. Condition and Trend 111
4.5.5. Sources of Expertise 117
4.5.6. Literature Cited 117
4.6. Caves and Cave Ice 121
4.6.1. Background and Importance 121
4.6.2. Data and Methods 122
4.6.3. Reference Conditions 126
4.6.4. Condition and Trend 127
4.6.5. Sources of Expertise 131
4.6.6. Literature Cited 131
4.7. Tinajas 135
4.7.1. Background and Importance 135
4.7.2. Data and Methods 136
4.7.3. Reference Conditions 137
4.7.4. Condition and Trend 137
4.7.5. Sources of Expertise 139
4.7.6. Literature Cited 139
4.8. Vegetation- Piñon and Juniper 141
4.8.1. Background and Importance 141
4.8.2. Data and Methods 143
4.8.3. Reference Conditions 144
4.8.4. Condition and Trend 147
4.8.5. Sources of Expertise 155
4.8.6. Literature Cited 155
4.9. Vegetation- Ponderosa Pine 159
4.9.1. Background and Importance 159
4.9.2. Data and Methods 161
4.9.3. Reference Conditions 162
4.9.4. Condition and Trend 165
4.9.5. Sources of Expertise 174
4.9.6. Literature Cited 175
4.10. Vegetation - Grasslands and Shrublands 177
4.10.1. Background and Importance 177
4.10.2. Data and Methods 181
4.10.3. Reference Conditions 185
4.10.4. Condition and Trend 187

Contents (continued)

Page

4.10.5. Sources of Expertise 196
4.10.6. Literature Cited 196
4.11. Vegetation - Distinct Communities 201
4.11.1. Background and Importance 201
4.11.2. Data and Methods 201
4.11.3. Reference Conditions 206
4.11.4. Condition and Trend 206
4.11.5. Sources of Expertise 208
4.11.6. Literature Cited 208
4.12. Exotic Plants 211
4.12.1. Background and Importance 211
4.12.2. Data and Methods 212
4.12.3. Reference Conditions 215
4.12.4. Condition and Trend 217
4.12.5. Sources of Expertise 220
4.12.6. Literature Cited 220
4.13. Cave Ecology and Species 225
4.13.1. Background and Importance 225
4.13.2. Data and Methods 226
4.13.3. Reference Conditions 228
4.13.4. Condition and Trend 228
4.13.5. Sources of Expertise 230
4.13.6. Literature Cited 230
4.14. Mammals 233
4.14.1. Background and Importance 233
4.14.2. Data and Methods 234
4.14.3. Reference Conditions 235
4.14.4. Condition and Trend 238
4.14.5. Sources of Expertise 240
4.14.6. Literature Cited 240
4.15. Bats 243
4.15.1. Background and Importance 243
4.15.2. Data and Methods 243
4.15.3. Reference Conditions 248
4.15.4. Condition and Trend 248
4.15.5. Sources of Expertise 256
4.15.6. Literature Cited 256
4.16. Landbirds 259
4.16.1. Background and Importance 259
4.16.2. Data and Methods 260
4.16.3. Reference Conditions 263
4.16.4. Condition and Trend 263
4.16.5. Sources of Expertise 270
4.16.6. Literature Cited 270
4.17. Herpetofauna 273
4.17.1. Background and Importance 273
4.17.2. Data and Methods 274
4.17.3. Reference Conditions 275
4.17.4. Condition and Trend 275

Contents (continued)

Page

4.17.5. Sources of Expertise 278
4.17.6. Literature Cited 278

Chapter 5: Discussion of Natural Resource Condition Assessment Findings and Considerations for Park Planning 279
5.1. Introduction 279
5.2. Connecting Natural Resource Condition Assessment Topics to Park Purpose, Significance, and Fundamental Resources & Values 279
5.3. State of the Park Reporting 280
5.4. Viewshed Resource Condition Brief 287
5.4.1. Noteworthy Highlights 287
5.4.2. Condition Rationale 287
5.5. Night Sky Resource Condition Brief 289
5.5.1. Noteworthy Highlights 289
5.5.2. Condition Rationale 289
5.6. Soundscape Resource Condition Brief 291
5.6.1. Noteworthy Highlights 291
5.6.2. Condition Rationale 291
5.7. Air Quality Resource Condition Brief 295
5.7.1. Condition Rationale 295
5.8. Surface Geology Resource Condition Brief 297
5.8.1. Noteworthy Highlights 297
5.8.2. Condition Rationale 297
5.9. Caves and Cave Ice Resource Condition Brief 299
5.9.1. Noteworthy Highlights 299
5.9.2. Condition Rationale 299
5.9.3. Management and Project Considerations 299
5.10. Tinajas Resource Condition Brief 301
5.10.1. Noteworthy Highlights 301
5.10.2. Condition Rationale 301
5.11. Piñon-Juniper Resource Condition Brief 305
5.11.1. Noteworthy Highlights 305
5.11.2. Condition Rationale 305
5.11.3. Management and Project Considerations 306
5.12. Ponderosa Pine Resource Condition Brief 309
5.12.1. Noteworthy Highlights 309
5.12.2. Condition Rationale 309
5.12.3. Management and Project Considerations 309
5.13. Grasslands and Shrublands Resource Condition Brief 313
5.13.1. Noteworthy Highlights 313
5.13.2. Condition Rationale 313
5.13.3. Management and Project Considerations 313
5.14. Distinct Vegetation Resource Condition Brief 315
5.14.1. Noteworthy Highlights 315
5.14.2. Condition Rationale 315
5.14.3. Management and Project Considerations 315
5.15. Exotic Plants Resource Condition Brief 317
5.15.1. Condition Rationale 317
5.15.2. Management and Project Considerations 317

Contents (continued)

Page

5.16. Cave Ecology and Species Resource Condition Brief....321
5.16.1. Noteworthy Highlights....321
5.16.2. Condition Rationale....321
5.16.3. Management and Project Considerations....321
5.17. Mammals Resource Condition Brief....323
5.17.1. Noteworthy Highlights:....323
5.17.2. Condition Rationale:....323
5.18. Bats Resource Condition Brief....325
5.18.1. Noteworthy Highlights....325
5.18.2. Condition Rationale....325
5.18.3. Management and Project Considerations....325
5.19. Landbirds Resource Condition Brief....329
5.19.1. Noteworthy Highlights....329
5.19.2. Condition Rationale....329
5.20. Herpetofauna Resource Condition Brief....331
5.20.1. Noteworthy Highlights....331
5.20.2. Condition Rationale....331
5.21. Literature Cited....333

Appendix A: Team Members, Subject Matter Experts/Reviewers, and GIS Data Summary....337

Appendix B: Viewshed Analysis Steps....341

Appendix C: Bortle Dark-Sky Scale....343

Appendix D: Soundscape Models....345

Appendix E: Geology Background....347

Appendix F: El Malpais Vegetation Map....357

Appendix G: Background on Bird Species of Conservation Concern Lists....359

Appendix H: El Malpais NM Bird Lists....363

Figures

Page

Figure 2.1.1-1. The vast majority (85%) of El Malpais NM is suitable for preservation as wilderness. Figure credit: El Malpais NM 6

Figure 2.1.2-1. El Malpais NM is located west of Albuquerque, New Mexico and east of Flagstaff, Arizona in Cibola County New Mexico. 7

Figure 2.1.2-2. Climate conditions at El Malpais NM (http://science.nature.nps.gov/im/units/scpn/climate/climate.cfm). 8

Figure 2.1.2-3. Average daily temperatures from Grants, New Mexico with average high temperatures shown in red and low temperatures shown in blue. 9

Figure 2.1.2-4. A map of parks within the Southern Colorado Plateau Network (including El Malpais) and the range of annual precipitation. 9

Figure 2.1.3-1. Average number of visitors by month to El Malpais NM from 1989-2014. 10

Figure 2.2.1-1. El Malpais NM is located within 15 subwatersheds (USGS 2014a). 11

Figure 2.2.2-1. The major volcanic fields in New Mexico are shown in this figure. El Malpais National Monument is part of the Zuni–Bandera volcanic field in west-central New Mexico (NPS Geologic Resources Division). 12

Figure 2.2.2-2. McCartys flow inflation pits are well preserved and excellent for research. 13

Figure 2.2.2-3. El Malpais contains the southernmost cave ice found in North America. 14

Figure 2.2.2-4. Camera setup at Cerro Encierro, El Malpais NM. 16

Figure 2.2.2-5. The national monument has five main plant community types as mapped by Muldavin et al. (2013). 17

Figure 2.2.2-6. Piñon-juniper (left) and Ponderosa pine (right). 18

Figure 2.2.2-7. Grasslands (left) and Apache plume (***Fallugia paradoxa***) (right), which is one of the predominant plants in the shortgrass-shrublands. 19

Figure 2.2.2-8. Yoda, an ancient Douglas Fir, is shown in the center frame, as well as two really old Douglas firs to the left and right. A clear sign of ancient age is the "inverted-carrot" trunk form (wide at bottom and pointed at top) and the dead crown tops (Grissino-Mayer et al. 1998). The tree on the right was cored and confirmed to start growing around AD 1308, so was just over 700 years old (Harley, pers. comm., 2015). 20

Figure 2.2.2-9. ***Phacelia serrate*** (cinders phacelia). is a species only known from El Malpais and Sunset Crater National Monuments where it grows on areas of open volcanic cinders. 21

Figure 2.2.2-10. The area of light-colored ground is a kipuka surrounded by the McCartys flow. 21

Figure 2.2.2-11. Pinyon jay (***Gymnorhinus cyanocephalus***) is known to occur at the park. 23

Figure 2.2.2-12. Elk (***Cervus canadensis***) (left) and Townsend's big-eared bats (***Corynorhinus townsendii***) (right)are two mammal species that occur in El Malpais NM. 23

Figure 2.2.2-13. Eastern collared lizards (***Crotaphytus collaris***) are known to occur at the park. 24

Figure 2.2.3-1. The reconstruction of total annual precipitation based on tree rings from Douglas fir and ponderosa pine in El Malpais (from Grissino-Mayer et al. 1997). 25

Figure 2.2.3-2. Time series used to characterize the historical range of variability and most recent percentile for annual mean temperature at El Malpais National Monument (including areas within 30-km [18.6-mi] of the park's boundary). The blue line shows temperature for each year, the gray line shows temperature averaged over progressive 10-year intervals (10-year moving windows), and the red asterisk shows the average temperature of the most recent 10-year moving window (2003–2012). The most recent percentile is calculated as the percentage of values on the gray line that fall below the red asterisk (Monahan and Fisichelli 2014). 26

Figure 2.2.3-3. Yoda an ancient Douglas-fir as seen on August 10, 2014. (Harley, pers. comm. 2015). 28

Figures (continued)

Page

Figure 2.3.1-1. The diagram shows the relationship of NRCAs to other park planning reports.....30

Figure 3.2.3-1. Condition, trend, and level of confidence key used in the NRCA.....43

Figure 3.2.3-2. An example of a good condition, unchanging trend, and high confidence level in the assessment graphic used in NRCAs.....44

Figure 4.1.2-1. The location of the vantage points used in this assessment. 49

Figure 4.1.2-2. The GigaPan system takes a series of images that are stitched together to create a single panoramic image.....50

Figure 4.1.2-3. An example of approximate distance classes used in this assessment. 51

Figure 4.1.2-4. Graphic illustration of how color (left) and shape (right) can influence whether features are in harmony with the environment, or are in contrast. Figure Source: NPS-Rob Bennetts.....52

Figure 4.1.2-5. Conceptual framework for hierarchical relationship of characteristics that influence the conspicuousness of features within a viewshed. 53

Figure 4.1.4-1. Panoramic views from one location at the top of El Calderon cinder cone. About 90 degrees are shown in each view, with about 15-20 degrees of overlap between one panorama and the next one. 55

Figure 4.1.4-2. Panoramic views from one location at Bandera Crater (not at the top of the crater). About 90 degrees are shown in each view, with ~15-20 degrees of overlap between one panorama and the next one. Note that one panorama is not shown (150-240) because it did not include anything not observable in the two adjacent views. Also note that the park is not visible in the top view, but it is visible in the other three views in the distance as one looks away from the trail/road. 56

Figure 4.1-4-3. These two photographs were taken from a location a few hundred feet to the west of those shown in Figure 4.1.4-2 (and at a slightly higher elevation). These photos were taken from the cinder trail/road seen in the previous figure, and provide a slightly better view towards the south. 57

Figure 4.1.4-4. Panoramic views from one location at the Sandstone Bluffs overlook. About 90 degrees are shown in each view, with about 15-20 degrees of overlap between one panorama and the next one. (Mt. Taylor can be seen in the background in the top and bottom panoramas). 58

Figure 4.1.2-5. View of parking area and entrance road at Sandstone Bluffs overlook. 59

Figure 4.1.4-6. Area visible (in blue-green) from the vantage points at El Malpais NM. The closest mountain to the north of the park is Mount Taylor, and the closest mountains to the south are the Gallina Mountains. Data sources: NPS (2011b), and USGS (2015).....60

Figure 4.1.4-7. Housing density surrounding El Malpais NM. Data sources: NPS (2011b), NPS (2014b), and Theobald (2005). 61

Figure 4.1.4-8. Road density surrounding El Malpais NM. Data sources: NPS (2011b), NPS (2014c), and ESRI (2010).....62

Figure 4.2.1-1. CCD camera set-up at Cerro Encierro in El Malpais National Monument. 65

Figure 4.2.2-1. Composite image illustrating the range of night sky conditions based on the Bortle Dark Sky Scale. 70

Figure 4.2.4-1. Modeled ALR map for El Mapais NP. A 200km ring around the park illustrates the distance at which anthropogenic light can impact night sky quality within the park. Photo Credit: NPS Natural Sounds and Night Skies Division. 72

Figure 4.2.4-2. Panoramic all-sky mosaic of all sources of light (natural and anthropogenic) at El Malpais National Monument from Cerro Encierro. Credit: NPS Night Skies and Natural Sounds Division. 73

Figures (continued)

Page

Figure 4.2.4-3. Panoramic all-sky mosaic of all sources of light (natural and anthropogenic) at El Malpais National Monument from lower meadow. Credit: NPS Night Skies and Natural Sounds Division. 73

Figure 4.2.4-4. Panoramic all-sky mosaic of all sources of light (natural and anthropogenic) at El Malpais National Monument from Sandstone Bluffs. Credit: NPS Night Skies and Natural Sounds Division. 73

Figure 4.3.1-1. Elk vocalizations contribute to the natural sounds heard at El Malpais NM. 77

Figure 4.3.1-2. A 6 dB reduction in background noise level would produce a 4x increase in listening area (NPS NSNSD 2014). 78

Figure 4.3.2-1. Locations of 2009 acoustical monitoring sites at El Malpais NM. 79

Figure 4.3.4-1. Percent time above reference sound levels within the 12.5-20,000 Hz frequency recorded at El Malpais NM's Lost Woman, Sandstone Bluffs, and Lava Falls acoustical monitoring sites. 81

Figure 4.3.4-2. There are very few roads surrounding El Malpais NM, creating relatively large patches without roads. This contributes to the monument's soundscape condition. Data Sources: NPS (2014) and ESRI (2005, 2010). 82

Figure 4.3.4-3. The modeled L_{50} impact sound level at El Malpais NM (Mennitt et al. 2013). Lighter colors represent higher impact areas. 83

Figure 4.4.1-1. El Malpais National Monument is located within a Class II airshed. 87

Figure 4.4.1-2. A cloudy day at El Malpais NM. 88

Figure 4.4.4-1. For 2004–2013, the trend in visibility at El Malpais NM improved on the 20% clearest days. Credit: NPS-ARD 2015a. 94

Figure 4.4.4-2. For 2004–2013, the trend in visibility at El Malpais NM remained relatively unchanged (no statistically significant trend) on the 20% haziest days. Credit: NPS-ARD 2015a... 94

Figure 4.4.4-3. Visibility data collected at BALD1, AZ IMPROVE station showing the composition of particle sources contributing to haze during the clearest days by year from 2004-2013. Credit: NPS-ARD 2015a. 95

Figure 4.4.4-4. Visibility data collected at BALD1, AZ IMPROVE station showing the composition of particle sources contributing to haze during the haziest days by year from 2004-2013. Credit: NPS-ARD 2015a. 95

Figure 4.4.4-5. Visibility data collected at BALD1, AZ IMPROVE station showing the distribution of clearest days by month for 2013. Credit: NPS-ARD 2015a. 96

Figure 4.4.4-6. Visibility data collected at BALD1, AZ IMPROVE station showing the distribution of haziest days by month for 2013. (Credit: NPS-ARD 2015a. 96

Figure 4.4.4-7. Locations of nitrogen sensitive vegetation at El Malpais National Monument using LANDFIRE data (E&S Environmental Chemistry, Inc. (2009). 98

Figure 4.4.4-8. Change in wet deposition levels From 1988-2008 throughout the United States. 99

Figure 4.5.1-1. Lava flow surface features are one of El Malpais' fundamental resources and values (NPS 2014). The monument's geologic features, especially the McCartys Flow, including the lava rise pits shown here, have great research and educational significance serving as an analog for volcanic features on Mars and the Moon. 103

Figures (continued)

Page

Figure 4.5.1-2. Generalized geologic map of El Malpais NM showing areas of surficial deposits, Quaternary volcanic rocks, sedimentary rocks, and Precambrian igneous and metamorphic rocks. Quaternary volcanic rocks include the young lava flows, cinder cones and cinder fields of the El Malpais period of volcanism that took place within the last 60,000 years and the previous phases of volcanism. Given that the monument is situated over the five youngest lava flows of the Zuni-Bandera Volcanic Field and the abundance of older volcanic rocks, sedimentary rocks are very rare within monument boundaries. Significant exposures of sedimentary rocks occur just north and east of monument boundaries. Map from KellerLynn (2012); NM Guidebook (2010). 105

Figure 4.5.1-3. The young lava flows, vents, cinder cones and cinder fields of the Zuni-Bandera Volcanic Field found with El Malpais monument boundaries (Maxwell 1986 and KellerLynn 2012). 106

Figure 4.5.2-1. A bomb found in the Kirtland Demolition Bombing Range on McCartys Flow in 1984 (Crumpler et al. 2013). 108

Figure 4.5.2-2. Small craters from the detonation of general purpose bombs dropped during training exercises from the Kirtland Army Air Base during World War II are visible on the sides and in the crater of McCartys Crater. The entire area around McCartys vent and the surrounding lava flow has been impacted by these ordnance explosions. 109

Figure 4.5.2-3. Tree mold in the El Calderon lava flow. 112

Figure 4.5.4-1. The vertical cut in the quarry on the El Calderon cinder cone. 115

Figure 4.6.1-1. Big Skylight Cave is one of four lava tube caves open to recreational caving in El Malpais NM. 121

Figure 4.6.1-2. Map showing the major volcanic units of El Malpais NM and the major lava tubes. Geology from KellerLynn (2012). 122

Figure 4.6.2-1. Time series showing the historic range of variability and the most recent percentile for mean annual temperature at El Malpais. The gray line shows temperature averaged over progressive 10-year intervals (10-year moving windows), the blue line shows mean temperature for each year, and the red asterisk show the average temperature of the most recent 10-year interval (2003-2012) (from Monahan and Fisichelli 2014). 123

Figure 4.6.2-2. Repeat photographs of the thick ice wall in Cave #029. Large amounts of charcoal are present on the floor, likely from fires from early visitors. This cave shows significant impact from human activity (Sandia Grotto 2003). The upper left photo is from the late 1980s, month unknown, and the upper right photo was taken on April 4, 2003. The photo on the left was taken on May 21, 2015. This photo sequence shows an apparent decrease in ice since the late 1980s. Note that the exact date of the 1980s photo is unknown and that the volume of ice in caves is seasonally dependent, so the actual trend of ice in this cave may not be illustrated by this sequence. However, during monitoring in May 2015, El Malpais staff observed markings on the wall of the cave that showed that the ice had receded by approximately 2 m (6.6 ft) (Eric Weaver, personal communication, 2015). 126

Figure 4.6.2-3. Junction Cave Impact Assessment Map. Map provided by El Malpais NM. 127

Figure 4.6.4-1. Reflective trail markers to reduce direct visitor impacts have been installed in Xenolith Cave. 131

Figure 4.7.1-1. Dry tinajas located on top of Sandstone Bluffs at El Malpais National Monument. .. 135

Figure 4.7.4-1. The average annual precipitation from 1938-2015 was 13.6 inches (WRCC 2016 - Station #292785). 137

Figures (continued)

Page

Figure 4.7.4-2. According to the National Drought Mitigation Center (2016), the western half of Cibola County, where El Malpais is located, is still in an abnormally dry condition, although greatly improved during 2015. Rectangle shows approximate location of the park. 138

Figure 4.7.4-3. RDI for El Malpais NM using data (1939-2015) from the El Morro National Weather Service station. RDI calculated by Jodi Norris, Landscape and Quantitative Ecologist, SCPN, using the DrinC software package. Figure Credit: Jodi Norris..... 138

Figure 4.8.1-1. Piñon-juniper vegetation atop El Calderon at El Malpais NM. 141

Figure 4.8.1-2. Distribution of the two main categories of Piñon-juniper vegetation at El Malpais NM based on recent vegetation mapping (Muldavin et al. 2013). 142

Figure 4.8.1-3. Piñon Jays (on left), specialize on piñon nuts as a food source, and Townsend's Solitaires (on right) eat juniper berries. 142

Figure 4.8.4-1. The exotic plant mullein (top) and where it was observed on El Calderon (bottom). This area of El Calderon was mined for cinders in the past (Eric Weaver, El Malpais NM, pers. comm.)..... 149

Figure 4.9.1-1. Ponderosa pine vegetation in the El Calderon area at El Malpais NM..... 159

Figure 4.9.1-2. Distribution of the two main categories of ponderosa pine vegetation at El Malpais NM based on recent vegetation mapping by Muldavin et al. (2013). 160

Figure 4.9.1-3. Abert's squirrels (***Sciurus aberti***) are a distinctive species of ponderosa pine forests on the Southern Colorado Plateau. 160

Figure 4.9.4-1. Ponderosa pine stump on the east side of Cerro Bandera with fire scars from before 1900. Source: Romme and Jacobs (2015). 167

Figure 4.9.4-2. Patch of dense ponderosa pine saplings and small trees on the northeast side of Cerro Bandera. Source: Romme and Jacobs (2015). 168

Figure 4.9.4-3. Checking for signs of insects and/or disease on one of the dead ponderosa pine trees observed at the national monument. 171

Figure 4.10.1-1. The largest area of grassland at El Malpais NM is the Fringed Sage/Blue Grama Lava Plains Grassland shown in the photo. 177

Figure 4.10.1-2. Muldavin et al. (2013) mapped 16% of the monument as six shrubland units and 5% as five grassland map units. 180

Figure 4.10.1-3. Climate conditions at El Malpais NM (http://science.nature.nps.gov/im/units/scpn/climate/climate.cfm). 181

Figure 4.10.2-1. There are 150 plots that were established in 2005-2006 for the vegetation mapping project (Muldavin et al. 2013) and 30 plots for fire effects monitoring data sampled more recently (2006-2013) at El Malpais NM..... 182

Figure 4.10.4-1. Fire effects monitoring plot sampled in 2010 in southwest Cerro Bandera, eleven years post-burn; predominant vegetation is blue grama. 187

Figure 4.10.4-2. Fourwing saltbush fire effects monitoring plot sampled in 2013. 187

Figure 4.10.4-3. Blue grama/Mesa Dropseed Sandy Plains grassland fire effects monitoring plot sampled in 2013. 187

Figure 4.10.4-4. The distribution of soil types based on NRCS (2013)..... 189

Figure 4.10.4-5. The geology of El Malpais NM (Muldavin et al. 2013). 190

Figure 4.11.1-1. Phacelia serrate (***cinders phacelia***) is an endemic species that grows only on volcanic cinders and is a USFWS Species of Concern. 201

Figures (continued)

Page

Figure 4.11.2-1. An ancient Douglas-fir growing on the Bandera lava flows in August 2014. This tree has experienced a partial cambial dieback, causing part of its crown to die. If it lives, it will have a smaller crown (Grant Harley, personal communication, 2015). 202

Figure 4.11.2-2. Map showing locations of kipukas by major substrate type: volcanic, sedimentary, and eolian. Areas of Quaternary alluvium (Qal) were grouped into substrate type based on the overall bedrock geology of the kipuka. Geologic mapping by Maxwell (1986) and KellerLynn (2012). Kipuka names are from Bleakly (1996) and Lewis (2003). The large kipukas that are mostly outside of the monument boundaries (Hole-in-the-Wall and Cerritos de Jaspe) are not shown except where inside the monument. Locations of the ancient Douglas-fir trees are from Grant Harley (personal communication, 2015). 203

Figure 4.12.1-1. ***Verbascum thapsus*** (common mullein) is a species of special concern at El Malpais NM because it grows well on young basaltic lava flows and cinder deposits. 211

Figure 4.12.2-1. Location of vegetation mapping and classification plots used by Muldavin et al. (2013). 216

Figure 4.13.2-1. Functional groups for cave-dependent species found during inventory efforts in 10 El Malpais NM caves and one BLM cave in 2007-2008 (Wynne 2013). 227

Figure 4.14.1-1. The American black bear is one of the large mammals known to occur in Cibola County and at El Malpais NM. 233

Figure 4.14.4-1. Elk at El Malpais NM. 235

Figure 4.15.1-1. Townsend's big-eared bat (Corynorhinus townsendii), one of the bat species occurring in New Mexico and El Malpais NM..... 243

Figure 4.15.2-1. Map showing occurrence of WNS, dated 5/28/15. Occurrences with solid color are confirmed, while those with dots are suspected (this may be difficult to see at this scale). At this time, the closest known (confirmed) occurrence of WNS to New Mexico is in Arkansas, and the closest occurrence of the fungus (but not WNS) is Oklahoma. Map available online at https://www.whitenosesyndrome.org/resources/map. 246

Figure 4.15.4-1. Bat Cave, in the El Calderon area of El Malpais NM. The cave is closed to the public to protect roosting bats. 250

Figure 4.15.4-2. Laguna de Juan Garcia, an important pool of water for bats at El Malpais NM, located in the northwest corner of the park. 254

Figure 4.16.1-1. Juniper Titmouse (***Baeolophus ridgwayi***) is one of the many species of birds known to inhabit El Malpais NM. 259

Figure 4.16.2-1. Bird Conservation Regions in North America. 260

Figure 4.16.2-2. Bird Conservation Regions in the vicinity of El Malpais NM and El Morro NM. Both parks are within the Southern Rockies - Colorado Plateau BCR (BCR 16). 261

Figure 4.16.4-1. A pair of Bald Eagles (***Haliaeetus leucocephalus***) at a snag in the North Pastures at El Malpais NM. 269

Figure 4.17.1-1. Canyon treefrog, one of the herpetofaunal species found at El Malpais NM; the treefrog shown here is resting on lava. 273

Figure 4.17.4-1. Western diamond-backed rattlesnake is a SGCN in New Mexico. 277

Tables

Page

Table 3.2.1-1. El Malpais National Monument NRCA Framework. 41

Table 4.1. El Malpais National Monument NRCA Indicators and Measures. 45

Table 4.1.2-1. Indicators and measures of viewshed and why they are important to the resource condition. 48

Table 4.1.2-2. Characteristics that influence how conspicuous human-made features are within a viewshed and the general effect. 50

Table 4.1.2-3. A matrix describing the six size classes used for visible human-made features. 52

Table 4.1.3-1. Qualitative reference condition classes used for scenic and historic integrity within the viewshed at El Malpais NM. 54

Table 4.1.4-1. Indicator and measures of viewshed condition, their corresponding assigned condition class, and the rationale for assigning condition class. 54

Table 4.1.4.2. Housing density surrounding El Malpais NM (within 30 km from the park). 60

Table 4.1.4-3. Definitions of grouped housing density classes used in the GIS analysis. Source: NPS 2013. 61

Table 4.1.4-4. Road density surrounding El Malpais NM (within 30 km of the park). 62

Table 4.2.2-1. Indicators and measures of the night sky and why they are important to resource condition. 66

Table 4.2.2-2. Night Sky Measurements at El Malpais NM. 67

Table 4.2.2-3. Bortle Dark Sky Scale (White et al. 2012) 69

Table 4.2.3-1. Night sky condition class summary for non-urban parks (i.e. parks with at least 90% of their property located outside an urban area). 70

Table 4.2.4-1. Summary of night sky condition rationale at El Malpais NM. 74

Table 4.3.2-1. Location characteristics of acoustical monitoring sites at El Malpais National Monument (excerpted from NPS-NSNSD 2009). 79

Table 4.3.3-1. Explanation of reference sound level values (NPS 2013). 80

Table 4.3.3-2. Reference conditions used to assess the sound levels at El Malpais National Monument. 81

Table 4.3.4-1. Values represent the minimum, maximum, and average L_{50} measurements in each acoustic environment (Excel table provided by E. Brown, 2015). 83

Table 4.3.4-2. Summary of the soundscape indicator and measures and their contribution to the overall soundscape condition. 84

Table 4.4.3-1. Reference conditions for air quality parameters (NPS-ARD 2015c). 92

Table 4.4.3-2. Mercury condition assessment matrix (NPS-ARD 2015b). 93

Table 4.4.4-1. Condition and trend results for air quality indicators at El Malpais National Monument (NPS-ARD 2015a) 93

Table 4.4.4-2. Ozone sensitive plants found at El Malpais National Monument (Bell, in review; Kohut 2004). 96

Table 4.4.4-3. Summary of the air quality indicators/measures and their contributions to the overall air quality NRCA (excerpted from NPS-ARD 2015a). 100

Table 4.5.1-1. The young lava flows of the Zuni-Bandera Volcanic Field exposed within El Malpais NM. 104

Table 4.5.2-1. The indicators and measures used to assess surface geology condition at El Malpais NM. 107

Tables (continued)

Page

Table 4.5.2-2. Known volcanic vents and edifices in El Malpais NM. 108

Table 4.5.2-3. Prioritization rankings for Abandoned Mineral Lands at El Malpais NM. 110

Table 4.5.2-4. Freeze-Thaw Index for Grants Municipal Airport. 111

Table 4.5.3-1. Reference conditions used to assess the current condition of geology for each indicator. 113

Table 4.5.4-1. Indicator, measure, and rationale of surface geology condition. 114

Table 4.6.2-1. Known Ice Caves in El Malpais NM. 124

Table 4.6.2-2. Number of permitted cavers at El Malpais NM 2013-2015. 125

Table 4.6.2-3. Rare cave minerals documented in El Malpais NM (Rogers and Mosch (1997) and Hill and Forti (1997)). 127

Table 4.6.3-1. Reference conditions used to assess the current condition of caves and cave ice for each indicator. 128

Table 4.6.4-1. Indicators, measures, and rationale used to assess the current condition of caves and cave ice. 129

Table 4.7.3-1. Reference conditions for tinajas. 137

Table 4.7.4-1. Summary of tinaja condition rationale. 139

Table 4.8.3-1. Piñon-juniper habitat types used as references (adapted from Romme et al. 2008, 2009). Fire regime information based on several sources (Romme et al. 2007, 2008, 2009; Floyd et al. 2000, 2004; Shinneman and Baker 2009). Reference photos below from Capulin Volcano NM (NPS photos; condition section [Table 4.8.4-1] contains photos for El Malpais NM). 144

Table 4.8.3-2. Synopsis of climate variability since the late 15th century at El Malpais NM, based on a tree-ring chronology developed by Henri Grissino-Mayer. Adapted from Table 3.15 (pages 108-110) in Grissino-Mayer (1995), and taken from Romme and Jacobs (2015, Table 1a). 147

Table 4.8.4-1. Vegetation types dominated by piñon and/or juniper at El Malpais NM and El Morro NM (adapted from national monument vegetation maps and observations by Romme and Jacobs on June 2-4, 2015). Fire regime information comes from Romme et al. (2009), Jacobs et al. (2008), and Grissino-Mayer (1995). Note that this classification is based on ecological processes and dynamics of the vegetation more than on floristic composition and physiognomy. Table (including photos) from Romme and Jacobs (2015). 148

Table 4.8.4-2. Indicators/measures of piñon-juniper condition for persistent piñon-juniper woodlands and juniper-piñon savannas. Table based on Tables 6a and 6b in Romme and Jacobs (2015). 153

Table 4.9.3-1. Vegetation types dominated by ponderosa pine at El Malpais NM and El Morro NM (adapted from national monument vegetation maps and observations by Romme and Jacobs on June 2-4, 2015). Fire regime information comes from Grissino-Mayer (1995), Grissino-Mayer and Swetnam (1997), and Allen et al. (2002). Note that this classification is based on ecological processes and dynamics of the vegetation more than on floristic composition and physiognomy. Table (including photos) from Romme and Jacobs (2015). 163

Table 4.9.3-2. Synopsis of climate variability since the late 15th century at El Malpais NM, based on a tree-ring chronology developed by Henri Grissino-Mayer. Adapted from Table 3.15 (pages 108-110) in Grissino-Mayer (1995), and taken from Romme and Jacobs (2015, Table 1a). 165

Tables (continued)

Page

Table 4.9.4-3. Indicators/measures of ponderosa pine condition for ponderosa pine-piñon-juniper woodland/savanna and ponderosa pine-piñon-juniper rocky woodlands. Table based on Tables 6c and 6d in Romme and Jacobs (2015). 172

Table 4.10.1-1. The 11 shrubland and grassland National Vegetation Classification (NVC) map units identified by Muldavin et al. (2013) at El Malpais NM and their corresponding areas occupied. 179

Table 4.10.2-1. Indicators and measures used to assess grasslands and shrublands at El Malpais National Monument. 183

Table 4.10.3-1. Reference conditions used to assess the current condition for measures of grassland and shrubland soil/site stability and biotic integrity. 186

Table 4.10.4-1. List of exotic plant species at El Malpais NM as recorded in the 2006-2009 vegetation map (VM) project (Muldavin et al. 2013) and at the fire effects monitoring (FEM) plots sampled between 2006 and 2013. 191

Table 4.10.4-2. The relative cover and number of C3 and C4 graminoid species found in the vegetation mapping project (VM) and during fire effects monitoring (FEM). 192

Table 4.10.4-3. Summary of the indicators and measures and their contributions to the overall assessment of grassland and shrubland condition. 195

Table 4.11.2-1. Endemic and Vulnerable Plant Associations present in El Malpais NM. 204

Table 4.11.2-2. Known anthropogenic disturbances on kipukas in El Malpais NM. 206

Table 4.11.4-1. Indicators, measures, and their contributions to the overall distinct vegetation condition rationale. 207

Table 4.12.2-1. Exotic plant species documented in El Malpais NM. 213

Table 4.12.2-2. Significance of exotic plant impact ranking for species recorded at El Malpais (Lightfoot et al. 1994, Bleakly 1997, ELMA 2009, SCPN 2014, and NPS 2015) using a subset of Hiebert and Stubbendieck's (1993) Handbook for Ranking Exotic Plants for Management and Control. 214

Table 4.12.2-3. Prevalence of exotic plant species detected in vegetation mapping 2006-2009 (Muldavin et al. 2013). 215

Table 4.12.3-1. Descriptions for determining condition based on exotic plant potential to alter native plant communities impact ranking and degree of prevalence. 217

Table 4.12.4-1. Significance of exotic plant impact for species documented in El Malpais NM. 218

Table 4.12.4-2. Indicators, measures, and their contributions to the overall exotic plants condition rationale. 221

Table 4.13.2-1. Arthropod morphospecies and other (non-bat) vertebrate observations by Wynne (2013). 227

Table 4.13.3-1. Reference conditions used to assess the current condition of cave ecology and species for each indicator. 228

Table 4.13.4-1. Indicators, measures, and their contributions to the overall cave ecology and species condition rationale. 229

Table 4.14.4-1. Mammal species recorded in El Malpais NM during surveys by Bogan et al. (2007; in 2003-2004), as well as by Valdez et al. (2002; in 1999-2000) and Lightfoot et al. (1994; early 1990s). Notes/entries with a letter are explained in the Comments column, and notes with a number are found below the table. 236

Table 4.14.4-2. Species detected at El Malpais NM that are Species of Greatest Conservation Need (SGCN) according to the New Mexico Department of Game and Fish (NMDGF 2006) and/or state or federally-designated as threatened or endangered. 238

Tables (continued)

Page

Table 4.14.4-3. Indicator and measure of mammal condition. 239

Table 4.15.3-1. Reference conditions for bats at El Malpais NM. 248

Table 4.15.4-1. Bat species recorded in El Malpais NM during surveys by Valdez (2012), Bogan et al. (2007), Valdez et al. (2002), and Lightfoot et al. (1994). Notes/entries with a letter are explained in the Comments column, and notes with a number are found below the table. All of these species were also listed in Table 4.14.4-1 in the previous section on Mammals. 249

Table 4.15.4-2. Bat species recorded in El Malpais NM, showing whether they roost or hibernate in caves or trees, and whether they have been observed in caves at the national monument. Note that a lack of observation/documentation does not mean that they do not occur. Also, cave names are included in only a few instances. 253

Table 4.15.4-3. Indicators and measures of bat condition. 255

Table 4.16.4-1. Summary of species detected during the three sets of surveys/observations (Johnson et al. 2007, Lightfoot et al. 1994, and the park's eBird data for 2011-early 2015) at El Malpais NM of conservation concern, as listed by government agencies and non-governmental organizations. 265

Table 4.16.4-2. Species of conservation concern detected during one, two, or three of the three sets of surveys/observations at El Malpais NM. Note that Lightfoot et al. (1994) included some species that were observed just outside of national monument boundaries. .. 267

Table 4.16.4-3. Indicator/measure of landbirds condition. 269

Table 4.17.4-1. Amphibian and reptile species recorded in El Malpais NM during surveys in 2002-2003 by Nowak and Persons (2008) and in the early 1990's by Lightfoot et al. (1994). For the species recorded by one or both of these surveys, we also indicate whether they were reported by Gehlbach (1965). 276

Table 4.17.4-2. Species detected during 2002-2003 and early 1990s surveys at El Malpais NM that are SGCN according to NMDGF (NMDGF 2006). None of the species are federally or state-listed as endangered/threatened. 277

Table 4.17.4-3. Indicator and measure of herpetofauna condition. 277

Table 5.2-1. Summary of natural resource topic relevance (denoted by black dots) as it relates to El Malpais National Monument's purpose and significance statements identified in the park's Foundation Document (NPS 2014a). 281

Table 5.3-1. State of the Park Natural Resource Summary Table 283

Executive Summary

The Natural Resource Condition Assessment (NRCA) Program, administered by National Park Service's (NPS) Water Resources Division, aims to provide documentation about current conditions of important park natural resources through a spatially explicit, multi-disciplinary synthesis of existing scientific data and knowledge. The NRCA for El Malpais National Monument began November 2015, and 17 focal study natural resources were chosen for the park's NRCA. These resources were organized into three categories: landscape-scale, supporting environment (i.e., physical resources), and biological integrity, which included wildlife and vegetation topics.

The landscape scale resources included viewshed, night sky, and soundscape. The viewshed and soundscape resources were in good condition, given the fact that the monument is located in a rural setting and surrounded by large areas of protected land. The night sky resource was in good to moderate condition and is unfortunately impacted by Albuquerque New Mexico's light pollution at some locations throughout the monument.

The monument's supporting physical environment resource topics included air quality, surface geology, caves and cave ice, and tinajas. The condition for all of these resources was moderate except for caves and cave ice where no condition determination was made due to the lack of data.

The biological integrity resources included four vegetation topics and exotic plants and five wildlife topics, which included cave ecology and organisms, mammals, bats, birds, and herpetofauna. The vegetation resources were in good condition, except for distinct vegetation and exotic plants, which are unknown at this time. The only wildlife topic condition rating was for bats, which was good. The remaining wildlife conditions are currently unknown due to lack of recent data.

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NPS

An NRCA includes current conditions for a subset of a park's natural resources.

Chapter 1: NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks." NRCAs also report on trends in resource condition (when possible), identify critical data gaps, and characterize a general level of confidence for study findings. The resources and indicators emphasized in a given project depend on the park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise to assess current conditions for a variety of potential study resources and indicators.

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement — not replace — traditional issue- and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

- are multi-disciplinary in scope;[1]
- employ hierarchical indicator frameworks;[2]

NRCAs Strive to Provide…

- Credible condition reporting for a subset of important park natural resources and indicators
- Useful condition summaries by broader resource categories or topics, and by park areas

1. The breadth of natural resources and number/type of indicators evaluated will vary by park.
2. Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures [conditions for indicators] condition summaries by broader topics and park areas
3. NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management "triggers").
4. As possible and appropriate, NRCAs describe condition gradients or differences across a park for important natural resources and study indicators through a set of GIS coverages and map products.
5. In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

Important NRCA Success Factors

- Obtaining good input from park staff and other NPS subject-matter experts at critical points in the project timeline
- Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures / indicators) broader resource topics, and park areas
- Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings

- identify or develop reference conditions/ values for comparison against current conditions;[3]
- emphasize spatial evaluation of conditions and GIS (map) products;[4]
- summarize key findings by park areas; and[5]
- follow national NRCA guidelines and standards for study design and reporting products.

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for understanding current conditions, and/ or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.

Due to their modest funding, relatively quick time frame for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

The credibility of NRCA results is derived from the data, methods, and reference values used in the project work, which are



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An NRCA is intended to provide useful science-based information products in support of all levels of park planning.

designed to be appropriate for the stated purpose of the project, as well as adequately documented. For each study indicator for which current condition or trend is reported, we will identify critical data gaps and describe the level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject-matter experts at critical points during the project timeline is also important. These staff will be asked to assist with the selection of study indicators; recommend data sets, methods, and reference conditions and values; and help provide a multi-disciplinary review of draft study findings and products.

NRCAs can yield new insights about current park resource conditions, but in many cases, their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is both credible and has practical uses for a variety of park decision making, planning, and partnership activities.

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities.

NRCA Reporting Products…

- Provide a credible, snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:
- Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations (near-term operational planning and management)
- Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values (longer-term strategic planning)
- Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public ("resource condition status" reporting)

What a NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[6] and help parks to report on government accountability measures.[7] In addition, although in-depth analysis of the effects of climate change on park natural



NPS

An NRCA uses a variety of data to assess the condition of a park's natural resources.

6. An NRCA can be useful during the development of a park's Resource Stewardship Strategy (RSS) and can also be tailored to act as a post-RSS project.

7. While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.

8. The I&M program consists of 32 networks nationwide that are implementing "vital signs" monitoring in order to assess the condition of park ecosystems and develop a stronger scientific basis for stewardship and management of natural resources across the National Park System. "Vital signs" are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.

resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) Program.[8] For example, NRCAs can provide current condition estimates and help establish reference conditions, or baseline values, for some of a park's vital signs monitoring indicators. They can also draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

Over the next several years, the NPS plans to fund a NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information on the NRCA program, visit http://www.nature.nps.gov/water/nrca/.


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Lava rise pits on the inflated surface of the McCartys Flow near Lava Falls.

Chapter 2: Introduction and Resource Setting

2.1. Introduction

2.1.1. Enabling Legislation/Executive Orders

El Malpais National Monument was established on December 31, 1987 by Public Law 100-225, identifying the purpose of the national monument as to:

"Preserve, protect, and interpret natural and cultural resources that are an integral part of the volcanic wilderness, including the Grants Lava Flow and Chacoan great house community of Las Ventanas." (NPS 2014a).

El Malpais NM's unique resources and values are further described in its significance statements as follows (excerpted from its Foundation Document (NPS 2014a)):

Volcanic Processes:
El Malpais protects many lava flows, young and old, that are home to a rich diversity of associated volcanic geologic features including one of the longest lava tube systems in the world.

Caves:
El Malpais National Monument preserves a high density and diversity of ecologically significant lava tube caves, including the southernmost ice caves in the United States. Access to a number of these caves provides a rare self-guided recreational and educational experience.

Lava-influenced ecosystem:
Lava-influenced environmental conditions have produced uncommon vegetation associations, unusual growth forms, and plant communities sheltered from modern disturbances.

Lava-influenced cultural landscape:
El Malpais preserves and protects a cultural landscape influenced by volcanic landforms, including the Chacoan great house community of Las Ventanas, ancient and historic trail networks, basalt architecture, and ritual landscapes.

Wilderness:
The wilderness of El Malpais National Monument, a vast volcanic landscape,

provides opportunities for inspiration and solitude, physical and navigational challenges, and scientific discovery.

El Malpais NM Wilderness

Wilderness is defined as "an area of undeveloped Federal land retaining its primeval character and influence without permanent improvements or human habitation…" in The Wilderness Act of 1964 (Public Law 88-577 [16 U.S.C. 1131-1136]). The 1990 General Management Plan for El Malpais NM identified areas within the national monument that are suitable for preservation as wilderness (NPS 1990). These wilderness-suitable areas make up approximately 39,255 hectares (97,000 acres) or 85% of the park (Figure 2.1.1-1). The areas have been managed as wilderness since 1990, although they are considered as recommended wilderness until they are officially designated by Congress (NPS 2014b). Once finished, the Wilderness and Backcountry Stewardship Plan will complete the planning process for wilderness that began in 1991 and 2003 (NPS 2014b [still in draft form]).

According to NPS (2014b), areas considered suitable wilderness at El Malpais NM possess the following unique qualities: "1) the vast

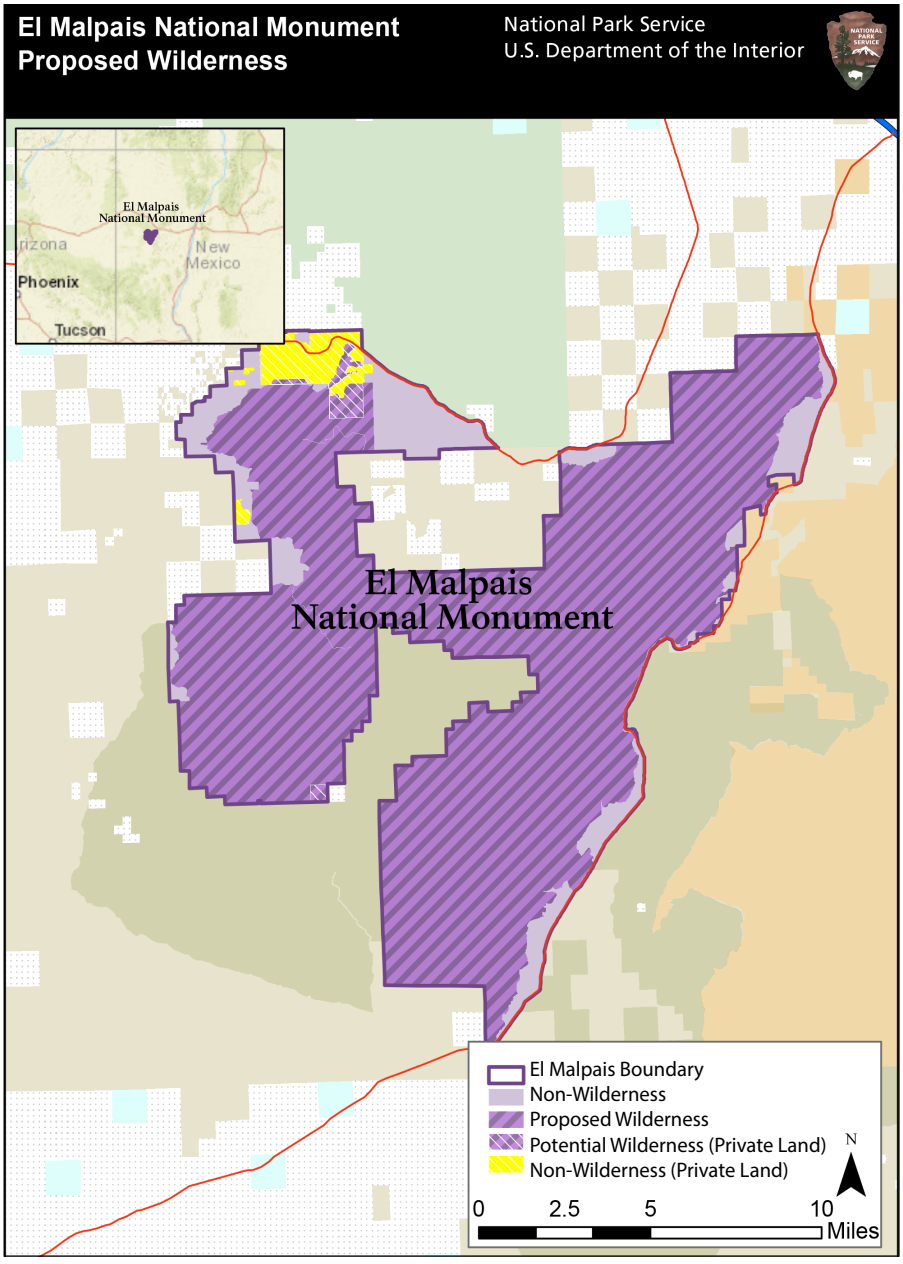


Figure 2.1.1-1. The vast majority (85%) of El Malpais NM is suitable for preservation as wilderness. Figure credit: El Malpais NM

extent of the rugged, volcanic landscape will humble even those with superior navigation skills; 2) the nature of the landscape, coupled with the diverse cultural heritage of this region, has uniquely shaped the human experience of El Malpais NM and limited contemporary development; 3) the many ages and types of lava flows present a mosaic of landscapes and terrain, resulting in different physical challenges, risks, and personal rewards; and 4) different lava flows greatly influence natural systems and processes, creating unique and varied habitats."

Within El Malpais NM, most of the lava fields were deemed suitable for wilderness designation, and in some areas, the margins of the McCarty's, Hoya de Cibola, Bandera, and Twin Craters flows were used to delineate the areas recommended for wilderness designation (NPS 2014b). Other undeveloped areas within the park that were not considered suitable as wilderness are considered backcountry (NPS 2014b).

2.1.2. Geographic Setting

El Malpais NM is located in Cibola County just south of Grants, New Mexico encompassing 47,217 hectares (116,626 acres). It is located along New Mexico Highway 53, which provides access to the park along its east and north boundaries and New Mexico Highway 117, which provides access along its eastern boundary. El Morro National Monument, with which it is co-administered, is located 27 miles to the west of the center of the park (Figure 2.1.2-1).

The national monument is largely surrounded by the even larger El Malpais National Conservation Area, managed by the Bureau of Land Management. The Conservation Area also contains two areas of designated wilderness and a third wilderness study area. The park is adjacent to the Pueblo of Acoma, the Cibola National Forest, and private lands.

Population

The total population was 21,928 in 2010 (NPS 2014c, U.S. Census Bureau 2011) throughout the 30-km surrounding and including the monument (3,119.2 km^2) with 8% of the population located within 3-km^2 of the monument's boundary (NPS 2014c, U.S. Census Bureau 2011). The 2010 population density was 3.69 people/km^2 throughout the

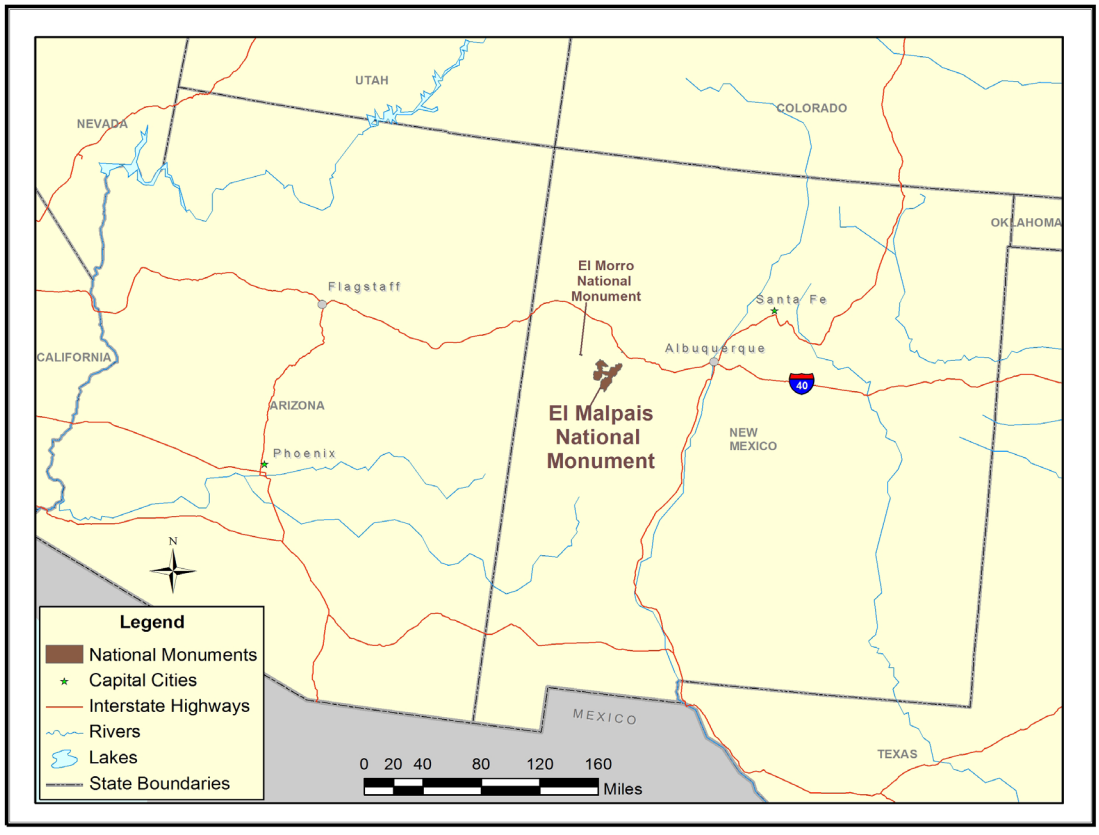


Figure 2.1.2-1. El Malpais NM is located west of Albuquerque, New Mexico and east of Flagstaff, Arizona in Cibola County New Mexico.

30-km area and 6.9 people/km² throughout the 3-km area surrounding and including the park (NPS 2014c, U.S. Census Bureau 2011).

Population data for Cibola County New Mexico indicate that between 1820-1990, the population density increased from 0.022 people/km² to 5.0 people/km² (Waisanen and Bliss 2002). Furthermore projections indicate the population density will decrease to 2.89 people/km² in 2030 throughout the county (University of New Mexico 2009).

Housing density data for 2010 classify 55% of the 30-km area surrounding the park as rural (NPS 2014d), and it is expected that it will remain primarily rural through 2100, which represents the last year housing density projections were made (Theobald 2005).

Climate

The climate of the U.S. Southwest is most influenced by its location between the mid-latitude and subtropical atmospheric circulation regimes. This creates the typical southwestern climate of dry, sunny days, with low annual precipitation. Rain comes in July-September from monsoon storms that originate in the Pacific Ocean and the Gulf of Mexico, and in November-March from winter storms that originate in the Pacific Ocean (Sheppard et al. 2002).

The Colorado Plateau, where the monument is situated, is an arid region with irregular rainfall, periods of drought, warm to hot growing seasons, and long winters with freezing temperatures (Davey et al. 2006). Climate conditions at El Malpais NM are shown in Figure 2.1.2-2.

Winter precipitation is generally followed by a seasonal dry period from April through June. This dry period is defined as much by the increased potential evapotranspiration that accompanies increased day length, solar radiation, and temperatures, as by decreased precipitation. The spring dry period is usually relieved by the onset of the Mexican/ Arizona monsoon, which lasts from July through September and is associated mostly with short-duration, high-intensity thunderstorms. The thunderstorms can be localized, leading to high year-to-year variability of precipitation over small areas across the park (Muldavin et al. 2013).

Temperature

The temperature in El Malpais NM typically varies over the year from 13°F to 88°F.

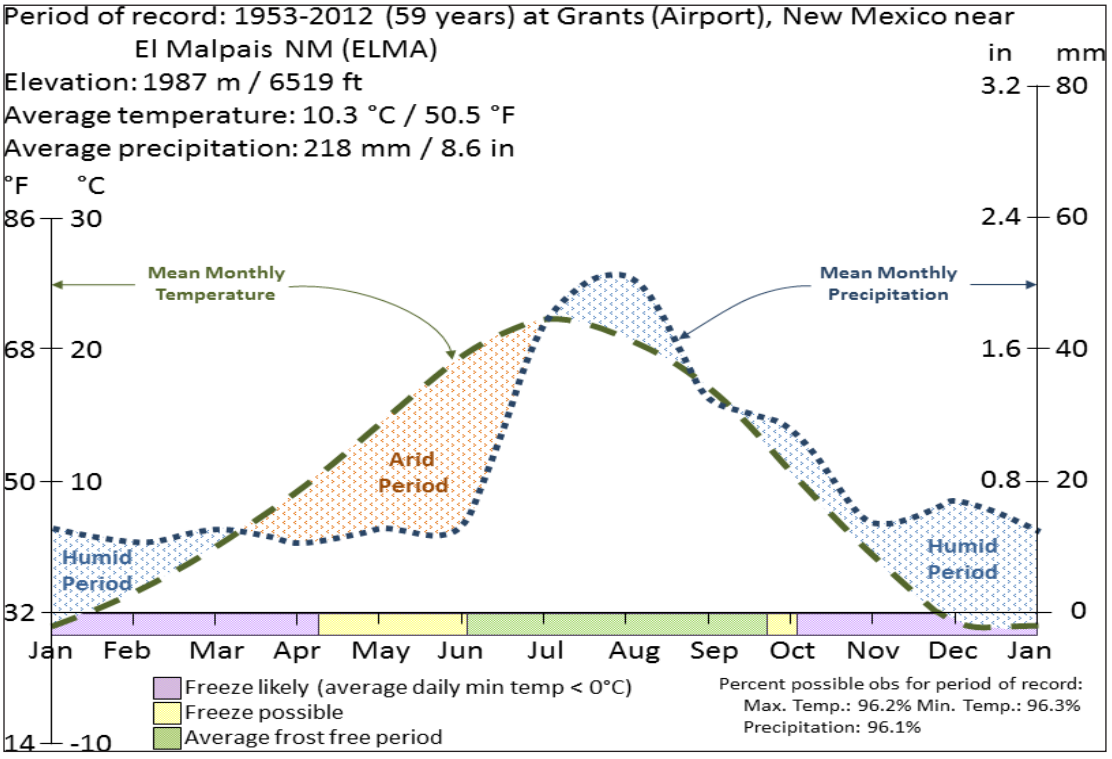


Figure 2.1.2-2. Climate conditions at El Malpais NM (http://science.nature.nps.gov/im/units/scpn/climate/climate.cfm).

The warm season is generally from May 25-September 7 with average daily high temperatures above 79°F. The cold season is generally November 26-February 23 with average daily high temperatures below 51°F. Figure 2.1.2-3 shows the average daily high and low temperatures.

Precipitation

El Malpais NM receives precipitation from both summer monsoons and winter storms with more precipitation coming in the summer than winter. The average annual precipitation in the area of the monument is 218 mm (8.6 in) (Figure 2.1.2-2), of which approximately a third falls in winter (October through March) and is delivered principally by low-pressure systems that sweep from west to east across the Southwest, and coalesce with moisture from the Pacific Ocean or the Gulf of Mexico (Muldavin et al. 2013). The average precipitation in the Colorado Plateau is 10-35 inches/year (Figure 2.1.2-4).

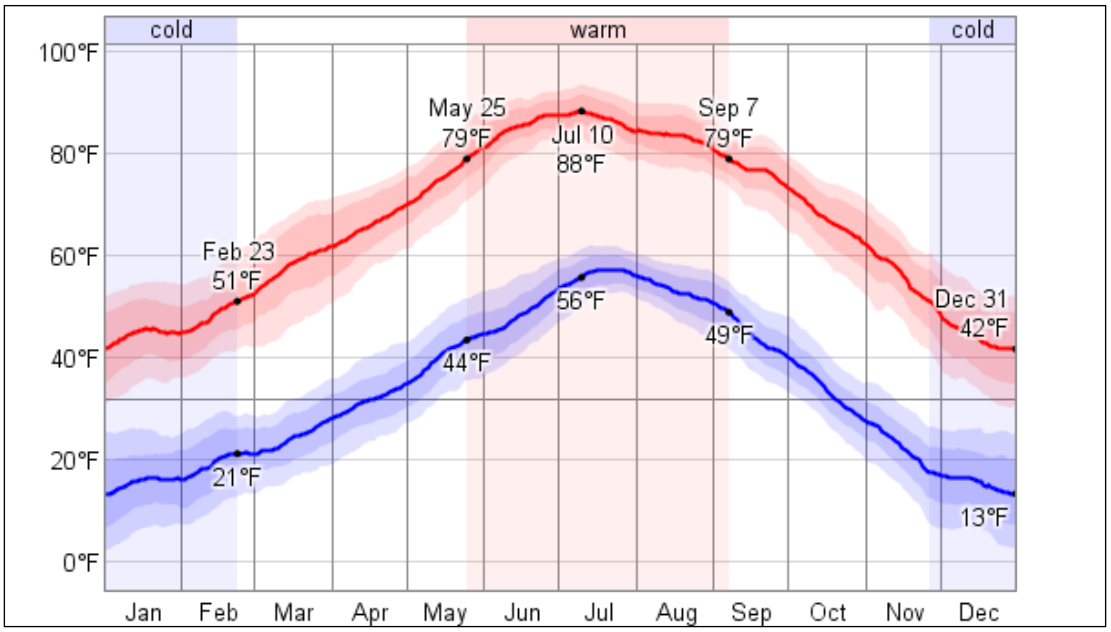


Figure 2.1.2-3. Average daily temperatures from Grants, New Mexico with average high temperatures shown in red and low temperatures shown in blue.

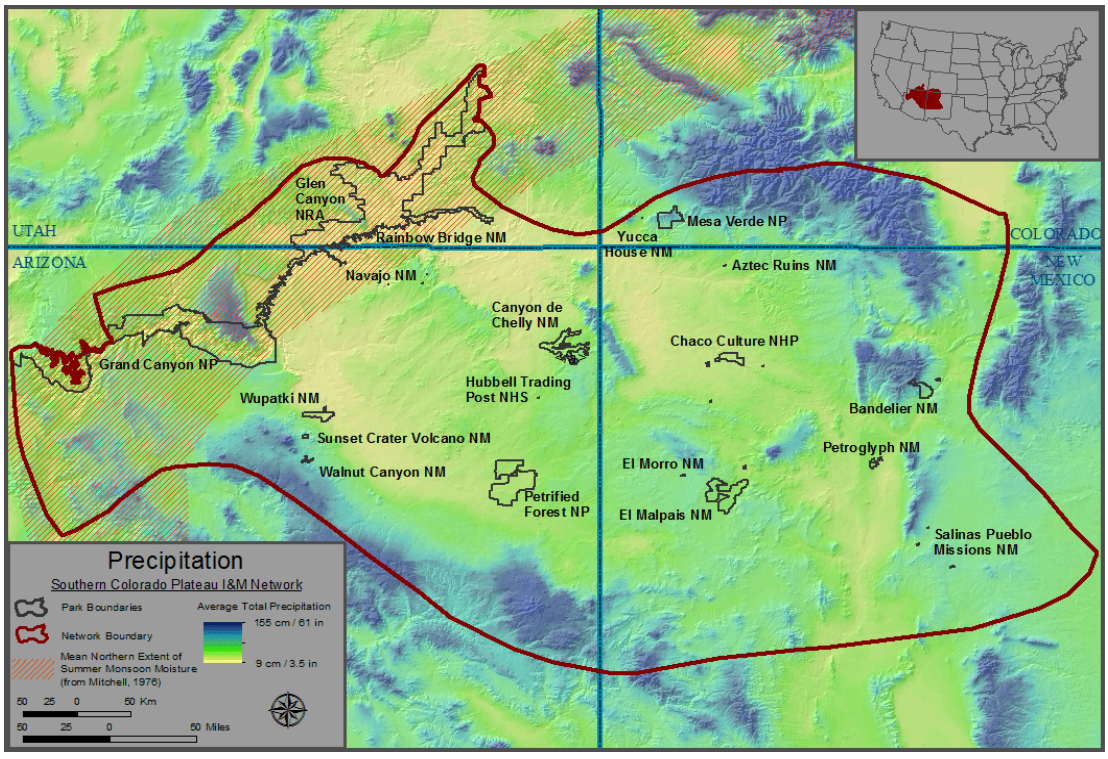


Figure 2.1.2-4. A map of parks within the Southern Colorado Plateau Network (including El Malpais) and the range of annual precipitation.

2.1.3. Visitation Statistics

Monthly visitation data for El Malpais NM are available for 1989-2015 (NPS Public Use Statistics Office 2016). A pneumatic tube counter is placed across Sandstone Bluffs Road, Bandera Crater/Ice Caves Road, El Calderon Road, Zuni-Acoma Trail Road, Big Tubes Road, and Lava Falls Road (NPS Public Use Statistics Office 2001). Traffic counts are summed and multiplied by a designated factor to reduce duplicate reporting of total recreation visits NPS Public Use Statistics Office 2001).

The total number of visitors each year ranged from a low of 52,554 (in 1989) to a high of 174,433 (in 2015). The months with the highest average number of visitors over the recording period were June-August (Figure 2.1.3-1).

2.2. Natural Resources

A summary of the natural resources at El Malpais NM is presented in this section and represents an overview of information known about the study area and monument resources prior to the completion of this condition assessment. For some of the natural resource assessments, new data were gathered and compiled and will be presented in Chapter 4 as applicable.

2.2.1. Ecological Units, Watersheds, and NPScape Landscape-scale

Ecological Units

El Malpais NM is located in the Arizona-New Mexico ecoregion subunit, which encompasses the highlands of eastern Arizona and western and central New Mexico (TNC 1999). This area contains the oldest mountains that are in the Southwest and much of the area is under federal ownership (TNC 1999). The park's elevation ranges between 1,950 and 2,554 m (6,398-8,380 ft).

Watershed Units

The national monument is located primarily within the Rio Grande Region drainage basin, which covers 437,054 km^2 (107,998,395 acres), with a small area of the park's northwest side that is situated in the Lower Colorado Region drainage basin (USGS 2014a). The drainage basin is further divided into the Rio Grande - Elephant Butte Basin Subregion (70,227km^{2,}, 17,353,470 acres) and the Rio Grande - Elephant Butte Basin (53,620.50 km^2, 13,249,914 acres). It is then further subdivided into the North Plains Subbasin, which drains an area of 3127km^2 (772,670 acres). The park encompasses a total of five watersheds and 15 subwatersheds (Figure 2.2.1-1) (USGS 2014a).

NPScape Landscape-scale

Several of the park's resources (e.g., viewshed, night sky, vegetation, wildlife, etc.) are affected by landscape scale processes, and this broader perspective can provide more comprehensive information to better understand resource conditions throughout the park.

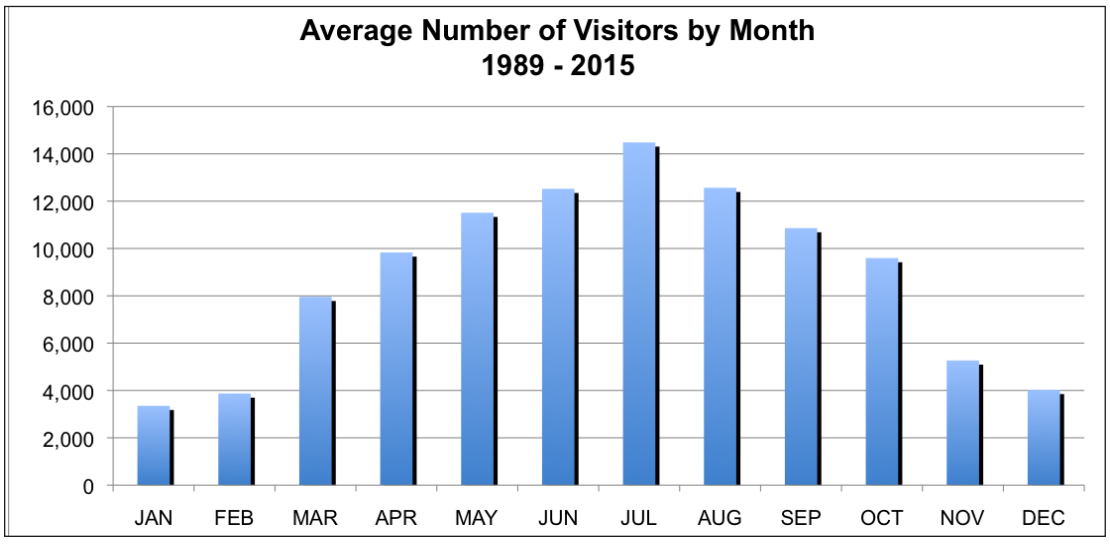


Figure 2.1.3-1. Average number of visitors by month to El Malpais NM from 1989-2014.

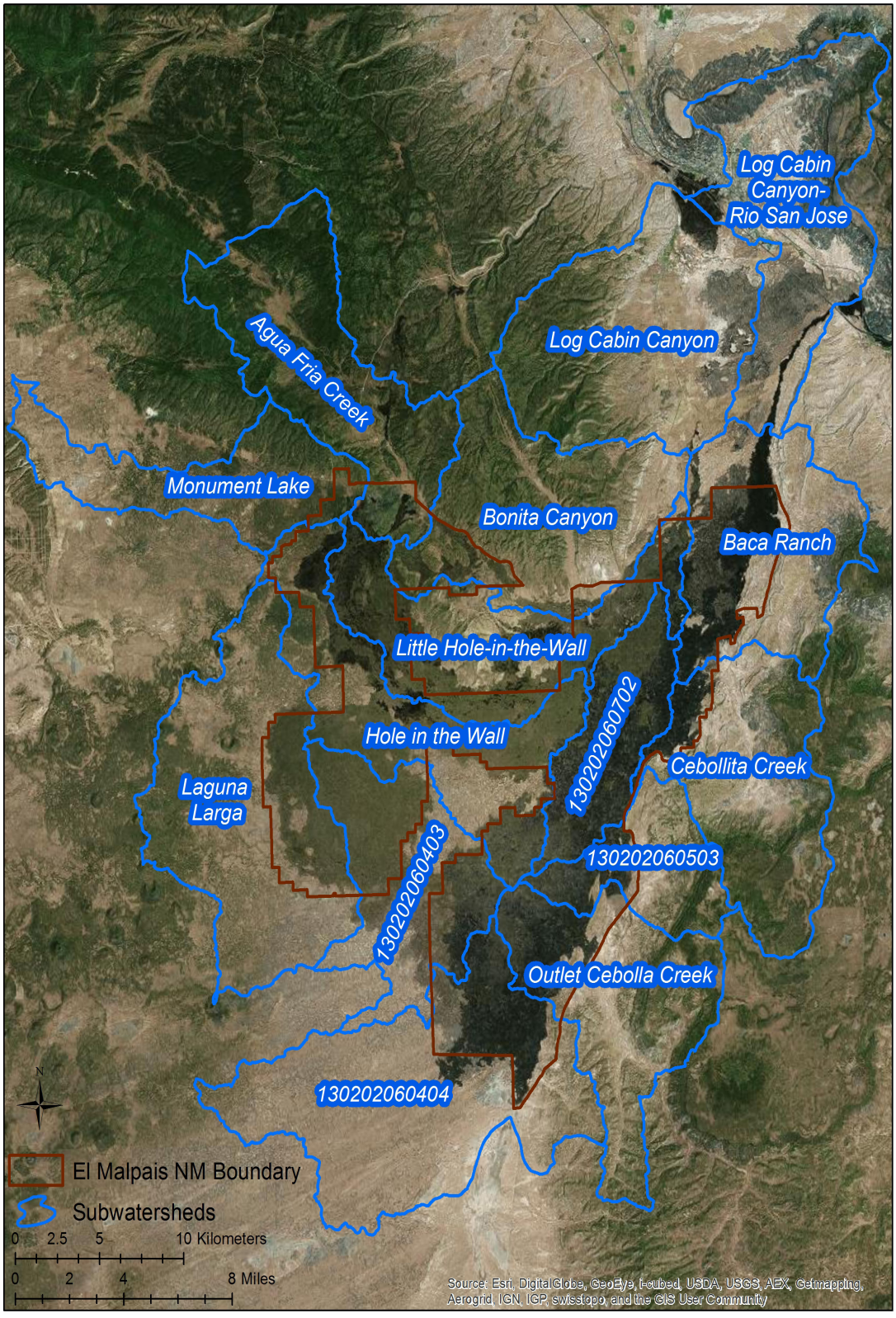


Figure 2.2.1-1. El Malpais NM is located within 15 subwatersheds (USGS 2014a).

Studies have shown that natural resources rely upon the larger, surrounding area to support their life cycles (Coggins 1987 as cited in Monahan et al. 2012), and most parks are not large enough to encompass self-contained ecosystems for the resources found within park boundaries.

As a result, the NPScape Program has identified an area within a 30-km (18.6 mi) radius of a given location as ecologically-relevant for

most natural resources based upon numerous ecological studies as cited in Monahan et al. (2012).

Most of the landscape-scale assessments for selected El Malpais NM resources were evaluated at the 30-km plus park boundary Area of Analysis (AOA) identified by the NPS NPScape Program (NPS 2011a), unless otherwise noted, to provide an ecological, landscape-scale context for resource conditions.

2.2.2. Resource Descriptions

Supporting Environment

Surface Geology

El Malpais, the "badlands" in Spanish, is a rugged volcanic landscape consisting of young lava flows, cinder cones and associated volcanic features, including an extensive network of lava tube caves. Sedimentary rocks are exposed in areas outside of the lava flows, and in kipukas, or "islands" of older rocks, that were not buried by lava flows. With park boundaries drawn to encompass the most significant young volcanic resources of the Zuni-Bandera Volcanic Field, El Malpais National Monument's geologic resources are at the heart of its significance.

The monument lies within the Zuni-Bandera Volcanic Field, which is in the transition zone between the stable Colorado Plateau to the north and the Basin and Range to the south and the Rio Grande Rift to the east- both of which are undergoing tectonic extension and rifting (USGS 2014b). Young volcanic fields including Zuni-Bandera, the San Francisco Peak Volcanic Field (which includes Sunset Crater Volcano National Monument), and the Uinkaret Volcanic Field north of Grand Canyon are found in several locations along the Basin and Range – Colorado Plateau Transition. The Zuni-Bandera Volcanic Field is also located along the Jimez Lineament, which is a northeast-trending alignment of young volcanic fields, including the Valles Caldera, shown in green in Figure 2.2.2-1.

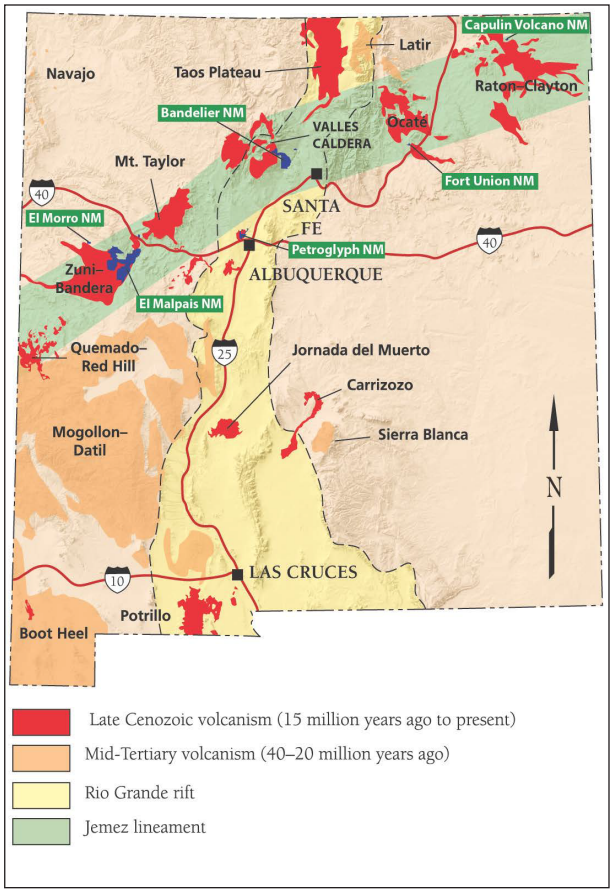


Figure 2.2.2-1. The major volcanic fields in New Mexico are shown in this figure. El Malpais National Monument is part of the Zuni–Bandera volcanic field in west-central New Mexico (NPS Geologic Resources Division).

The volcanoes in and around El Malpais erupted basalt (a type of fluid lava with a chemical composition high in magnesium and iron and low in silica that erupts non-violently) in Hawaiian-style volcanism. Mildly explosive eruptions built cinder cones, such as El Calderon and Bandera Crater. Lava flows were erupted either at the base of cinder cones or from other volcanic vents such as fissures or broad edifices with gentle slopes called shield volcanoes. Nine major lava flows were erupted within the last 60,000 years (KellerLynn 2012). These lava flows show characteristics of two major types: pahoehoe, or ropy lava, or aa, blocky lava. The lava flows at El Malpais also have a variety of other flow features, such as spatter cones, inflation pits, squeeze ups, and tree molds, one of the few paleontological resources found in volcanic rocks (KellerLynn 2012). El Malpais geology was mapped by Maxwell in 1986 and contains the best examples of Hawaiian style lava flows in the continental United States (KellerLynn 2012).

El Malpais is especially notable for containing the McCartys Flow, which formed from the most recent volcanic eruption in New Mexico (Crumpler 2011), approximately 3,900 years before present (Dunbar and Philips 2004). It is also one of the largest and most voluminous young lava flows on the continent (Larry Crumpler, New Mexico Museum of Nature and Science, personal communication, 2015), with a length of approximately 48 km (30 miles) (Garry et al. 2011). El Malpais is also the best place on the continent for people to view the products of young basaltic volcanism, giving the area great educational value, particularly in a spectacular setting with the backdrop of the Sandstone Bluffs (Larry Crumpler, New Mexico Museum of Nature and Science, personal communication, 2015).

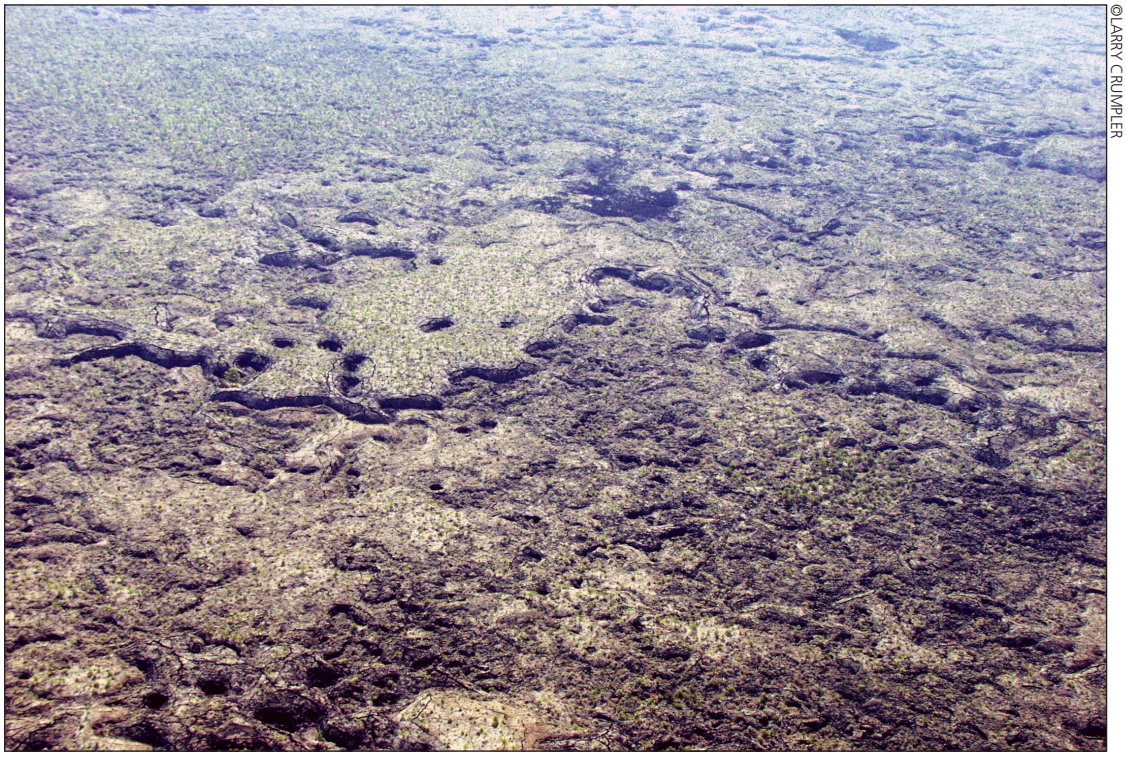
Volcanic rocks exposed in El Malpais have been the subject of important volcanological research, especially on the formation of inflation structures on the McCartys flow (Garry et al. 2011) (Figure 2.2.2-2). In fact, the McCartys flow has inflation features that are better preserved and serve as better research subjects than those on the 1859 flow on the Big Island of Hawaii (Crumpler, personal communication, 2015).

The young lava flows of El Malpais mostly buried a terrain of Pennsylvanian to Cretaceous sedimentary rocks and older lava flows from earlier episodes of volcanism in the Zuni-Bandera field. The monument lies at the southern edge of the Zuni Uplift and Precambrian rocks exposed in the core of the uplift are exposed along the northern monument boundary (Maxell 1986; KellerLynn 2012).

Fossils are known from several of the sedimentary units exposed within the park (Tweet et al. 2009). Tree molds in the young lava flows have been found in at least 10 locations on the Bandera and McCartys flows (Eric Weaver, Physical Science Technician ELMA, personal communication, 2015).

Caves and Cave Ice

The lava tube caves in the monument are among the site's most significant and most sensitive resources. The caves provide a record of the flow dynamics of the lava flows with many physical features produced during flow emplacement, contain rare cave minerals, provide perennial and seasonal ice deposits, contain sensitive microclimates that support ferns and mosses at entrances and in skylights, provide important habitat for



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Figure 2.2.2-2. McCartys flow inflation pits are well preserved and excellent for research.

bats and other cave organisms, and provide recreational opportunities for monument visitors.

El Malpais contains one of the longest lava tube systems in the world and contains the southernmost ice caves in North America (NPS 2014e) (Figure 2.2.2-3). A lava tube is a roofed conduit in a lava flow that can form via a number of processes (Jackson 1997). Lava tubes form in fluid basaltic lava flows that travel many miles from their source. Lava tube caves are caves in the segments of lava tubes that have not either collapsed or became plugged by congealed lava (Larson 1993).

As of early 2015, 441 caves, or subsurface geologic features, were known in the park, including 20 caves first located between late 2014 and early 2015 (Eric Weaver, Acting Branch Chief of Natural Resources, personal communication 2015). Subsurface features documented at El Malpais are of four types: lava tube caves, surface tubes, talus caves, and alcoves. Surface tubes are small features formed by the draining of a lava toe and are as wide as several meters (Larson 1993). An alcove is a relatively small recess in the wall of a lava tube (Larson 1993), and a talus cave consists of interconnected spaces between blocks of talus (Jackson 1997). Lava tube caves at El Malpais are mostly known from the Twin Crater, Hoya de Cibola and Bandera flows (Maxwell 1986 and KellerLynn 2012). They have also been found near the vent for the McCartys flow (Marinakis 1997; Crumpler 2011; and Weaver, personal communication, 2015).

A variety of formations, or speleothems, are found in El Malpais caves, including benches, lava stalagmites, stalactites, helictites and shark-tooth lavacicles (Rogers and Mosch 1997a; and Marinakis 1997). At least 16 rocks, minerals and mineraloids have been identified as speleothems, including secondary minerals (Rogers and Mosch 1997b).

Seasonal or perennial ice has been documented in 40 caves in El Malpais since 1997 (Marinakis 1997, NPS 2012, and Eric Weaver, Acting Branch Chief of Natural Resources, pers. comm., 2015). Perennial ice deposits generally occur as frozen pools on the cave floor, and seasonal ice may form as ice stalagmites and stalactites (Rogers and Mosch 1997b). No detailed studies have been completed on ice caves within the national monument, but Dickfoss et al. (1997) studied the privately-owned Candelaria Ice Cave. Ice deposits in Candelaria Ice Cave are more extensive than those in caves in the monument. The oldest accelerator mass spectrometry radiocarbon date was obtained from a twig enclosed in ice from Candelaria Ice Cave and was 3116 ± 77 years before present (Dickfoss et al. 1997). The age of ice in El Malpais caves is unknown.


NPS

Figure 2.2.2-3. El Malpais contains the southernmost cave ice found in North America.

Development of a Cave Management Plan is considered to be the top resource management priority at El Malpais (KellerLynn 2012). Prior to June 2013, the National Park Service did not require permits to enter El Malpais caves, so previous recreational use data are not available. In December 2010, all caves in the monument were closed to protect against the spread of White-nose Syndrome and to bring the park into compliance with NPS policy and federal law (Pate 2013). Four El Malpais caves re-opened for recreational caving in June 2013 with the requirement that all cavers receive a permit (NPS 2014e). Cave visitor use data are collected as part of the permitting process (Weaver, personal communication, 2015).

Acting Branch Chief of Natural Resources, Eric Weaver, initiated the development of a geodatabase of cave resources found in El Malpais (Weaver, personal communication, 2015). This database will include information on the location of caves, access, degree of visitor impact, mineralogical resources, biological resources and other cave resources (Weaver, personal communication, 2015).

Air Quality

Different categories of air quality areas (Class I and II) have been established through the authority of the Clean Air Act of 1970 (42 U.S.C. §7401 et seq. (1970)). Like most National Park Service areas, El Malpais National Monument is designated as a Class II airshed.

No air quality monitoring stations are located within the required distances to derive trends for ozone, visibility, or atmospheric deposition of nitrogen or sulphur for the national monument, but the NPS' Air Resources Division provides interpolated data to assess air quality conditions, which will be used in the Chapter 4 condition assessment. To date, four plants in the national monument are known to be ozone sensitive species (NPS ARD 2006).

Tinajas

Tinajas or 'small jars' are small bedrock pools of surface water that are essential to the survival of aquatic and semiaquatic organisms and wildlife. The tinajas found throughout El Malpais are intermittent and supplied by meteoric input. These pools are colonized by amphibians and aquatic invertebrates that are temporary pool specialists such as spadefoot toads and branchiopod crustaceans. The species that utilize these temporary pools have developed dispersal adaptations that allow them to persist throughout drying cycles.

Lightfoot et al. (1994) found Canyon Treefrog (*Hyla arenicolor*) to be common throughout the monument, occurring in lava tube collapse features within the lava flows, as well as in tinajas and stock tanks on the east side of El Malpais. Nowak and Persons (2008) speculated the absence of this species during the herpetofauna inventory period between 2002-2003 may have been related to drought conditions, which would adversely impact water availability in tinajas.

Landscape-scale Resources

Viewshed,

At El Malpais, the physical landscape of sandstone bluffs, mesas, and valleys likely played a role in the centuries of use of the landscape by people—from scouting hunting grounds to watching for people approaching. From a cultural and historical perspective, the views are not just about the scenery, but an important way to better understand the connection between natural and cultural resources at El Malpais NM. Visualizing the natural landscape together with cultural events is a critical part of the visitor experience. Viewshed analyses are a way to measure the integrity of the landscape and how it contributes to visitor experience from natural, historical, and cultural perspectives.

Night Sky

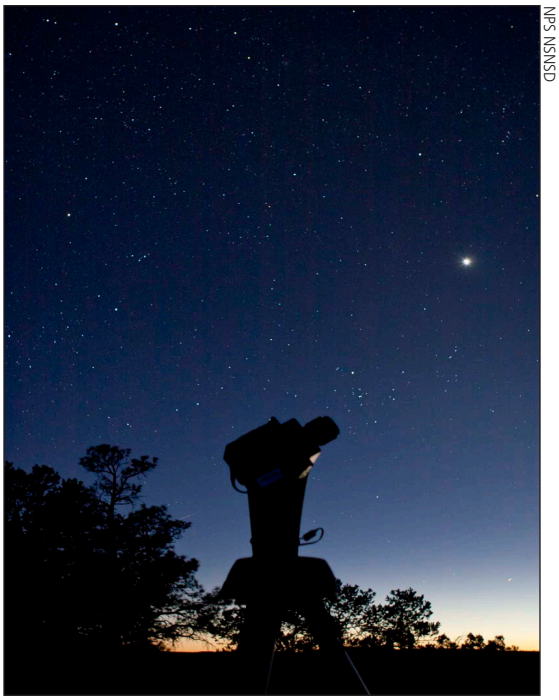
Ancestral Puebloan groups as well as southern Athabaskan (includes Navajo and Apache) groups were the predominant early residents of this region, and the night sky was important to their culture and religion, with rituals and ceremonies often tied to phases of the moon (Malville and Putnam 1993).

Dark night skies are considered an aesthetic in national parks and offer an experiential quality that is also integral to natural and cultural resources (Moore et al. 2013). In an estimated 20 national parks, stargazing events are the most popular ranger-led program (NPS 2010). But the values of night skies go far beyond visitor experience and scenery. The photic environment affects a broad range of species, is integral to ecosystems, and is a natural physical process (Moore et al. 2013).

The NPS Night Skies and Natural Sounds Division collected data on the quality of the night skies at El Malpais from Cerro Encierro on April 20, 2012 (Figure 2.2.2-4).

Soundscape

Baseline acoustical data were collected by scientists from NPS' NSNSD at El Malpais NM from June-July 2009. A 'snapshot report'



NPS NSNSD

Figure 2.2.2-4. Camera setup at Cerro Encierro, El Malpais NM.

was created with a full report expected after data analysis is completed (NPS NSNSD 2009). As a result of the brief report, distinctions between intrinsic versus extrinsic sounds were not differentiated. Regardless, the percent time exceedences above the sound pressure level of 45 dBA were infrequent, except for at the Lost Woman site between 0700-1900. Overall, the data collected indicate a relatively quiet environment at the locations monitored.

Landcover

O'Neill et al. (1997) suggested that the simplest indication of biotic condition may be the amount of land cover change from natural to non-natural. Converted lands may likely influence and possibly inhibit species' movements and habitat requirements (O'Neill et al. 1988; With & Crist 1995; Pearson et al. 1996; McIntyre & Hobbs 1999; Kupfer et al. 2006; Fischer & Lindenmayer 2007; Vranckx et al. 2012 as cited in Monahan et al. 2012).

Almost 100% (99.3%) of the 30-km area, including and surrounding the monument contains a natural land cover type (NPS 2014f, Fry et al. 2011) as compared to an average of 76% of the lands surrounding most national parks (Monahan et al. 2012). A discussion of the amount of landcover change within the 30-km area, which is considered ecologically relevant, will be further discussed in the Chapter 4 vegetation assessment.

Biological Resources

Vegetation

The vegetation at El Malpais National Monument is diverse. The monument lies at the southern margin of the Colorado Plateau and is astride the continental divide. The vegetation pattern of the monument is intimately intertwined with its geology (Muldavin et al. 2013). The young lava flows and cinder cones of the Zuni-Bandera Volcanic Field, in addition to outcrops of sedimentary rock, provide a variety of environmental factors in which plants grow. The national monument has five main plant community types (Figure 2.2.2-5). In addition, three distinct vegetation communities (ancient trees, endemic plant associations and plant species, and kipuka vegetation) result from the interplay between the national monument's geology and vegetation.

The primary earliest study of the area's vegetation was conducted by Lindsey (1951), who studied the vegetation, unique communities, and climate of the lava flows in what is now El Malpais NM and the surrounding vicinity. Lindsey (1951) described three vegetation communities, or "belts," on the lava flows- the mixed Douglas fir and ponderosa pine belt (the upper belt), the ponderosa pine belt (intermediate), and the Apache plume shrub belt (the lower belt). There was a period of approximately 40 years with few studies of the vegetation on what would become El Malpais NM, then a number of studies/inventories were conducted, such as those by Bleakly (1994), Lightfoot et al. (1994), Bleakly and Lightfoot (1995), Grissino-Mayer (1995), Grissino-Mayer and Swetnam (1997), and Bleakly (1997).

Lightfoot et al. (1994) conducted surveys at the national monument as part of a three-year vegetation and wildlife inventory. They surveyed a number of sites with the goal of sampling both typical and unique environments within the park. Bleakly (1994) also studied the vegetation of the park and set out to compile a complete list of the vascular flora of the area, describe communities not

described by Lindsey (1951), and study the habitat of *Phacelia serrate* (cinders phacelia), which is an endemic species found in the monument. Bleakly (1994) also presented a vegetation map showing four vegetation types or communities in the monument and on surrounding lands: bare to sparse grass/shrub; grass or grass/shrub; shrub/conifer; and mixed conifer. Approximately 424 species of vascular plants were reported by Bleakly (1994) and Lightfoot et al. (1994), including 28 non-native species, which were found mostly along roadsides. It should be noted that much of the vegetation work reported in Lightfoot et al. (1994) appears to be the work reported in Bleakly (1994). Current data document 531 species in El Malpais (NPS 2015), including 40 species of exotic plants (Lightfoot 1994; Bleakly 1997; NPS 2009; Muldavin et al. 2013; NPS 2014g and NPS 2015).

Muldavin et al. (2013) classified and mapped the vegetation at the national monument, using data collected from field plots in 2006-2009, in accordance with the national classification/mapping program that is a cooperative effort by the U.S. Geological Survey and the NPS. We present a number of figures in the NRCA based on the Muldavin et al. (2013) work.

Piñon-Juniper

Across the western United States, piñon-juniper vegetation covers approximately 100 million acres (40 million hectares; Romme et al. 2008). There is great diversity in piñon-juniper structure, composition, and disturbance regimes. At El Malpais NM, piñon-juniper areas are dominated by piñon pine (*Pinus edulis*) and one-seed juniper (*Juniperus monosperma*), as well as Rocky Mountain juniper (*Juniperus scopulorum*). Piñon-juniper comprises approximately 20% of the total area of the monument according to recent vegetation mapping efforts by Muldavin et al. (2013; Figure 2.2.2-6 (left)). Muldavin et al. (2013) reported two main types of piñon-juniper (i.e., piñon-juniper woodland and juniper woodland and savanna).

At El Malpais NM, piñon-juniper woodlands occur below ponderosa pine forests on the elevation gradient, and on sedimentary

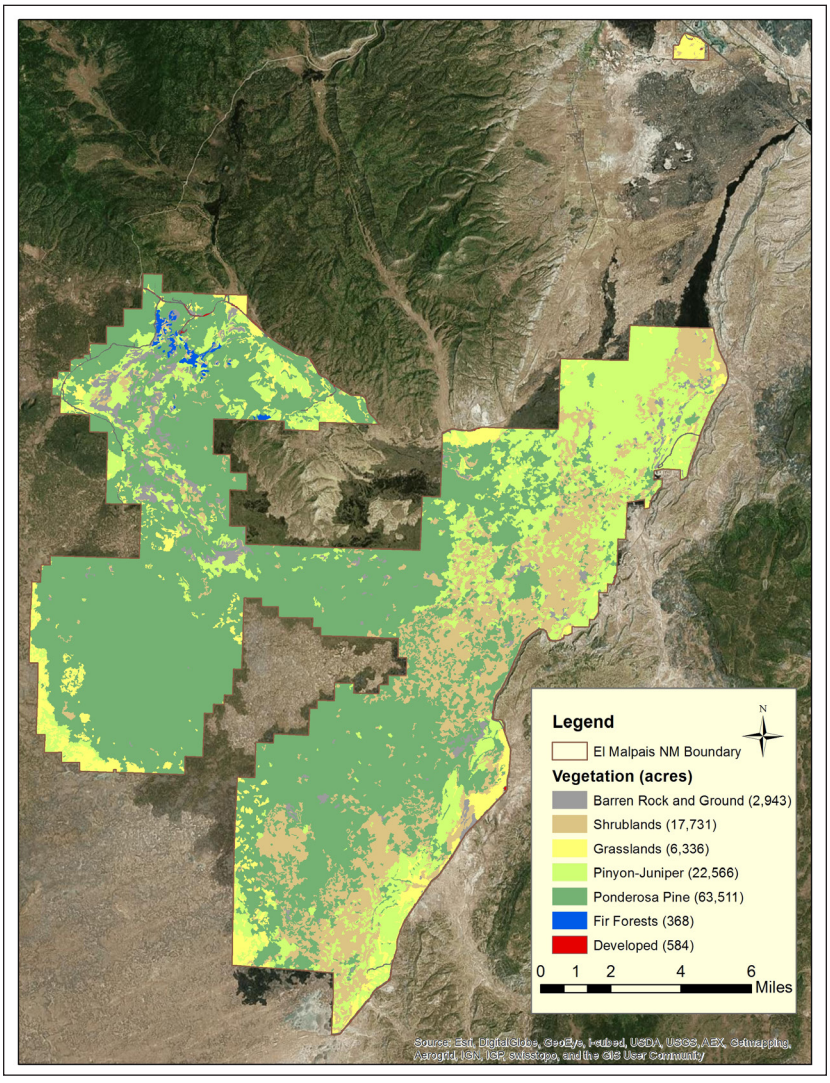


Figure 2.2.2-5. The national monument has five main plant community types as mapped by Muldavin et al. (2013).

kipukas, outcrops, and cinder cones (Lightfoot et al. 1994). Substrates include sandstones, limy sandstones, and sandy soils originating from these rocks and cinders. The Fire Management Plan for the park further indicates that this community typically occurs on south and west facing slopes of cinder cones, ridges on the east side of the monument, and limestone and sandstone ridges on the west side of the monument, as well as on kipukas (Bureau of Land Management and NPS 2001). Although this vegetation community is dominated by piñon pine and one-seed juniper, other trees such as ponderosa pine (*Pinus ponderosa*) and oaks (*Quercus spp.*) occur, as well as a number of shrubs, herbs, and grasses.





Figure 2.2.2-6. Piñon-juniper (left) and Ponderosa pine (right).

Ponderosa Pine

New Mexico and Arizona contain approximately 2.5 million hectares (6 million acres) of ponderosa pine (*Pinus ponderosa*) forests (Graham and Jain 2005). At El Malpais NM, woodlands and savannas dominated by ponderosa pine comprise approximately 56% of the total area of the monument (Muldavin et al. 2013; Figure 2.2.2-6 (right). Muldavin et al. (2013) described two main groups of ponderosa pine (ponderosa pine forest and woodland, and ponderosa pine savanna).

Ponderosa pine vegetation occurs at the national monument at higher elevations, in general above about 2,200 meters (7,220 feet), both on and off of lava flows (Lightfoot et al. 1994). This vegetation type at the park is variable in composition and structure, from relatively dense ponderosa pine forest to more open woodlands of ponderosa pine and piñon pine. According to Bleakly (1994), the largest individual ponderosa pines and the densest stands are in the more mesic northern and western areas of the national monument. Although ponderosa pine is the dominant tree species, others noted as common by Lightfoot et al. (1994) include Colorado piñon (*Pinus edulis*), one-seed juniper (*Juniperus monosperma*), Rocky Mountain juniper (*Juniperus scopulorum*), and Gambel oak (*Quercus gambelii*). Vegetation in the understory is composed of mostly grasses, especially mountain muhly (*Muhlengergia montana*), pine dropseed (*Blepharoneuron tricholepsis*), Western wheatgrass (*Elymus smithii*), and blue gramma (*Bouteloua gracilis*).

Fire is a key ecosystem process in southwestern ponderosa pine forests (Allen et al. 2002). A study in the 1990s focused on the history of fire on the El Malpais NM landscape. Grissino-Mayer and Swetnam (1997) analyzed the fire history in ponderosa pine forests on cinder cones and shield volcanoes, on ancient, highly-eroded basalt flows, on young, moderately-eroded lava flows, and on kipukas. Sites studied varied in the past occurrence of grazing, logging, and fire suppression. Wildfire patterns were analyzed using fire scars on stumps, logs, and snags, and from samples obtained from living trees. The researchers found that fires occurred in 37% of the years (246 out of 660) between 1333 and 1993. Wildfires started becoming less common around 1880, and again around 1940. The first change occurred when livestock grazing became widespread in the area, and the second change was probably related to fire suppression (Grissino-Mayer and Swetnam 1997). The authors also found that from 1700-1880, fire occurred in ponderosa pine forests on the cinder cone/shield volcano and ancient basalt flows about once every three years; in the kipukas about once every seven years; and in the young basalt flow about once every 11 years. Fire regimes in the kipukas studied appeared to be largely unaffected by human disturbance.

Grassland/Shortgrass Prairie

Grasslands at El Malpais NM have been described primarily by Bleakly (1994) and BLM and NPS (2001, based on Bleakly 1994), and more recently by Muldavin et al. (2013). Lightfoot et al. (1994) also discussed these areas and referred to them as juniper savannas. Only a small portion of the monument is dominated by grasslands (about 6% (Figure 2.2.2-7, left)), with much more of this vegetation type occurring on adjacent lands (Bleakly 1994). Bleakly (1994) referred to these areas as the grass/shrub vegetation type. Within the park, grasslands occur primarily on the west side of the park and on the east side of the park. On the west side of the national monument, grasslands occur at elevations of around 2,134 to 2,316 m (7,000 to 7,600 ft.) on generally level land with basalt-based soils (BLM and NPS 2001). As reported in Bleakly (1994), the substrate is old and eroded enough to have fairly well-developed eolian soils. Alluvium has been deposited adjacent to most of the flows on all sides, and soils are at least eight feet deep. These areas had been heavily grazed within the last approximately 100 years. Grasslands on the east side of the park are at lower elevations, also on generally flat land, and occur on sandstone-derived soils (BLM and NPS 2001). Deep soils have resulted from alluvium being deposited in the low-lying areas. Temporary lakes or ponded areas may form next to the lava flows due to runoff (Bleakly 1994). These grasslands were also heavily grazed in the last 100 years.

BLM and NPS (2001) described the grasslands as typically dominated by blue grama (*Bouteloua gracilis*). Other typical grasses include other gramas, little bluestem (*Schizachyrium scoparium*), three-awn (*Aristida spp.*), squirreltail (*Elymus elymoides*), junegrass (*Koeleria macrantha*), and ring muhly (*Muhlenbergia torreyi*). Common shrubs are rabbitbrush (*Chysothamnus nauseosus*, also known as *Ericameria nauseosa*), gray horsebrush (T*etradymia canescens*), sages (*Artemisia spp.*), and broom snakeweed (*Gutierrezia sarothrae*). Bleakly (1994) noted that oneseed junipers (*Juniperus monosperma*) are sometimes found on outcrops.

Muldavin et al. (2013) reported one main grassland group at the park, but as described in Chapter 4, this one group can be separated into six smaller (Level 2) map units.

Shortgrass-Shrublands

Shortgrass-shrublands cover a moderate proportion of the land within El Malpais NM (about 15%) (Figure 2.2.2-7 (right)). These areas have been addressed by Bleakly (1994), Lindsey (1951), and Muldavin et al. (2013). In Bleakly's (1994) work on the vegetation of the national monument, he mapped four broad vegetation zones, including bare to sparse grass/shrub. He reported that this vegetation type occurs on the newer lava flows; in particular, it is found on the McCartys flow and on upper parts of the Bandera flow. The





Figure 2.2.2-7. Grasslands (left) and Apache plume (*Fallugia paradoxa*) (right), which is one of the predominant plants in the shortgrass-shrublands.

main feature of this group is the "geologically new volcanic substrate whose surface may be pahoehoe (McCartys) or aa (Bandera)." Plants in these areas consist of a small number of species of grasses, shrubs, and stunted conifers.

Muldavin et al. (2013) recently mapped the shrubland communities at the park and described three main groups. These groups are discussed in more detail in Chapter 4, in the Grassland/Shrubland section; the most abundant of these at the national monument is one dominated by Apache plume and skunkbush sumac.

Distinct Vegetation Communities

The distinct vegetation communities at El Malpais NM result from biogeographic, or geo-ecologic, interrelationships. In fact, the close correlation between bedrock geology and vegetation at El Malpais is one of the hallmarks of the lava flow-influenced ecosystem identified as one of the monument's statements of significance in El Malpais' Foundation Document (NPS 2014a). This close correlation between geology and vegetation at El Malpais is further evident in the monument's vegetation map and classification report: vegetation map units frequently contain geologic terms such as "lava" or "cinder" (Muldavin et al. 2013).

The lava flow-influenced ecosystem at El Malpais has produced four distinct vegetation communities: ancient trees (Figure 2.2.2-8), an endemic plant species, *Phacelia serrette* (cinders phacelia), endemic plant associations, including the vegetation communities found growing on kipukas. These distinct vegetation communities are very unique aspects of the park's biological and geological heritage.

Endemic Plant Associations & Vulnerable Plant Associations

Due to its very nature with young basaltic lava flows and exposures of older sedimentary rock that have more developed soils, El Malpais NM contains varied environments in which plants to grow, with the bedrock geology having a profound influence on the monument's vegetation communities (Muldavin et al. 2013). Following the guidelines of the National Vegetation Classification Standard, Muldavin et al. (2013) identified five plant associations that have not been described elsewhere, with six additional associations that are regionally endemic. Fourteen additional associations only known from the El Malpais region were designated as "Park Specials" that need further documentation before being included in the National Vegetation Classification, with an additional four types of sparse vegetation that are also unique. El Malpais has a very high percentage of endemic plant associations.



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Figure 2.2.2-8. Yoda, an ancient Douglas Fir, is shown in the center frame, as well as two really old Douglas firs to the left and right. A clear sign of ancient age is the "inverted-carrot" trunk form (wide at bottom and pointed at top) and the dead crown tops (Grissino-Mayer et al. 1998). The tree on the right was cored and confirmed to start growing around AD 1308, so was just over 700 years old (Harley, pers. comm., 2015).

Of the 50 plant associations identified at El Malpais by Muldavin et al. (2013), 38% are endemic to the park (including the 14 Park Specials), with another 12% that are regionally endemic. Additionally, seven plant associations are considered vulnerable in the Global Conservation Assessment Ranking (refer to section 4.11 for details).

Cinders phacelia

One species of endemic plant is known to occur in the park: Phacelia serrate (cinders phacelia). The species is only known from El Malpais and Sunset Crater National Monuments where it is restricted to areas of open volcanic cinders (Figure 2.2.2-9). The species was first recorded in El Malpais in 1993 (Bleakly 1997).


NPS

Figure 2.2.2-9. *Phacelia serrate* (cinders phacelia). is a species only known from El Malpais and Sunset Crater National Monuments where it grows on areas of open volcanic cinders.

Kipukas

Kipukas are areas or features of older geology surrounded by younger geology. The vegetation communities found on kipukas at El Malpais NM are strongly influenced by bedrock geology as they are throughout the monument's lava flow-influenced ecosystem.

Because they are areas of older rock surrounded by younger lava flows, kipukas at El Malpais may be made up of any unit of the park's geologic map (Figure 2.2.2-10), except on the McCartys flow, which is the youngest lava flow in the Zuni-Bandera Volcanic Field and is approximately 3,900 years old (Dunbar and Philips 2004). El Malpais kipukas are of three major substrate types: 1) sedimentary, 2) eolian, or 3) volcanic substrates, where the kipukas are made of older lava flows than the ones surrounding them.

Because the most recent volcanism in El Malpais was nearly 4,000 years before present,


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Figure 2.2.2-10. The area of light-colored ground is a kipuka surrounded by the McCartys flow.

the vegetation growing on the kipukas has not been influenced by volcanic activity, as the vegetation in the park is younger than the lava flows. Previous studies such as Bleakly (1996) that attempted to determine whether the kipuka vegetation had been disturbed by lava flow emplacement were based on assumptions of the age of the volcanic activity that were much younger than determined via age determinations in later studies (Dunbar and Philips 2004). Additionally, as further evidence that the vegetation in the monument is younger than the volcanic activity, the oldest known plants in the park are the ancient trees, which are found on the younger lava flows (Grissino-Mayer et al. 1997).

The largest kipukas (Hole-in-the-Wall and Cerritos de Jaspe) within the El Malpais area are mostly outside of monument boundaries. A good example of a large kipuka completely within the national monument is Los Medanitos - just north of Acoma-Zuni trail. It was created when inflation lava flows from McCartys surrounded the much older lava of the Hoya de Cebola. Bleakly (1997) reports that areas with sedimentary substrates were excluded from the park boundary because they are more easily grazed thereby excluding the larger kipukas from the national monument's boundary.

While kipukas are identifiable on the geologic map (KellerLynn 2012), no systematic study of the vegetation growing on kipukas exists. Muldavin et al. (2013) mapped the monument's vegetation and described some plant associations that are only found on sedimentary substrates including kipukas, such as *Pinus edulis* / *Achnatherum scribneri* Woodland.

Lewis (2003) studied the fire regimes of a small subset of five kipukas in the Hoya de Cibola and Bandera flows in the western part of the monument. He found that some of the studied kipukas were disturbed by logging and/or grazing, and some were relict areas that had not been disturbed by these activities. He also reported that an area of lava flow between two of these kipukas also appeared to be free of the impacts of past logging and grazing.

Ancient Trees

The youngest lava flows in El Malpais (Bandera and McCartys flows) offer an unusual habitat for trees such as *Pinus ponderosa* (ponderosa pine) and *Pseudotsuga menziesii* (Douglas fir), which typically grow in stunted form on the lava flows. The lava flows provide a more mesic environment by concentrating moisture in fractures that provide suitable growing conditions for deep-rooted trees. The lack of soil development on these young lava flows along with the lack of grasses inhibit wildfires (Grissino-Mayer et al. 1997), which is a major factor in allowing these trees to reach great age.

Grissino-Mayer et al. (1997) completed tree ring analysis on *Pinus ponderosa* and *Pseudotsuga menziesii* growing in two locations on the Bandera lava flow. Results from this study show that El Malpais contains some of the oldest living trees in the southwest, dating back to 719 CE. Together with wood collected from dead trees on the lava flows, the El Malpais tree ring record spans more than 2000 years to 136 BCE, the longest single site chronology in the southwest (Grissino-Mayer et al. 1997).

Wildlife

Birds

There have been only a few inventories of the birds at El Malpais NM. Prior to the early 1990s, birds in the park were "poorly known and undocumented" (Lightfoot et al. 1994). Lightfoot et al. (1994) conducted surveys at the national monument as part of a larger vegetation and wildlife inventory. These researchers recorded 109 bird species out of the 162 species of vertebrates they observed (Figure 2.2.2-11). The authors noted that the most extensive information on bird species in the general area of the park prior to their work was county records from the New Mexico Department of Game and Fish (NMDGF) for the entire county (i.e., Klingel 1992). About a decade after Lightfoot et al.'s work, a second inventory of the birds at El Malpais NM was conducted. Johnson et al. (2007) carried out point counts, area-search surveys, and incidental observations in 2002 and 2003. Surveys/counts/observations were made primarily during the breeding

season (May-July), but the researchers also conducted a non-breeding winter survey (in February). They recorded a total of 75 species and provided information on evidence of breeding in the park for each species. No comprehensive, park-wide surveys of birds have occurred at the park since that by Johnson et al. (2007) in 2002-2003. However, personnel at the national monument and others in the vicinity have conducted (and continue to conduct) informal bird surveys (and submitted the results to eBird [Audubon and Cornell Lab of Ornithology 2014]). Three state-listed birds have been recorded at the national monument (Gray Vireo [*Vireo vicinior*], Bald Eagle [*Haliaeetus leucocephalus*], and Peregrine Falcon [*Falco peregrinus*] (Johnson et al. 2007, NPS 2014h, NMGDF 2015).

Mammals

There have been a small number of studies of mammals in or in the immediate vicinity of El Malpais NM over the past several decades. Hooper (1941) looked at mammals on the lava fields and adjacent lands of the area and recorded 60 species and subspecies of mammals (Figure 2.2.2-12 (left)). One-half a century later, Lightfoot et al. (1994) conducted mammal surveys at the national monument as part of a larger vegetation and wildlife inventory. Of the 162 species of vertebrate animals observed by Lightfoot et al. (1994), 36 were mammals.



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Figure 2.2.2-11. Pinyon jay (*Gymnorhinus cyanocephalus*) is known to occur at the park.

The most recently conducted survey of mammals in the national monument was that by Bogan et al. (2007) in 2003 and 2004. Prior to the surveys, about 48 species were believed to occur at the national monument (Stuart 2000). Bogan et al. (2007) had a goal of documenting as many species as possible, and they focused on groups of mammals having the most species, such as rodents and carnivores. They documented 45 species of mammals at the park (20 rodent species, 12 bat species, eight carnivore species, three ungulate species, and two lagomorphs species). However, 53 species have been documented overall and are considered to be present at the park, and a number of additional species may be present (Bogan et al. 2007).



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Figure 2.2.2-12. Elk (*Cervus canadensis*) (left) and Townsend's big-eared bats (*Corynorhinus townsendii*) (right) are two mammal species that occur in El Malpais NM.

No comprehensive surveys or monitoring of mammals have occurred at the park since that by Bogan et al. (2007). No federally-listed mammals are known to occur at the park at the present time, but the Mexican gray wolf, which is federally and state-endangered, has been documented at the park on occasion in recent years.

Bats

The most recent mammal inventory, conducted in 2003-2004 by Bogan et al. (2007), documented 12 species of bats at the national monument (Figure 2.2.2-12 (right)). A survey for bats was conducted a few years earlier by Valdez et al. (2002) who recorded a total of 15-16 species during their work in 1999 and 2000 in the national monument and adjacent lands. They surveyed bats using mist nets and echolocation detectors, and in addition to documenting the occurrence and distribution of bats at the monument, they collected information on relative abundance, reproduction, and seasonal activity. Their work identified a handful of dominant species (Western small-footed myotis [*Myotis ciliolabrum*], long-eared myotis [*M. evotis*], long-legged myotis [*M. volans*], and big brown bat [*Eptesicus fuscus*]) that were common in habitats at middle and high elevations.

Of the bat species documented at El Malpais NM, none are federally-listed, but one species, the spotted bat (*Euderma maculatum*), is state-threatened (Bogan et al. 2007; NMDGF 2015a). There are a number of known bat roosts at El Malpais NM for Mexican (or Brazilian) free-tailed bats (*Tadarida brasiliensis*) and for Townsend's big-eared bats (*Corynorhinus townsendii*) (Figure 2.2.2-12 (right)). Bats use caves at the national monument for both hibernacula (winter hibernation sites) and maternity roosts (sites where female bats raise their young).

Although bats have been studied more than some of the other mammal groups at El Malpais NM, research and management needs remain (Wynne 2013). For example, Wynne points out that more information is needed on the winter habitat requirements of year-round bat residents of the park, specifying the need for inventories of bats during the winter to locate additional hibernacula. Some of this work is underway; for example, researchers are studying microclimate conditions in lava caves used by hibernating bats and are collecting information on additional caves that have "significant" hibernacula (Buecher 2012). Also, during the winter of 2014-2015 park interns collected information on bat hibernacula locations (David Hays, former Natural Resources Branch Chief, El Malpais NM, pers. comm.).

Amphibians and Reptiles

Lightfoot et al. (1994) conducted herpetofauna surveys at the national monument as part of a larger vegetation and wildlife inventory. They recorded 15 reptile and two amphibian species out of the 162 species of vertebrates they observed (Figure 2.2.2-13). These authors included additional information on an earlier study by Gehlbach (1965), which focused on amphibians and reptiles of the Zuni Mountains area, including land around the present-day park (Lightfoot et al. 1994). The most recent inventory was conducted in 2002-2003 by the U.S. Geological Survey's (USGS) Southwest Biological Science Center for the Southern Colorado Plateau Network (Nowak and Persons 2008). Inventory goals were to document 90% of the herpetofaunal species present at the park, identify species of special concern at the park, and make



NPS (MURPHY)

Figure 2.2.2-13. Eastern collared lizards (*Crotaphytus collaris*) are known to occur at the park.

recommendations for a monitoring program. Nowak and Persons (2008) recorded 18 species of herpetofauna (13 reptile and five amphibian species), many of the same species as recorded by the Lightfoot et al. (1994) inventory. The authors of the 2002-2003 inventory estimated that inventory completeness at the park was 78%, meaning that additional species are likely to be found at the national monument. They also named several additional species that probably occur or may occur at the park. No comprehensive surveys or monitoring of amphibians or reptiles have occurred at the park since that by Nowak and Persons (2008). No federally or state-listed amphibians or reptiles are known to occur at El Malpais NM.

Cave Ecology/Organisms

The basaltic lava flows between 3,900 and 60,000 years ago formed at least 175 lava tube caves and ice caves in El Malpais, which are some of the most fragile ecosystems on Earth (Wynne et al. 2007, Soto 2013). Ice caves are particularly sensitive to changes in climate, and often harbor significant archeological artifacts (such as Zuni and Acoma Pueblo pottery) as well as paleontological resources (such as undated bones; E. Weaver, pers. comm. 2016). Caves are important for their formations and features, and the habitat they provide for bats and specialized invertebrates. Cave fauna are particularly sensitive to disturbance and changes in cave ecology (Soto 2013).

2.2.3. Resource Issues Overview

Climate Change

Like many places, the Southwest is already experiencing the impacts of climate change. The predictions are that the Southwest will likely continue to become warmer and drier with continued climate change (Garfin et al. 2014, Monahan and Fisichelli 2014). The Southern Colorado Plateau is vulnerable to the impacts of climate change due to its semi-arid climate.

According to Kunkel and others (2013), the historical climate trends (1895-2011) for the southwest (including the states of Arizona, California, Colorado, Nevada, New Mexico, and Utah) have seen an average annual temperature increase of 0.9ºC (greatest in winter months) and more than double the number of four-day periods of extreme heat. Future climate predictions (Kunkel et al. 2013) for 2070-2099 (based on climate patterns from 1971-1999) estimate temperatures could rise between 2.5ºC and 4.7ºC.

Over the course of history, as evidenced in tree rings, precipitation patterns have fluctuated with above-normal periods and below-normal periods of time. The most intense above-normal, wet period was from 1971-1992, which exceeded the previous wettest period of 521-660 AD (Grissino-Mayer 1996, Grissino-Mayer et al. 1997; Figure 2.2.3-1). Extreme dry periods occurred between 300 and 500 AD and in the 15th-17th centuries (Stahle et al. 2009). Future climate predictions (Kunkel et al. 2013) for 2070-2099 (based on climate patterns from 1971-1999) estimate precipitation may decrease up to 9%.

Monahan and Fisichelli (2014) assessed the magnitude and direction of changes in climate for El Malpais for 25 variables including temperature and precipitation between

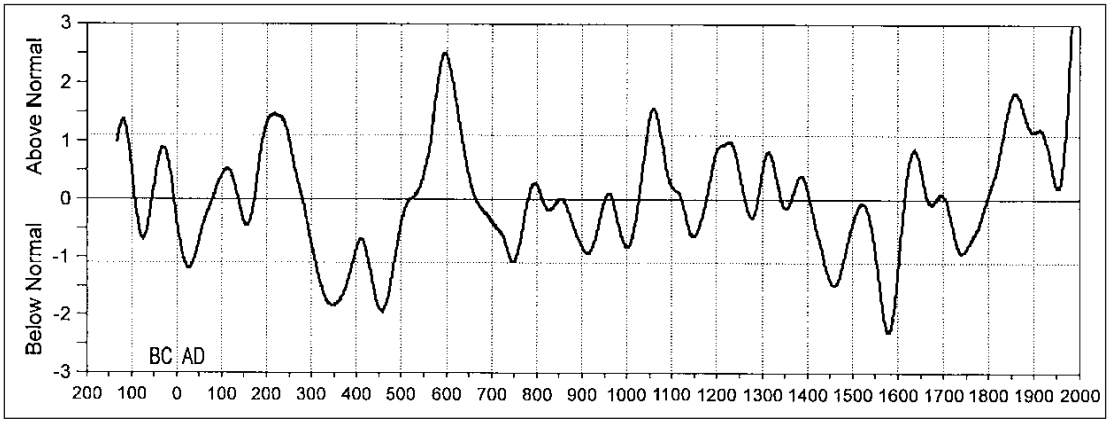


Figure 2.2.3-1. The reconstruction of total annual precipitation based on tree rings from Douglas fir and ponderosa pine in El Malpais (from Grissino-Mayer et al. 1997).

1901-2012 (historical range of variability (HRV)). Results for extreme climate were defined as experiencing either <5th percentile or >95th percentile climates relative to the HRV. The results for the extreme climate variables at El Malpais NM were as follows:

- Five temperature variables were "extreme warm" (annual mean temperature, minimum temperature of the coldest month, mean temperature of the driest quarter, mean temperature of the warmest quarter, and mean temperature of the coldest quarter);
- No temperature variables were "extreme cold;"
- No precipitation variables were "extreme dry;"
- No precipitation variables were "extreme wet" (brief can be accessed at (http://science.nature.nps.gov/climatechange/?tab=0&CEtab=3&PanelBrief3=open#PanelBrief).

The results for the temperature of each year between 1901-2012, the averaged temperatures over progressive 10-year intervals, and the average temperature of 2003-2012 (the most recent interval) are shown in Figure 2.2.3-2.

The results indicate that recent climate conditions have already begun shifting beyond the HRV, with the 2003-2012 decade representing the warmest decade on record. Garfin et al. (2014) expects more sustained extreme heat and fewer and less extreme cold periods. Overall, it's likely that future climate change will increasingly affect all aspects of park resources and operations (Monahan and Fisichelli 2014).

Geologic

Some cinder cone features in the park have been impacted by past cinder mining (KellerLynn 2012), and the NPS has adopted a social trail on the El Calderon cinder cone in order to prevent additional erosion (Weaver, personal communication, 2015). The McCartys cinder cone was used as a bombing target during World War II (KellerLynn 2012), and the potential exists for unexploded ordnance to still be found within the monument. Currently, a remedial investigation/feasibility study is underway (Bering Sea Environmental 2015).

Several geologic issues were identified in the Geologic Resources Inventory (KellerLynn 2012), including mass wasting, especially rockfall from the Zuni Sandstone at Sandstone

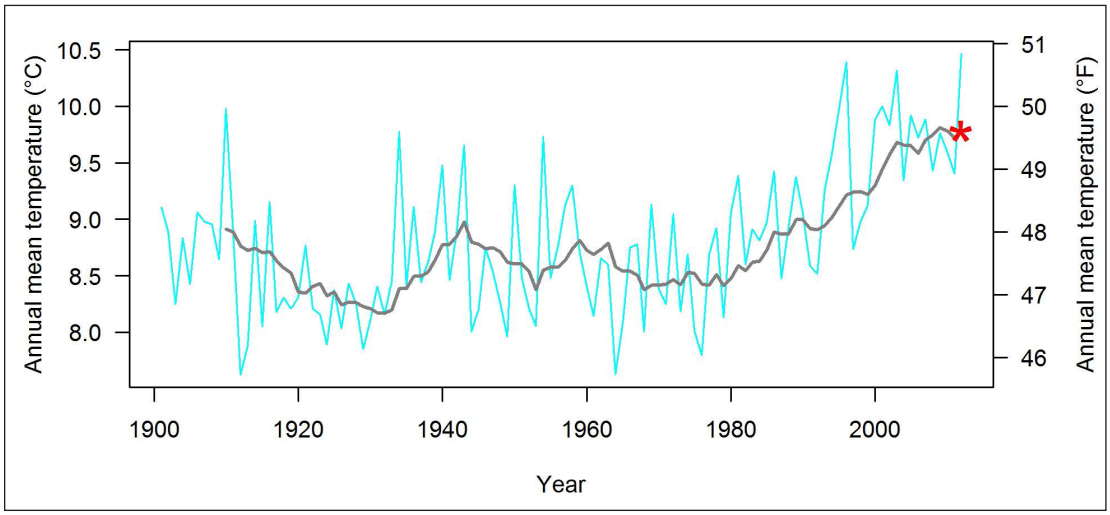


Figure 2.2.3-2. Time series used to characterize the historical range of variability and most recent percentile for annual mean temperature at El Malpais National Monument (including areas within 30-km [18.6-mi] of the park's boundary). The blue line shows temperature for each year, the gray line shows temperature averaged over progressive 10-year intervals (10-year moving windows), and the red asterisk shows the average temperature of the most recent 10-year moving window (2003–2012). The most recent percentile is calculated as the percentage of values on the gray line that fall below the red asterisk (Monahan and Fisichelli 2014).

Bluffs, arroyo formation, flooding, recent and potential volcanism, and seismic activity.

Walkup (2012) completed a draft report on volcanic resources/hazards report for El Malpais, which indicates that there may be localized potential hazards of ash/tephra fall, earthquakes, gas, lava eruptions, and volcanic projectiles. The Yellowstone Volcano Observatory is responsible for monitoring volcanic activity in the state of New Mexico (USGS 2013).

The El Malpais area is considered volcanologically active because it has had volcanic activity in the last 10,000 years. However, it is unlikely that any of the existing vents will erupt again because such basaltic vents usually erupt just once. The 2014 USGS Seismic Hazard Map for New Mexico indicates that there is the earthquake peak ground acceleration of between 10 and 14 g (percent of gravity) that has a 2% chance of being exceeded in 50 years (USGS 2015).

Cave and Cave Ice

The persistence of ice in caves at El Malpais is under threat due to climate change. While most, if not, all caves with perennial ice have a cold air trap that limits connectivity with the atmosphere (Weaver, personal communication, 2015), caves at El Malpais are shallow and will be impacted by surface temperatures. Monahan and Fisichelli (2014) report that five recent temperature variables for El Malpais were extreme warm, and no temperature variables were extreme cold.

Breakdown is a natural process that acts upon caves, and the entryways and floors of many of El Malpais caves are covered by breakdown. The ceilings of many of the lava tube caves are naturally highly fractured due to joints that formed during the cooling of the lava flow. Rock fall is therefore an inherent risk in lava tube caves.

Extirpated Species

There are several mammal species considered extirpated in the vicinity of El Malpais NM. One of these species, the Mexican gray wolf (*Canis lupus baileyi*), is discussed in the Mammal assessment of the NRCA; members of an experimental population in New Mexico and Arizona have been documented in the national monument in recent years. Other extirpated species include the black-footed ferret (*Mustela nigripes*), bison (*Bison bison*), bighorn sheep (*Ovis canadensis*), grizzly bear (*Ursus arctos*), and jaguar (*Panthera onca*).

The black-footed ferret was reported in the vicinity of the national monument by Hooper (1941), but the species is thought today to be extirpated near the park (Bogan et al. 2007). There were unsubstantiated reports of black-footed ferrets at the prairie dog town along NM-117 prior to the early 1990s, but Lightfoot et al. (1994) suggested the animals observed were misidentified. Frey and Yates (1996) reported that the last confirmed occurrence of the species in New Mexico was in 1934.

The bison does not appear on the master list of mammals for the national monument from Bogan et al. (2007). Both the State (NMDGF 2015b) and Frey and Yates (1996) list the species as extirpated, with the last confirmed occurrence of the bison in New Mexico being in 1884 (Frey and Yates 1996). Captive herds, however, have been reintroduced into the state (Frey and Yates 1996, NMDGF 2015b).

Bighorn sheep are known to have occurred in the national monument vicinity. They were generally extirpated in the state by around 1900-1903 due to disease, forage competition, and overhunting (Frey and Yates 1996, Windes 2008), but some may have survived into the 1950s in the lava fields of the national monument (Windes 2008) and some have been reintroduced in New Mexico in portions of their historic range (Frey and Yates 1996).

Bighorn sheep bone fragments have been discovered in a number of lava tube caves at the park. Windes (2008) wrote about a "series of features" in a lava tube believed to have been used to trap bighorn sheep (as early as the 900s and 1000s, and as late as the 1700s and later). The past occurrence of bighorn sheep at what is now El Malpais NM is also described in an oral history of the Elders of the Ramah Navajo tribe recorded by Douglas

Henio in 1992 (S. Baumann, El Malpais NM, pers. comm.).

The grizzly bear is considered unconfirmed for the park by Bogan et al. (2007). This species is noted as extirpated by both NMDGF (2015b) and Frey and Yates (1996). According to Frey and Yates (1996), its last confirmed occurrence in the state was in 1930.

The jaguar was last verified in the state around 1900-1905, but unconfirmed reports have been made in recent years (NMDGF 2015b). According to the U.S. Fish and Wildlife Service (2015a), the only New Mexico county in which the jaguar may occur is Hidalgo County (in the extreme southwest corner of the state).

Of the extirpated animal species discussed, bighorn sheep have been identified for reintroduction at the national monument (NPS 2014b). Other species for which there appears to be support for reintroduction are black-footed ferrets, bison, and Mexican gray wolves (NPS 2014a). Personnel at the national monument are currently working with the Bureau of Land Management (BLM) to evaluate the possibility of reintroducing black-footed ferrets into the park and the surrounding land administered by BLM (Eric Weaver, El Malpais NM, pers. comm.).

Bats

Bats in North America are being threatened by a recently-discovered disease known as White-nose syndrome (WNS). WNS affects hibernating bats and is named for the white fungus that grows on the muzzle and other parts of the body (USFWS 2014). It was first documented in New York in the winter of 2006-2007, and has since spread across the eastern and midwestern U.S. and eastern Canada. In the U.S., the occurrence of WNS has been confirmed in seven species of bats that hibernate in caves, and the fungus has been observed on an additional five species. Of these species, one from each group is known to occur at El Malpais NM. According to the USFWS (May 2015) map of occurrence, the closest state with confirmed cases of WNS is Arkansas, and the fungus (but no disease) was recently confirmed in Oklahoma (USFWS 2015b). Government agencies and non-governmental organizations are working together to study WNS in bats and develop ways to deal with the disease (USFWS 2014). Efforts are being made at El Malpais NM to look for the fungus in caves that show evidence of bat use (Northup 2013) and to look for evidence of the disease itself in bats (Valdez 2012). Results of these efforts are discussed in Chapter 4.

Vegetation

Personnel at the national monument have a goal of restoring some areas of shortgrass prairie that have been encroached by piñon-juniper woodland in recent years. Example areas that are in need of restoration are the El Calderon area and the vegetation extending north and south along the lava flow margin in the Lava Falls area (David Hays, former Natural Resources Branch Chief, El Malpais NM, pers. comm.).

Ancient Trees

Climate change from increased temperatures and drought may be threatening ancient trees in El Malpais. A 650-year-old Douglas fir nicknamed 'Yoda' died in 2014 (Fleck 2014) (Figure 2.2.3-3).



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Figure 2.2.3-3. Yoda an ancient Douglas-fir as seen on August 10, 2014. (Harley, pers. comm. 2015).

Exotic Plants
Vascular plant lists prepared for El Malpais National Monument (Lightfoot et al. 1994; Bleakly, 1997; NPS 2009; NPS 2014g,h and NPS 2015) and the El Malpais Vegetation Classification and Distribution Mapping Report (Muldavin et al. 2013) document the presence of exotic or non-native plants. While Muldavin et al. (2013) provides limited information on the occurrences of exotic plants at El Malpais, no studies or reports have focused exclusively on the condition of exotic plants throughout the park.

2.3. Resource Stewardship

2.3.1. Management Directives and Planning Guidance

In addition to NPS staff input based on the park's purpose, significance, and fundamental resources and values, and other potential resources/ecological drivers of interest, the NPS Washington (WASO) level programs guided the selection of key natural resources for this condition assessment. This included Southern Colorado Plateau Inventory and Monitoring (I&M) Network (SCPN) Program, I&M NPScape Program for landscape dynamics, Air Resources Division for air quality, and the Natural Sounds and Night Skies Program for the soundscape and night sky sections.

SCPN I&M Program
In an effort to improve overall national park management through expanded use of scientific knowledge, the I&M Program was established to collect, organize, and provide natural resource data as well as information derived from data through analysis, synthesis, and modeling (NPS 2011b). The primary goals of the I&M Program are to:

- inventory the natural resources under NPS stewardship to determine their nature and status;
- monitor park ecosystems to better understand their dynamic nature and condition and to provide reference points for comparisons with other altered environments;
- establish natural resource inventory and monitoring as a standard practice throughout the National Park System that transcends traditional program, activity, and funding boundaries;
- integrate natural resource inventory and monitoring information into NPS planning, management, and decision making; and
- share NPS accomplishments and information with other natural resource organizations and form partnerships for attaining common goals and objectives (NPS 2011b).

To facilitate this effort, 270 parks with significant natural resources were organized into 32 regional networks. El Malpais NM is part of the SCPN, which includes 18 additional parks. Through a rigorous multi-year, interdisciplinary scoping process, SCPN selected a number of important physical, chemical, and/or biological elements and processes for long-term monitoring. These ecosystem elements and processes are referred to as 'vital signs', and their respective monitoring programs are intended to provide high-quality, long-term information on the status and trends of those resources. El Malpais NM's upland ecosystems (i.e., vegetation and soils) and land surface phenology were selected for monitoring by SCPN (NPS SCPN 2015).

Park Planning Reports
Natural Resource Condition Assessments
The structural framework for NRCAs is based upon, but not restricted to, the fundamental and other important values identified in a park's Foundation Document or General Management Plan. NRCAs are designed to deliver current science-based information translated into resource condition findings for a subset of a park's natural resources. The NPS State of the Park (SotP) and Resource Stewardship Strategy (RSS) reports rely on credible information found in NRCAs as well as a variety of other sources (Figure 2.3.1-1).

Foundation Document
Foundation Documents describe a park's purpose and significance and identify fundamental and other important park resources and values. A Foundation Document was completed for El Malpais

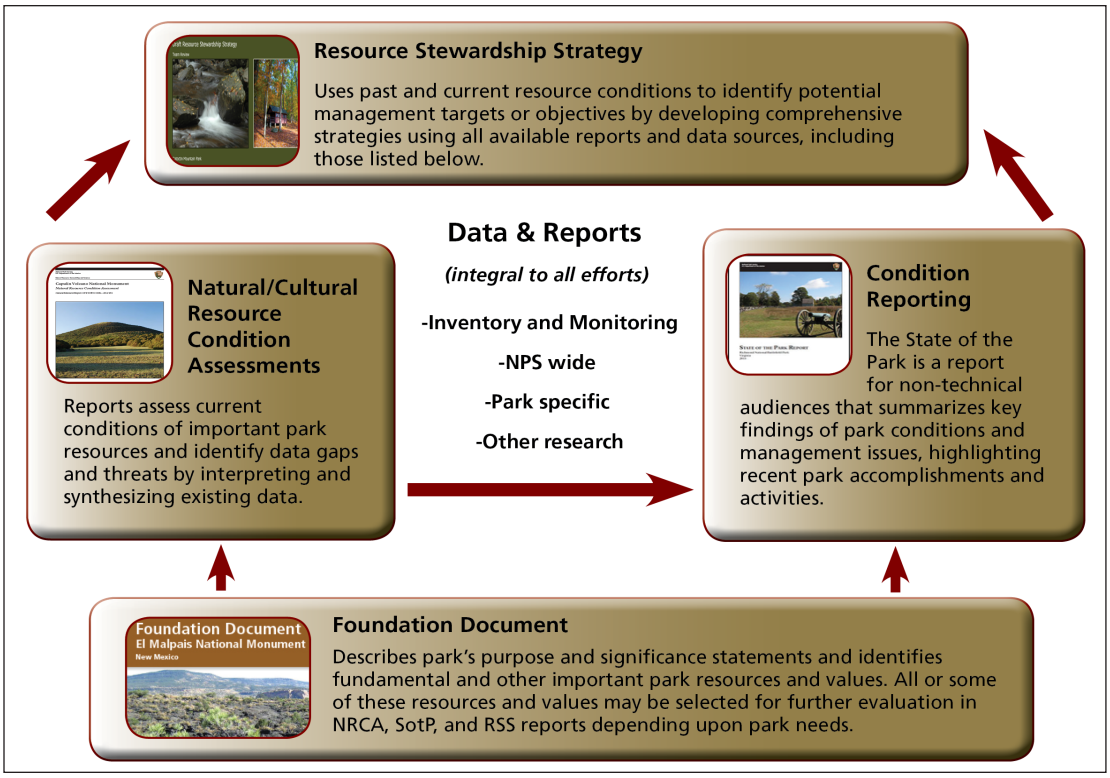


Figure 2.3.1-1. The diagram shows the relationship of NRCAs to other park planning reports.

NM in 2014 and was used to identify some of the primary natural features throughout the monument for the development of its NRCA, such as geology, caves and cave ice, and unique vegetation.

State of the Park

A State of the Park (SotP) report is intended for non-technical audiences and summarizes key findings of park conditions and management issues, highlighting recent park accomplishments and activities. NRCA condition findings are used in SotP reports, and Chapter 5 includes a SotP condition summary for the natural resources assessed in this NRCA.

Resource Stewardship Strategy

A Resource Stewardship Strategy (RSS) uses past and current resource conditions to identify potential management targets or objectives by developing comprehensive strategies using all available reports and data sources including NRCAs. National Parks are encouraged to develop an RSS as part of the park management planning process. Indicators of resource condition, both natural and cultural, are selected by the park. After each indicator is chosen, a target value is determined and the current condition is compared to the desired condition. An RSS has not yet been started for the monument.

2.3.2. Status of Supporting Science

Available data and reports varied significantly depending upon the resource topic. The existing data used to assess condition of each indicator and/or to develop reference conditions are described in each of the Chapter 4 assessments. In addition to data from the SCPN I&M and research conducted by other scientists and programs, subject matter expert, Dr. William H. Romme, Professor emeritus of fire ecology and senior research scientist in the Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, CO provided technical assistance pertaining to the monument's vegetation and fire ecology during a June 2015 field assessment.

Additional Washington level programs, including I&M NPScape, Climate Change Response Program, Natural Sounds and Night Skies, Air Resources, and the Geologic Resources Divisions provided a wealth of information for the monument's condition assessments.

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NPS

Sandstone Bluffs overlook at El Malpais National Monument.

Chapter 3: Study Scoping and Design

This NRCA is a collaborative project between the El Malpais and El Morro NMs staff, SCPN staff, Intermountain Region, and cooperators from Utah State University, University of West Florida, and Northern Rockies Conservation Cooperative. The cooperative agreements were established through the Colorado Plateau and the Gulf Coast Cooperative Ecosystem Studies Units.

The purpose of the condition assessment is to provide a "snapshot-in-time" evaluation of the condition of a select set of national monument natural resources that were chosen by the project team during the November 4-5, 2014 scoping meeting. Condition findings will aid national monument staff in the following objectives:

- Develop near-term management priorities
- Engage in watershed or landscape scale partnership and education efforts
- Conduct park planning (e.g., compliance, Resource Stewardship Strategy, and resource management plans).

3.1. Preliminary Scoping

The approach we used to select natural resources was to assess the fundamental and important values of the national monument by listing the resources identified in its Foundation document (NPS 2014). We then refined this list of resources during our scoping meeting discussions (for a complete list of team members, please refer to Appendix A). The resources assessed were limited to natural-based topics, but cultural resources were taken into consideration within the context of the natural resources where appropriate.

The discussions focused on:

1. Confirming the purpose of the national monument and its related significance statements and values as they related to each of the chosen NRCA topics
2. Identifying important concerns and issues for each topic
3. Identifying data sources and gaps for each natural resource topic chosen.

Certain constraints are placed on NRCAs, including the following:

- Condition assessments are conducted using existing data and information.
- Identification of data needs and gaps is driven by the resources chosen.

Specific project expectations and outcomes included the following:

- For chosen natural resources, consolidate available national monument data, reports, and geospatial information from appropriate sources including national monument resource staff, scientific literature, the NPS Data Store and NPSpecies, which are both part of the Integrated Resource Management Applications (IRMA),, SCPN Inventory and Monitoring data, and available third-party sources.
- Enlist the help of subject matter experts for each resource topic when appropriate and feasible (refer to Appendix A for subject matter expert list).
- Define an appropriate description of reference conditions for each of the natural resource topics and indicators so statements of current condition can be developed for the NRCA report.
- Where applicable, develop GIS products and graphic illustrations that provide spatial representation of resource data, ecological processes, resource stressors, trends, or other valuable information that can be better interpreted visually.
- Conduct analysis of specific existing datasets about key natural resource indicators.
- Discuss the issue of natural resource indicators that are not contained within the national monument or controlled directly by national monument management activities (e.g., viewshed condition). These can represent stressors that impact natural resource components in the national monument but are not under NPS jurisdiction.

National monument and natural resource management staff participated in on-site meetings and reviewed interim and final products. National monument staff, I&M staff, and writer/editors data mined information for each of the resource topics.

3.2. Study Design

3.2.1. Indicator Framework, Focal Study Resources and Indicators

The national monument's NRCA utilizes an assessment framework adapted from "The State of the Nation's Ecosystems 2008: Measuring the Lands, Waters, and Living Resources of the United States", by the H. John Heinz III Center for Science, Economics and the Environment. This framework was endorsed by the National NRCA Program as an appropriate framework for listing resource components, indicators/measures, and resource conditions.

Each NRCA project represents a unique assessment of key natural resource topics that are important to the specific park that is being assessed. For the purposes of this NRCA, 16 key national monument resources were chosen for assessment and are listed in Table 3.2.1-1. This list of focal study resources is not all inclusive of every natural resource at the national monument, but includes natural resources and processes that were of greatest significance for park staff at the time of this assessment. The framework table also shows the topics where we included landscape-level data from the National Park Service Inventory and Monitoring NPScape Program and/or climate data from various sources. NPScape is a landscape dynamics monitoring project that provides datasets and information to help characterize these landscape-scale factors relevant to park resources (Monahan et al. 2012). For some of the natural resource condition assessments, the landscape-level or climate data will be used as indicators and/or measures and sometimes as discussion points only. Landscape-level and climate data will also be incorporated into NRCA Chapters 2 (park setting) and 5 (management considerations).

Reference conditions were identified with the intent of providing a benchmark to which the current condition of each indicator/measure could be compared. Attempts were made to utilize existing research and documentation to identify reference conditions; however, many of the indicators lack a quantifiable reference condition according to literature and data

Table 3.2.1-1. El Malpais National Monument NRCA Framework.

Natural Resources	Indicators	Measures
I. Landscape-scale		
Viewshed	• Scenic and Historic Integrity	• Intactness of View • Conspicuousness of Non-contributing Features
Night Sky	• Sky Brightness	• All-sky Light Pollution Ratio • Maximum Vertical Illuminance • Horizontal Illuminance • Zenith Sky Brightness
	• Sky Quality	• Bortle Dark Sky Scale
Soundscape	• Sound Level	• % Time Above Reference Sound Levels • L_{50} Impact
II. Supporting Environment		
Air Quality	• Visibility	• Haze Index
	• Ozone	• Human Health • Vegetation Health
	• Wet Deposition	• Total Nitrogen • Total Sulfur • Mercury • Predicted Methylmercury Concentration
Surface Geology	• Surface Lava Flow Features	• Lava Flow Intactness
	• Vents and Edifices	• Vents and Edifices Intactness
	• Disturbed Lands	• Abandoned Mineral Lands Priority Ranking
	• Paleontological Resources	• Freeze / Thaw Impact • Human Impact
Caves and Cave Ice	• Cave Meteorology	• Temperature • Humidity
	• Perennial and Seasonal Ice	• Presence / Absence
	• Direct Visitor Impacts	• Degree of Impact
	• Stability - Breakdown	• No Measure
	• Rare Minerals	• No Measure
Tinajas	• Climate Variables	• Amount of Precipitation • Reconnaissance Drought Index
III. Biological Integrity		
Vegetation		
Piñon-Juniper	• Is species presence & distribution consistent with conditions and within natural range of variability? • Are stand densities within their range of natural variability for their growing conditions? • Are age class distributions of trees consistent with expected range of variability? • Do the trees and understory plants appear vigorous and healthy? • Are ecological processes (e.g., fire) operating within natural range of variability? • Are the current levels of insects / disease within the normal range?	
Ponderosa Pine	• Is species presence & distribution within natural range of variability? • Are stand densities within their range of natural variability for their growing conditions? • Are age class distributions of trees consistent with expected range of variability? • Do the trees and understory plants appear vigorous and healthy? • Are ecological processes (e.g., fire) operating within natural range of variability? • Are the current levels of insects / disease within the normal range?	
Distinct Vegetation Communities	• Ecological Integrity	• No Measures

Table 3.2.1-1. El Malpais National Monument NRCA Framework (continued).

Natural Resources	Indicators	Measures
Grasslands and Shrublands	• Soil / Site Stability	• Soil Cover • Biological Soil Crust
	• Biotic Integrity	• Landscape-scale Diversity • Local Species Composition • General Life Cycles / Disturbance • Proportion of Functional Groups • Proportion of C3 and C4 Species
Exotic Plants	• Potential to Alter Native Plant Communities	• Significance of Exotic Plant Impact
	• Prevalence of Exotic Plants	• Number in Vegetation Plots
Wildlife		
Cave Ecology and Species	• Cave-dependent Species	• Invertebrates • Cave Entrance Flora
Mammals	• Species Occurrence	• Presence / Absence
Bats	• Species Occurrence	• Presence / Absence
	• White-nose Syndrome/Fungus	• Presence / Absence
	• Habitat Availability / Condition	• Free from / with Minimal Human Disturbance
Birds	• Species Occurrence	• Presence / Absence
Herpetofauna	• Species Occurrence	• Presence / Absence

reviewed for this project. When a quantifiable reference condition for a given resource was not feasible, an attempt was made to include a qualitative reference to provide some context for interpreting current condition.

3.2.2. Reporting Areas

National Monument

The primary focus of the reporting areas for the NRCA was within the national monument's authorized boundary (114,106 acres/46.172 ha 84.8% of which is a recommended wilderness area) (NPS 2014). However, while no evaluation of condition was made of non-NPS lands, some of the analyses encompassed areas beyond the monument's boundary.

Landscape-scale

As described in Chapter 2, the area within 30-km (18.6 mi) of the monument's boundary plus the area within the park was examined for selected resources to provide an ecological, landscape-scale context unless otherwise noted (NPS 2011).

3.2.3. General Approach and Methods

This study involved reviewing existing literature and data for each of the resources listed, and, where appropriate, analyzing the data to provide summaries or to create new spatial representations. After gathering data regarding current condition of indicators and measures, a quantitative or qualitative statement was developed comparing the current condition(s) at the national monument to the reference condition(s).

Data Mining

Data and literature were found in multiple forms: NPS reports and monitoring plans, other reports from various state and federal agencies, published and unpublished research documents, databases, and tabular data. Geospatial data were provided by the national monument and Laura Trader, Fire Ecologist at Bandelier National Monument. Data and literature acquired throughout the data mining process were analyzed for thoroughness, relevancy, and quality. All reasonably accessible and relevant data were used to conduct assessments. Copies of all reports and datasets referenced will be provided to national monument staff on a DVD.

Subject Matter Experts

Subject matter experts were consulted while developing this assessment. Consultations

ranged from on-site visits to personal communication, and reviews of resource assessment sections.

Data Analyses and Development

Data analyses and methodology for each resource condition assessment can be found within each section of Chapter 4.

Geographic Information System (GIS) technology was utilized to graphically depict the status and distribution of information when possible.

Final Assessments

Assessments were finalized after incorporating comments from national monument staff, SCPN staff, and subject matter experts. The final assessments represent the most relevant and timely data available for each resource topic based on the recommendations and insight provided by national monument staff, researchers, subject matter experts, and assessment writers.

Indicator/Measures Assessment Format

Indicator assessments are presented in a standard format that is consistent with *State of the Park* reporting (NPS 2012). The major components are as follows:

The condition/trend/level of confidence graphic provides a visual representation for each resource indicator and is intended to give readers a quick interpretation of the authors' assessments of condition. The level of confidence ranges from high-low and indicates how confident we are with the data used to determine condition. The written statements of condition, located under the "*Condition and Trend*" heading within each resource topic section in Chapter 4, provides a more in-depth description of each indicator and associated measure(s)' condition. Figure 3.2.3-1 shows the condition/trend/confidence level scorecard used to describe the condition for each assessment.

Circle colors provide indication of condition based upon the chosen indicators/measures and reference conditions. Red circles signify that a resource is of significant concern; yellow circles signify that a resource is in moderate condition; and green circles denote that an indicator and/or measure is in good condition. A circle without any color, which is almost always associated with the low confidence symbol-dashed line, signifies that there is insufficient information to make a statement about condition; therefore, condition is unknown.

We include an indicator condition and overall rationale summary table at the end of each resource topic's section to convey the relevancy of each measure to the overall condition interpretation.

Arrows inside the circles signify the trend of the indicator/measure condition. An upward pointing arrow signifies that the indicator is improving; double pointing arrows signify

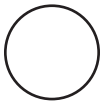
Condition Status		Trend in Condition		Confidence in Assessment	
	Warrants Significant Concern		Condition is Improving		High
	Warrants Moderate Concern		Condition is Unchanging		Medium
	Resource is in Good Condition		Condition is Deteriorating		Low
	An open (uncolored) circle indicates that current condition is unknown or indeterminate; this condition status is typically associated with unknown trend and low confidence.				

Figure 3.2.3-1. Condition, trend, and level of confidence key used in the NRCA.



Figure 3.2.3-2. An example of a good condition, unchanging trend, and high confidence level in the assessment graphic used in NRCAs.

that the indicator's condition is currently unchanging; a downward pointing arrow indicates that the indicator's condition is deteriorating. No arrow denotes that the trend of the indicator's condition is currently unknown. Figure 3.2.3-2 is an example of a final condition graphic used in the indicator assessments.

An Overview of NRCA Chapter 4

Background and Importance

This section of the NRCA report provides information regarding the relevance of the resource to the national monument. This section also explains the characteristics of the resource to help the reader understand context.

Data and Methods

The indicators/measures are listed in this section describing how we quantitatively or qualitatively assessed the natural resource condition. This section summarizes the existing datasets and methodology used for evaluating the indicators/measures for condition.

Reference Conditions

This section explains the reference conditions that were used to evaluate the current condition for each indicator and measure. Additionally, explanations of available data and literature that describe the reference conditions are located in this section.

Condition and Trend

This section provides a discussion of the condition and trend for each indicator/measure based on the assessment approach. The condition for each indicator/measure is listed in a summary table at the end of this section to provide a summary. The level of confidence and key uncertainties are also included in this section providing a summary of the data gaps and uncertainties relative to the condition assessment.

Sources of Expertise

Individuals who were consulted for the focal study resources are listed in this section. A short paragraph describing their background is also included.

Literature Cited

This section lists all of the referenced sources for the assessment. A DVD is included in the final report with copies of all literature cited unless the citation was from a book. When possible, links to websites are also included.

3.3. Literature Cited

Coggins, G.C. 1987. Protecting the wildlife resources of national parks from external threats. Land and Water Law Review, 22, 1-27 as cited in Monahan et al. 2012.

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Chapter 4: Natural Resource Conditions

In Chapter 4 we present the background and importance, data and methods, and condition and trend for each focal study resource that was assessed for the park. A list of page numbers where each measure is first presented is in Table 4.1.

Table 4.1. El Malpais National Monument NRCA Indicators and Measures.

Natural Resources	Indicators	Measures	Page
I. Landscape-scale			
Viewshed	• Scenic and Historic Integrity	• Intactness of View	49
		• Conspicuousness of Non-contributing Features	50
Night Sky	• Sky Brightness	• All-sky Light Pollution Ratio	67
		• Maximum Vertical Illuminance	67
		• Horizontal Illuminance	67
		• Zenith Sky Brightness	67
	• Sky Quality	• Bortle Dark Sky Scale	68
Soundscape	• Sound Level	• % Time Above Reference Sound Levels	79
		• L_{50} Impact	79
II. Supporting Environment			
Air Quality	• Visibility	• Haze Index	90
	• Ozone	• Human Health	90
		• Vegetation Health	91
	• Wet Deposition	• Total Nitrogen	91
		• Total Sulfur	91
		• Mercury	91
		• Predicted Methylmercury Concentration	91
Surface Geology	• Surface Lava Flow Features	• Lava Flow Intactness	107
	• Vents and Edifices	• Vents and Edifices Intactness	107
	• Disturbed Lands	• Abandoned Mineral Lands Priority Ranking	109
	• Paleontological Resources	• Freeze / Thaw Impact	110
		• Human Impact	111
Caves and Cave Ice	• Cave Meteorology	• Temperature	122
		• Humidity	122
	• Perennial and Seasonal Ice	• Presence / Absence	123
	• Direct Visitor Impacts	• Degree of Impact	125
	• Stability - Breakdown	• No Measure	125
	• Rare Minerals	• No Measure	126
Tinajas	• Climate Variables	• Amount of Precipitation	136
		• Reconnaissance Drought Index	136

Natural Resources	Indicators	Measures	Page
III. Biological Integrity			
Vegetation			
Piñon-Juniper	• Is species presence & distribution consistent with conditions and within natural range of variability? • Are stand densities within their range of natural variability for their growing conditions? • Are age class distributions of trees consistent with expected range of variability? • Do the trees and understory plants appear vigorous and healthy? • Are ecological processes (e.g., fire) operating within natural range of variability? • Are the current levels of insects / disease within the normal range?		143
Ponderosa Pine	• Is species presence & distribution within natural range of variability? • Are stand densities within their range of natural variability for their growing conditions? • Are age class distributions of trees consistent with expected range of variability? • Do the trees and understory plants appear vigorous and healthy? • Are ecological processes (e.g., fire) operating within natural range of variability? • Are the current levels of insects / disease within the normal range?		161
Grasslands and Shrublands	• Soil / Site Stability	• Soil Cover • Biological Soil Crust	182-183 183
	• Biotic Integrity	• Landscape-scale Diversity • Local Species Composition • General Life Cycles / Disturbance • Proportion of Functional Groups • Proportion of C3 and C4 Species	184 184 184 184-185 185
Distinct Vegetation Communities	• Ecological Integrity	• No Measure	202
Exotic Plants	• Potential to Alter Native Plant Communities	• Significance of Exotic Plant Impact	212
	• Prevalence of Exotic Plants	• Number in Vegetation Plots	215
Wildlife			
Cave Ecology and Species	• Cave-dependent Species	• Invertebrates • Cave Entrance Flora	227 228
Mammals	• Species Occurrence	• Presence / Absence	234
Bats	• Species Occurrence	• Presence / Absence	244
	• White-nose Syndrome/Fungus	• Presence / Absence	245
	• Habitat Availability / Condition	• Free from / with Minimal Human Disturbance	247
Birds	• Species Occurrence	• Presence / Absence	260
Herpetofauna	• Species Occurrence	• Presence / Absence	274

4.1. Viewshed

Indicators/Measures

- Scenic and Historic Integrity (2 measures)

Condition – Trend – Confidence



Good – Insufficient Data – High

4.1.1. Background and Importance

The conservation of scenery is established in the National Park Service (NPS) Organic Act ("… to conserve the scenery and the wildlife therein…"), reaffirmed by the General Authorities Act, as amended, and addressed generally in the NPS Management Policies (Section 1.4.6 and 4.0; Johnson et al. 2008). Although no management policy currently exists exclusively for scenic or viewshed management and preservation, parks are still required to protect scenic and viewshed quality as one of their most fundamental resources. According to Wondrak-Biel (2005), aesthetic conservation, interchangeably used with scenic preservation, has been practiced in the NPS since the early twentieth century. Aesthetic conservation strove to protect scenic beauty for park visitors to better experience the values of the park. The need for scenic preservation management is as relevant today as ever, particularly with the pervasive development pressures that challenge park stewards to conserve scenery today and for future generations.

El Malpais NM (Figure 4.1.1-1) was established to preserve, protect, and interpret natural and cultural resources that are an integral part of the volcanic wilderness, including the Grants Lava Flow and Chacoan great house community of Las Ventanas (NPS 2014a). Within park boundaries are: a number of young and old lava flows and associated geological features, such as one of the longest lava tube systems in the world; several vegetative communities, including uncommon vegetation associations, unusual growth forms, and undisturbed plant communities; a vast area that meets criteria for designation as wilderness; a diversity of native wildlife; and a cultural landscape that includes ancient and historic trail networks, basalt architecture, ritual landscapes, and



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Figure 4.1.1-1. View to the south from the Sandstone Bluffs overlook at El Malpais NM.

the Chacoan great house community of Las Ventanas (NPS 2014a). The Pueblos of Zuni, Acoma, and Laguna, and the Ramah Navajo, consider El Malpais an important part of their history and culture. Spanish and Anglo cultures also played a role in the history of the national monument.

One landscape feature outside of the national monument, Mt. Taylor, which can be seen from various locations within the park, is both a conspicuous part of the scenery and a sacred landscape to a number of Native American cultures in the area (Benedict and Hudson 2008). Mt. Taylor, which reaches 11,301 ft (3,445 m) in elevation at its summit, and the San Mateo mountains, are situated to the northeast of the national monument. The ability to view the mountain from a distance and the abundant natural resources associated with it and the San Mateo mountains have drawn people to the area for hundreds of years (Benedict and Hudson 2008). The area continues to be of great importance to many tribes in an historical, cultural, and religious context. [Note that Mt. Taylor can be seen in the first panorama in Figure 4.1.4-3 in the Condition section of this assessment].

Visitor Experience

Inherent in virtually every aspect of this assessment is how features on the visible landscape influence the enjoyment, appreciation, and understanding of the national monument by visitors. The indicators we use for condition of the viewshed are based on studies related to perceptions people hold toward various features and attributes of the viewsheds. We also focus on how the historic integrity of the viewshed enhances the opportunity for visitors to better understand the historical and cultural significance of the area that includes present day El Malpais NM.

From a cultural and historical perspective, the views are not just about the scenery, but an important way to better understand the connection between natural and cultural resources at El Malpais NM. Visualizing this connection as part of the landscape is a critical part of the visitor experience.

4.1.2. Data and Methods

Viewsheds are considered in this assessment within two interrelated contexts: natural scenic integrity and historic integrity. Impacts that degrade one aspect likely degrade the other as well. For example, modern structures or roadways visible on the landscape may detract from the natural scenic integrity of the viewshed, as well as the sense of place that a historically authentic landscape evokes. Depending on the context, scenic and historic integrity may be distinct, or there may be so little practical difference that they are the same. We qualitatively assess how features on the landscape contribute (or not) to the scenic and historic integrity of the site.

Indicator

Scenic and Historic Integrity

The overall indicator of viewshed condition we use in this assessment is a combination of scenic and historic integrity. For this overall indictor we used two measures (intactness and conspicuousness) from key vantage points (Table 4.1.2-1). Each of these measures is described in greater detail below.

Scenic integrity is defined as the state of naturalness or, conversely, the state of

Table 4.1.2-1. Indicators and measures of viewshed and why they are important to the resource condition.

Indicators of Condition	Measures	Why are these indicators/measures important to resource condition?
Scenic and Historic Integrity	Intactness of View	Intactness represents how much the viewshed has been altered from its reference state, which in turn influences scenic quality as well as the sense of place in a natural and historic context.
	Conspicuousness of non-contributing features	Non-contributing features that are more conspicuous tend to detract more from the scenic quality and/or the sense of place in an historic context.

disturbance created by human activities or alteration (U.S. Forest Service [USFS] 1995). This focuses on the features of the landscape related to non-contributing human alteration.

Historic integrity is the authenticity of a site's historic identity, evidenced by the survival of physical characteristics that existed during its historic period. Historic integrity is based on those features of the cultural and natural landscape, from the perspective of an observer, that contribute to the sense of place and enhance the visitor experience. In this assessment, we focus on those features that have a visual impact and contribute to the story of El Malpais NM. We evaluate features as contributing (i.e., enhancing the scenic and historic features of the landscape) or noncontributing (i.e., detracting from the scenic and historic integrity).

We assess scenic and historic integrity by evaluating specific human-made features that can be seen from key vantage points and whether or not those features are contributing or noncontributing to the scenic and historic integrity of the view. For noncontributing features, we further assess the characteristics that make them more or less conspicuous, which influences the level of impact they have. We then supplement this assessment with a GIS-based analysis showing areas that are visible from key vantage points. The GIS analysis provides spatial orientation of housing and road developments that may impact the quality of the viewshed.

Viewshed Vantage Points

For this assessment, we focused primarily on the landscape views visitors are most likely to experience. The vantage points we used (chosen by the park) were the El Calderon cinder cone, Sandstone Bluffs overlook, and Bandera Volcano (on private property, but providing a view of the park; Figure 4.1.2-1). These views are generally the highest, most accessible overlooks within the national monument, receive high visitation, and represent the points from which most visitors view the surrounding landscape. As such, these views play a major role in how visitors perceive El Malpais NM within the context of its surrounding landscape. The Bandera Volcano (or Crater) vantage point is located at Bandera Volcano and Ice Cave, a private tourist attraction.

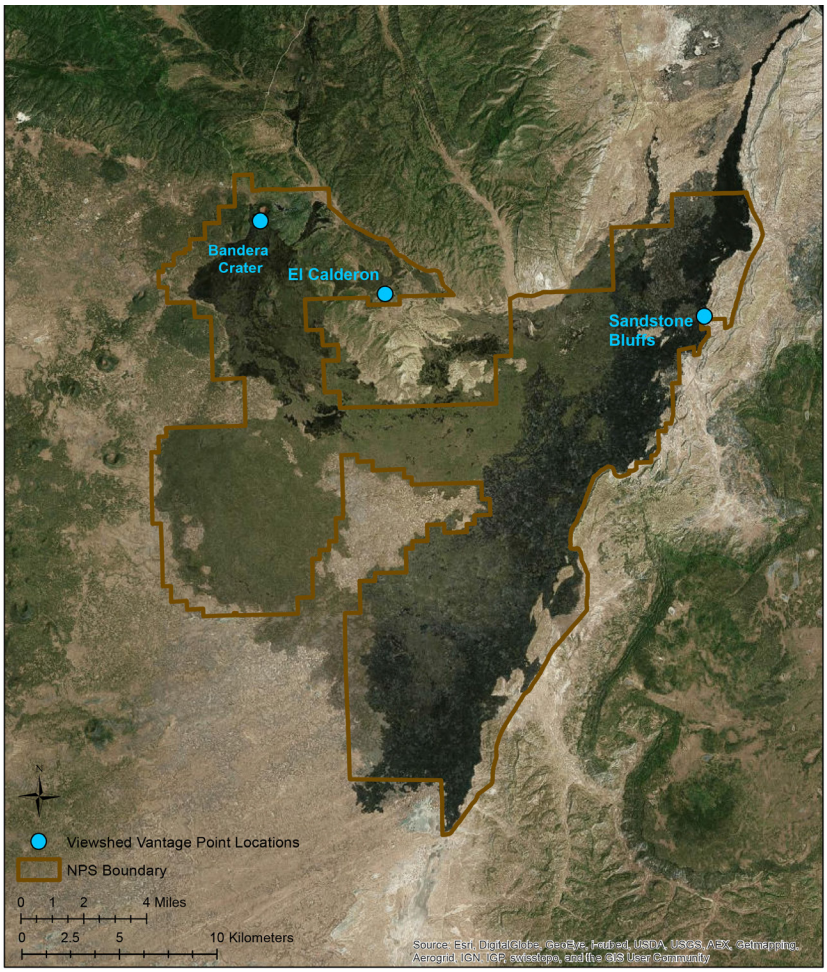


Figure 4.1.2-1. The location of the vantage points used in this assessment.

Measure
Intactness of View

The extent of intactness provides a measure of the degree to which the viewshed is unaltered from its original (reference) state, particularly the extent to which intrusive or disruptive elements may diminish the character of the scene (USFS 1995, Johnson et al. 2008).

We used a series of panoramic images to portray the viewshed from an observer's perspective. These images were taken using a Canon PowerShot digital camera and the GigaPan Epic 100 system, a robotic camera mount coupled with stitching software (Figure 4.1.2-2). A series of images are automatically captured and the individual photographs



Figure 4.1.2-2. The GigaPan system takes a series of images that are stitched together to create a single panoramic image.

are stitched into a single high-resolution panoramic image. These photographs provided a means of illustrating the features on the landscape related to viewshed integrity.

We recognize that visitor perceptions of an altered landscape are highly subjective, and there is no completely objective way to measure this. Research has shown, however, that there are certain landscape types and characteristics that people tend to prefer over others. In general, there is a wealth of research demonstrating that people tend to prefer natural over human-modified landscapes (Zube et al. 1982, Kaplan and Kaplan 1989, Sheppard 2001, Kearny et al. 2008, Han 2010). Human-altered components of the landscape (e.g., roads, buildings, powerlines, and other features) that do not contribute to the scenic or historic context are often perceived as detracting from the scenic and historic character of the viewshed.

Despite this generalization for natural landscape preferences, studies have also shown that not all human-made structures or features have the same impact on visitor preferences. Visitor preferences can be influenced by a variety of factors including cultural background, familiarity with the landscape, and their environmental values (Kaplan and Kaplan 1989, Virden and Walker 1999, Kaltenborn and Bjerke 2002, Kearney et al. 2008).

Measure

Conspicuousness of Noncontributing Features

Substantial research has demonstrated that human-made features on a landscape are perceived more positively when they are considered in harmony with the landscape (e.g., Kaplan and Kaplan 1989, Gobster 1999, Kearney et al. 2008). For example, Kearney et al. (2008) showed that survey respondents tended to prefer development that blended with the natural setting through use of colors, smaller scale, and vegetative screening. For this measure, we focused on four characteristics, or groups of characteristics, that have been demonstrated to contribute to the conspicuousness of man-made features: (1) distance from a given vantage point, (2) size, (3) color and shape, and (4) movement and noise. A general relationship between these characteristics and their influence on conspicuousness is presented in Table 4.1.2-2, and more detailed descriptions of these human-made features are presented below.

Table 4.1.2-2. Characteristics that influence how conspicuous human-made features are within a viewshed and the general effect.

Characteristic	Less Conspicuous	More Conspicuous
Distance	Distant from the vantage point	Close to the vantage point
Size	Small relative to the landscape	Large relative to the landscape
Color and Shape	Colors and shapes that blend into the landscape	Colors and shapes that contrast with the landscape
Movement and Noise	Lacking movement or noise	Exhibits obvious movement or noise



Figure 4.1.2-3. An example of approximate distance classes used in this assessment.

Distance. The impact that individual human-made features have on perception is substantially influenced by the distance from the observer to the feature(s). Viewshed assessments using distance zones or classes often define three classes: foreground, middle ground, and background (Figure 4.1.2-3). For this assessment, we have used the distance classes that have been used recently by the National Park Service:

- *Foreground* = 0-½ mile from vantage point
- *Middle ground* = ½-3 miles from vantage point
- *Background* = 3-60 miles from vantage point.

Over time, different agencies have adopted minor variations in the different specific distances used to define these zones, but the overall logic and intent has been consistent.

The foreground is the zone where visitors should be able to distinguish variation in texture and color, such as the relatively subtle variation among vegetation patches, or some level of distinguishing clusters of tree boughs. Large birds and mammals would likely be visible throughout this distance class, as would small or medium-sized animals at the closer end of this distance class (USFS 1995). Within the middle ground there is often sufficient texture or color to distinguish individual trees or other large plants (USFS 1995). It is also possible to distinguish larger patches within major plant community types (such as riparian areas), provided there is sufficient difference in color shades at the farther distance. Within the closer portion of this distance class, it still may be possible to see large birds when contrasted against the sky, but other wildlife would be difficult to see without the aid of binoculars or telescopes. The background distance class is where texture tends to disappear and colors flatten. Depending on the actual distance, it is sometimes possible to distinguish among major vegetation types with highly contrasting colors (for example, forest and grassland), but any subtle differences within these broad land cover classes would not be apparent without the use of binoculars or telescopes, and even then may be difficult.

Size

Size is another characteristic that may influence how conspicuously a given feature dominates the landscape, and how it is perceived. For example, Kearney et al. (2008) found human preferences were lower for human-made developments that tended to dominate the view, such as large, multi-storied buildings, and were more favorable toward smaller, single-family dwellings. In another study, Brush and Palmer (1979) found that farms tended to be viewed more favorably than views of towns or industrial sites, which

Table 4.1.2-3. A matrix describing the six size classes used for visible human-made features.

	Low Volume	Substantial Volume
Low Height	Single family dwelling (home, ranch house)	Small towns, complexes
Substantial Height	Radio and cell phone towers	Wind farms, oil derecks
Substantial Length	Small roads, wooden power lines, fence lines	Utility corridors, highways, railroads

ranked very low on visual preference. This is consistent with other studies that have reported rural family dwellings, such as farms or ranches, as quaint and contributing to rural character (Schauman 1979, Sheppard 2001, Ryan 2006), or as symbolizing good stewardship (Sheppard 2001).

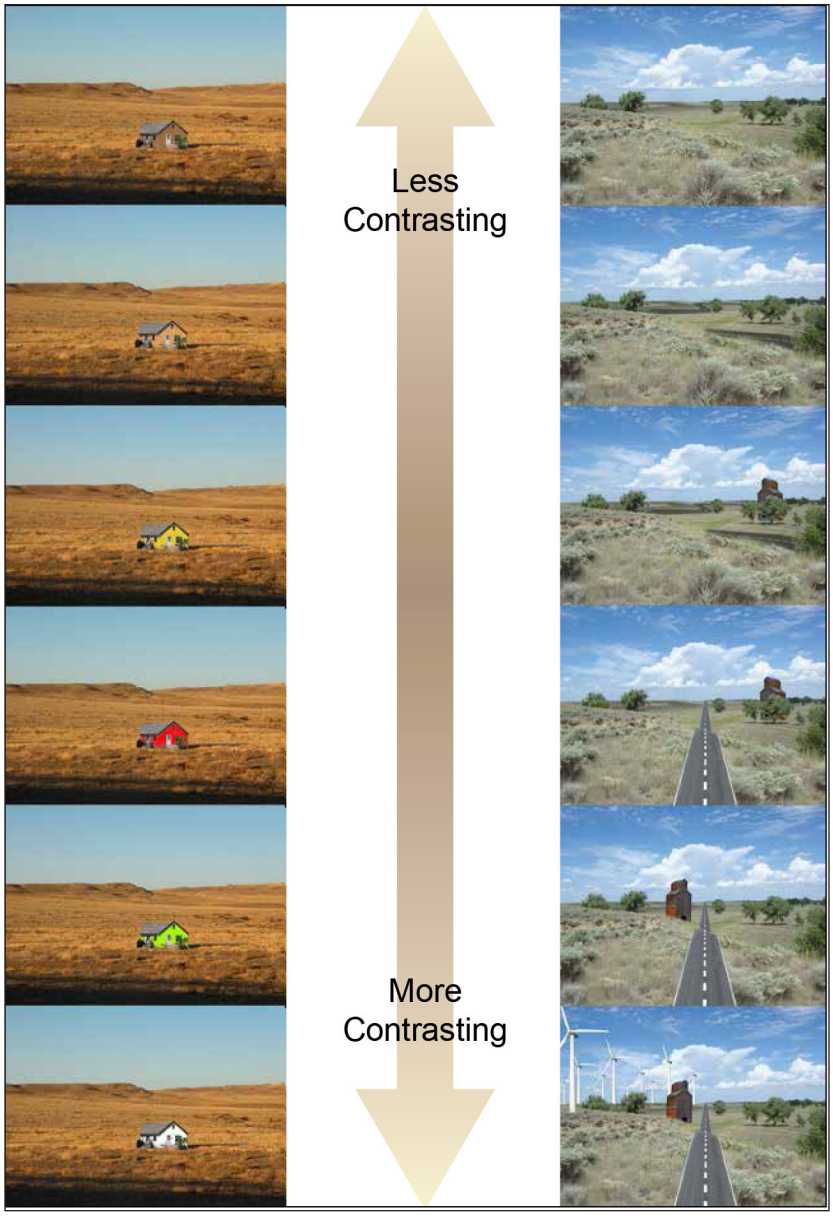


Figure 4.1.2-4. Graphic illustration of how color (left) and shape (right) can influence whether features are in harmony with the environment, or are in contrast. Figure Source: NPS-Rob Bennetts

We considered the human-made features on the landscape surrounding El Malpais NM as belonging to one of six size classes (Table 4.1.2-3), which reflect the preference groups reported by studies. Using some categories of perhaps mixed measures, we considered size classes within the context of height, volume, and length.

Color and Shape

Studies have shown that how people perceive a human-made feature in a rural scene depends greatly on how well it seems to fit or blend in with the environment (Kearney et al. 2008, Ryan 2006). For example, Kearney et al. (2008) found preferences for homes that exhibit lower contrast with their surroundings as a result of color, screening vegetation, or other blending factors (see Figure 4.1.2-4). It has been shown that colors lighter in tone or higher in saturation relative to their surroundings have a tendency to attract attention (contrast with their surroundings), whereas darker colors (relative to their surroundings) tend to fade into the background (Ratcliff 1972, O'Connor 2008). This is consistent with the findings of Kearney et al. (2008), who found that darker color was one of the factors contributing to a feature blending in with its environment and therefore being preferred. Some research has indicated that color can be used to offset other factors, such as size, that may evoke a more negative perception (O'Connor 2009). Similarly, shapes of features that contrast sharply with their surroundings may also have an influence on how they are perceived.

This has been a dominant focus within visual resource programs of land management agencies (Ribe 2005). The Visual Resource

Management Program of the Bureau of Land Management (BLM; BLM 1980), for example, places considerable focus on design techniques that minimize visual conflicts with features such as roads and power lines by aligning them with the natural contours of the landscape. Based on these characteristics of contrast, we considered the color of a feature in relative harmony with the landscape if it closely matched the surrounding environment, or if the color tended to be darker relative to the environment. We considered the shape of a feature in relative harmony with the landscape if it was not in marked contrast to the environment.

Movement and Noise

Motion and sound can both have an influence on how a landscape is perceived (Hetherington et al. 1993), particularly by attracting attention to a particular area of a viewshed. Movement and noise parameters can be perceived either positively or negatively, depending on the source and context. For example, the motion of running water generally has a very positive influence on perception of the environment (Carles et al. 1999), whereas noise from vehicles on a highway may be perceived negatively. In Carles et al.'s 1999 study, sounds were perceived negatively when they clashed with aspirations for a given site, such as tranquility. We considered the conspicuousness of the impact of movement and noise to be consistent with the amount present (that is, little movement or noise was inconspicuous, obvious movement or noise was conspicuous).

Hierarchical Relationship among Conspicuousness Measures

The above-described characteristics do not act independently with respect to their influence on the conspicuousness of features; rather, they tend to have a hierarchical effect. For example, the color and shape of a house would not be important to the integrity of a park's viewshed if the house was located far away from the vantage point. Thus, distance becomes the primary characteristic that affects the potential conspicuousness. Therefore, we considered potential influences on conspicuousness in the context of a hierarchy based on the distance characteristics having the most impact on the integrity of the viewshed, followed by the size characteristic, then both the color and shape, and finally, the noise and movement characteristic (Figure 4.1.2-5).

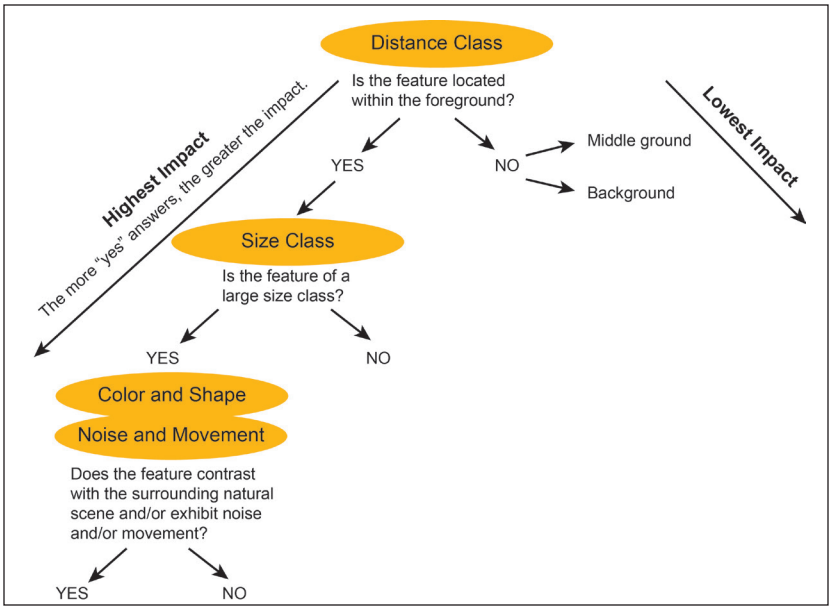


Figure 4.1.2-5. Conceptual framework for hierarchical relationship of characteristics that influence the conspicuousness of features within a viewshed.

GIS Viewshed Analysis

We supplement our assessment with a Geographic Information System (GIS) analysis to provide spatial context for these measures. Viewshed analyses were conducted to depict the total visible area seen from each of the three key vantage points. Aerial maps of each of the vantage points were generated based on digital elevation models (DEMs) to predict the area visible from a given vantage point taking into account changes in elevation and other obstructions such as tree, mountain, or building heights. We show visible areas within 30 km (18.6 km) of the park and those well outside of this distance, but note that features at greater distances (e.g., outside of the 30 km) have relatively less impact on scenic or historic integrity than those in closer proximity. For this reason, we focus on visible areas within 30 km of the park. Also note that areas visible from the three vantage points are combined on one map. Complete details of the viewshed analysis process are listed in Appendix B.

Table 4.1.3-1. Qualitative reference condition classes used for scenic and historic integrity within the viewshed at El Malpais NM.

Class	Scenic & Historic Integrity
High Integrity *(Good Condition)*	Some noncontributing features or developments may be visible, but the vast majority of the landscape is dominated by natural or historic features. The integrity of the natural and historic context is well preserved such that an observer can easily visualize the historic aspect of the viewshed. As such, the features that contribute to the natural and historic integrity are well preserved and the noncontributing features are generally absent or are sufficiently inconspicuous so as to not detract from the sense of place.
Moderate Integrity *(Moderate Concern)*	Noncontributing features or developments occupy a moderate portion of the landscape and/or are moderately conspicuous, but sufficient intactness retains much of its integrity. The integrity of the natural and historic context is also largely preserved such that an observer can experience a natural viewshed.
Low Integrity *(Significant Concern)*	The vast majority of the landscape is dominated by noncontributing features or developments that are conspicuous enough that little integrity or "sense of place" remains. The integrity of the natural and historic context is essentially lost either from the contributing factors not being well preserved or the noncontributing features overwhelming the potential to experience a natural viewshed.

In addition, using 2010 data provided by NPScape (NPS 2011a), road density and housing density were overlaid on the map to provide an additional measure of viewshed integrity (intactness). NPScape was developed by NPS Natural Resource Stewardship and Science by compiling and analyzing landscape-scale U.S. Census Bureau data that linked measurable attributes of landscape (i.e., road density, population and housing density, and others) to resources within natural resource-based parks, resulting in the NPScape database (Budde et al. 2009, Monahan et al. 2012).

4.1.3. Reference Conditions

The indicators and measures of viewshed condition at El Malpais NM are inter-related and intended to provide information about how well the views maintain their scenic quality and their ability to evoke a sense of place in an historic and cultural context.

The basis for determining condition in an assessment such as this is a comparison between current condition and a reference condition. We used a qualitative reference state for the scenic and historic integrity of the viewshed (Table 4.1.3-1). Embedded within these reference conditions are both the intactness of view and conspicuousness of features that do not contribute to the scenic and historic integrity.

4.1.4. Condition and Trend

Overall, the scenic and historic integrity of the viewsheds at El Malpais NM are in good condition. From the three vantage points, the landscape surrounding and within the national monument remains intact (Figures 4.1.4-1 through 4.1.4-4; Table 4.1.4-1). From the vantage points, noncontributing features that can be seen are relatively minor, consisting of a road and parking area and an extremely small sign.

Table 4.1.4-1. Indicator and measures of viewshed condition, their corresponding assigned condition class, and the rationale for assigning condition class.

Indicator of Condition	Measures	Condition	Rationale for Condition
Scenic and Historic Integrity	Intactness of View	Good	Views are mainly intact with few non-contributing features, consistent with good condition.
	Conspicuousness of non-contributing features	Good	Noncontributing features are relatively inconspicuous, consistent with good condition.

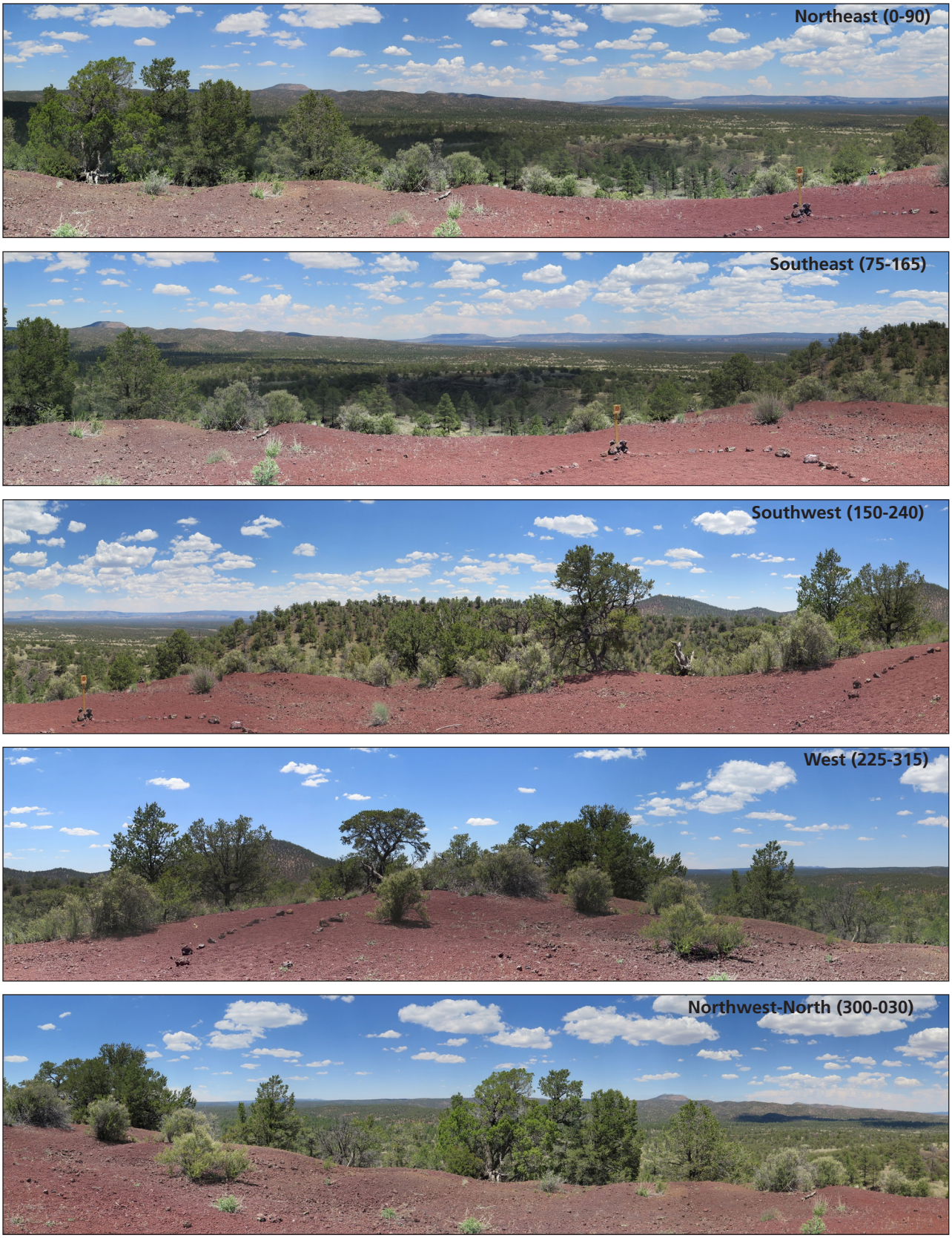


Figure 4.1.4-1. Panoramic views from one location at the top of El Calderon cinder cone. About 90 degrees are shown in each view, with about 15-20 degrees of overlap between one panorama and the next one.



Northeast (0-90)



Southeast (75-165)



West (225-315)



Northwest-North (300-030)

Figure 4.1.4-2. Panoramic views from one location at Bandera Crater (not at the top of the crater). About 90 degrees are shown in each view, with ~15-20 degrees of overlap between one panorama and the next one. Note that one panorama is not shown (150-240) because it did not include anything not observable in the two adjacent views. Also note that the park is not visible in the top view, but it is visible in the other three views in the distance as one looks away from the trail/road.



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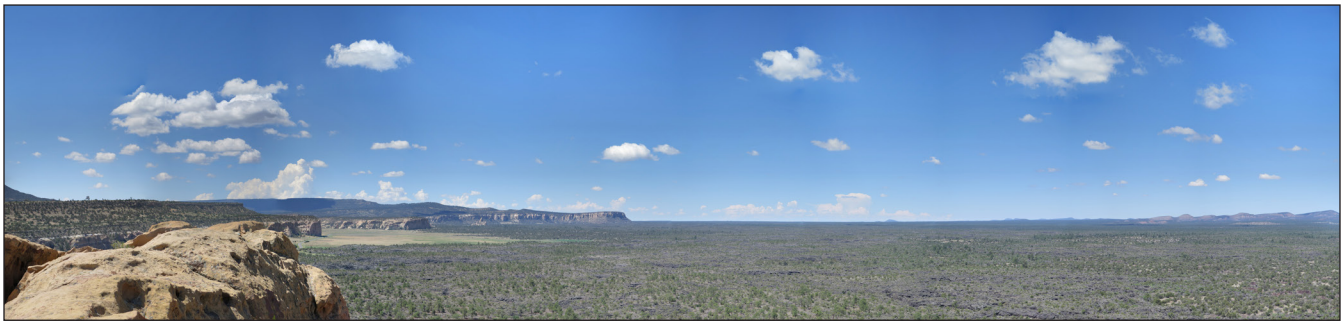
Figure 4.1-4-3. These two photographs were taken from a location a few hundred feet to the west of those shown in Figure 4.1.4-2 (and at a slightly higher elevation). These photos were taken from the cinder trail/road seen in the previous figure, and provide a slightly better view towards the south.



Northeast (0-90)



Southeast (70-165)



Southwest (150-240)



West (225-315)



Northwest-North (300-030)

Figure 4.1.4-4. Panoramic views from one location at the Sandstone Bluffs overlook. About 90 degrees are shown in each view, with about 15-20 degrees of overlap between one panorama and the next one. (Mt. Taylor can be seen in the background in the top and bottom panoramas).

The views from El Calderon are intact, with few or no noncontributing features, at least that can be seen in the panoramas (Figure 4.1.4-1). If noncontributing features are present, they are inconspicuous. The only obvious human-made object visible is the small, wooden park sign that can be seen in the nearby foreground looking toward the east/southeast. The sign, however, is very small and inconspicuous in color.

The views from the Bandera Volcano/Crater vantage point are also intact, and only one noncontributing feature can be seen (Figure 4.1.4-2. This feature is the cinder entrance trail/road (from where the panoramas were taken), but as it is narrow, curves with the cone, and consists of the same material as the ground, it is fairly inconspicuous. Note that the national monument is visible in the distance in the second through fourth views only. Additionally, no noncontributing features are visible from the two additional photographs that were taken a few hundred feet to the west of the vantage point (Figure 4.1.4-3). Recall that all of these images were taken from private property.

From the Sandstone Bluffs overlook vantage point, the views are largely intact, except that the parking area and parking area entrance road are somewhat visible (in the foreground) in views towards the east (Figure 4.1.4-4, top two panoramas). From the exact location of the vantage point, these noncontributing features are not very visible, but from other locations in close proximity, they are more visible (see Figure 4.1.4-5). The parking area is relatively small, however, and the visible portion of the road is roughly parallel to the bluffs. The trees and shrubs adjacent to the bluffs also help to minimize the visual effect of the parking area and road. There is the added component, however, of moving, albeit slowly moving, vehicles and their associated noise. Route 117 also runs in the middleground/background of views towards the east, northeast, and southeast, but the roadway seems to blend fairly well into the landscape from this location.

Overall, based on the panoramic images from the three vantage points, the scenic and historic integrity of the views are in good condition. The majority of the landscape is dominated by natural features, and there are no major impediments to experiencing a "sense of place." Impressive views are available to the visitor at the vantage points used in this assessment.

GIS-based Analysis

For our GIS-based analysis, we estimated the areas visible from the vantage points (Figure 4.1.4-6). It is important to keep in mind that these estimates of visible area are approximations based on digital elevation models. These are estimates only, and it should not be assumed that they are accurate enough for the purposes of planning specific projects. Such cases may require verification and adjustment for the specific context



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Figure 4.1.2-5. View of parking area and entrance road at Sandstone Bluffs overlook.

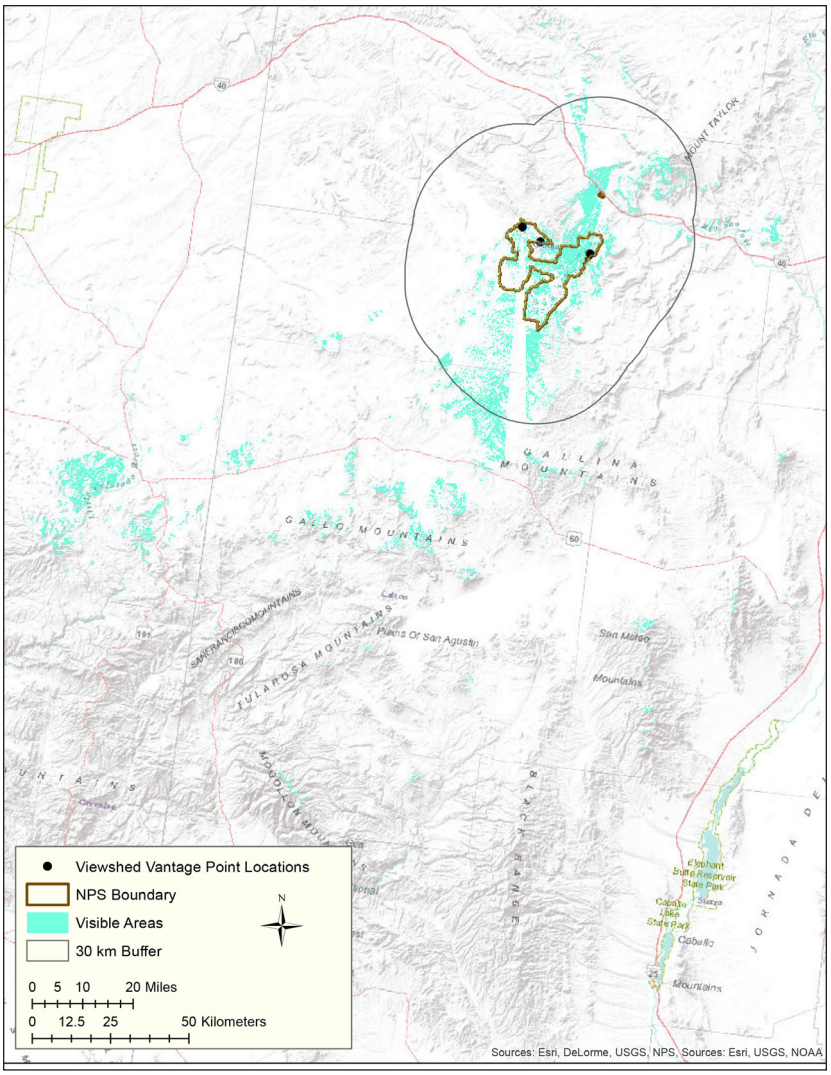


Figure 4.1.4-6. Area visible (in blue-green) from the vantage points at El Malpais NM. The closest mountain to the north of the park is Mount Taylor, and the closest mountains to the south are the Gallina Mountains. Data sources: NPS (2011b), and USGS (2015).

intended. Based on our analysis, the area within the park that is most visible from the vantage points is the eastern half of the park, especially the northeastern portion. Outside of the park, visible areas are mainly to the north and the south of the park. Overall, visible areas include some areas that are substantial distances from the national monument, such as Mt. Taylor to the northeast (mostly inside the 30 km buffer) and portions of the Gallina and Gallo Mountains to the south (outside of the 30 km buffer). Visible areas outside of the 30 km buffer are excluded from analysis of housing and road density data (see below), because roads and houses occurring at this distance from the national monument would generally not be expected to negatively affect the viewshed.

Housing density and road density are considered for their potential intrusion into the landscape when they occur within the 30 km buffer area. Housing density within 30 km of the national monument falls primarily into the rural category (Figure 4.1.4-7). The rural category composes 96.85% of the colored area within the area of interest (Table 4.1.4-2), and the housing density within this category ranges from private undeveloped to 4-6 units per square kilometer (Table 4.1.4-3). Table 4.1.4-2 shows all the housing density categories appearing in the figure and their related areas. The areas mapped as exurban and denser in Figure 4.1.4-7 are in the vicinity of Grants and Milan (the area north of the eastern portion of the park). A second area of mainly exurban development is farther to the east (from Grants) along Interstate 40. However, all of these areas of housing/development are not visible from the three vantage points we used in this assessment. The second half of Table 4.1.4-2 shows the area within each density class for the visible areas only. The density class most visible from the vantage points is that with the lowest housing density, the rural category (accounting for 92.98% of the colored area visible). Note that

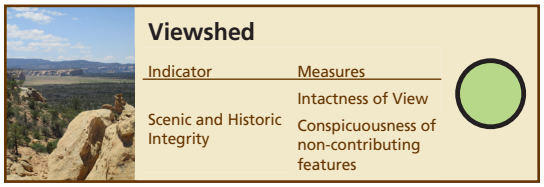
Table 4.1.4.2. Housing density surrounding El Malpais NM (within 30 km from the park).

All Areas		
Density Class	Area (km²)	Percent
Rural	4,028.20	96.85%
Exurban	118.94	2.86%
Suburban	6.95	0.17%
Urban	0.22	0.005%
Commercial / Industrial	4.41	0.11%
Urban-Regional Park	0.48	0.01%
Total Area	**4,159.20**	
Visible Areas Only		
Density Class	Area (km²)	Percent
Rural	338.58	92.98%
Exurban	20.63	5.66%
Suburban	3.18	0.87%
Urban	0.19	0.05%
Commercial / Industrial	1.53	0.42%
Urban-Regional Park	0.05	0.01
Total Area	**364.16**	

all colored areas in Figure 4.1.4-7 constitute a total of over 4,000 square kilometers, but the (colored) visible areas only make up about 364 square kilometers.

Road density generally followed a similar pattern as housing density. Areas of greatest density were near the cities/towns along Interstate 40, as well as to the west and northwest of the national monument (Figure 4.1.4-8). According to the analysis, the vast majority of roads within the 30 km buffer area (83.28%) were in the two lowest-density categories (Table 4.1.4-4, top portion). Again, recall that the entire area within the area of interest is not visible from the three vantage points. Within the visible area only, the two lowest density categories made up even a slightly greater proportion of the (colored) total area visible (i.e., 85.92%; Table 4.1.4-4, bottom portion).

Although housing and roads can degrade the visual integrity of the landscape and viewsheds, our analysis for El Malpais NM indicated that these forms of development were not dense enough within the area of interest to lead to a lowering of the condition rating for scenic and historic integrity at the national monument.



Overall Condition

Based on this assessment, we considered the viewshed at El Malpais NM to be in good condition. Noncontributing features were relatively few and inconspicuous, leaving the site primarily intact from a scenic standpoint, which also allows the visitor to imagine the landscape from an historic and cultural point of view.

4.1.5. Sources of Expertise

For assessing the condition of this resource, we relied primarily on the panoramic images and literature on this topic. Kim Struthers provided GIS expertise. Park personnel took the panoramic images.

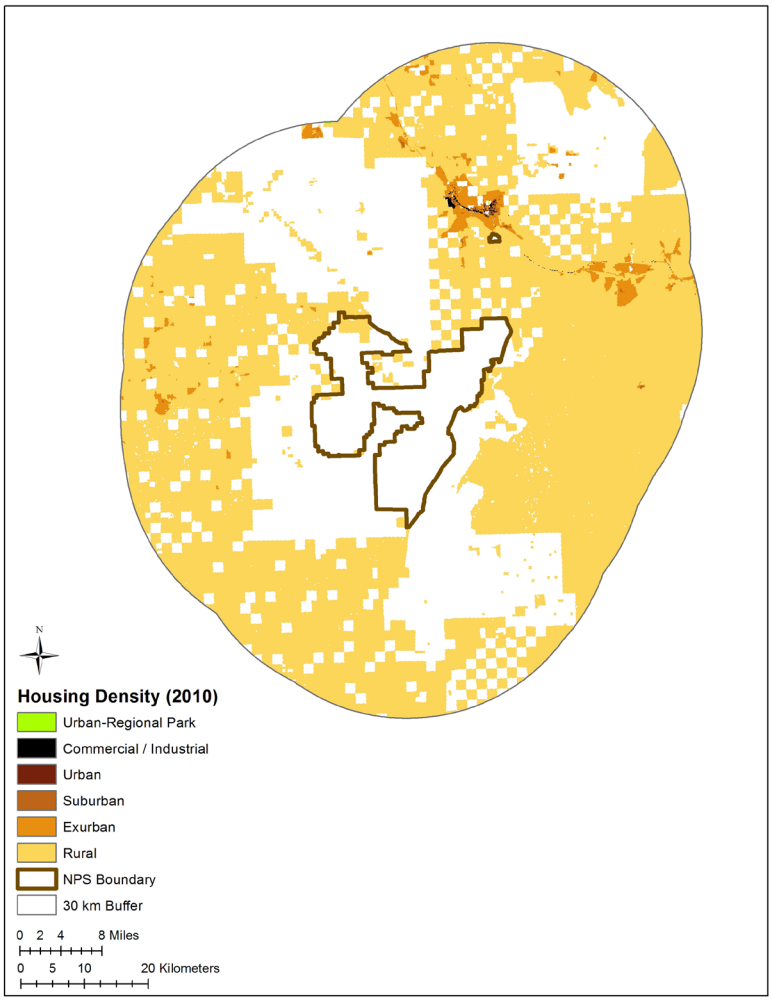


Figure 4.1.4-7. Housing density surrounding El Malpais NM. Data sources: NPS (2011b), NPS (2014b), and Theobald (2005).

Table 4.1.4-3. Definitions of grouped housing density classes used in the GIS analysis. Source: NPS 2013.

All Areas	
Density Class	Class Definition
Rural	class ranges from private/ undeveloped to 4-6 units per km^2
Exurban	class ranges from 7-12 units per km^2 to 50-146 units per km^2
Suburban	class ranges from 146-495 units per km^2 to 495-1,235 units per km^2
Urban	class ranges from 1,235-2,470 units per km^2 to >2,470 units per km^2
Commercial / Industrial	-----
Urban-Regional Park	-----

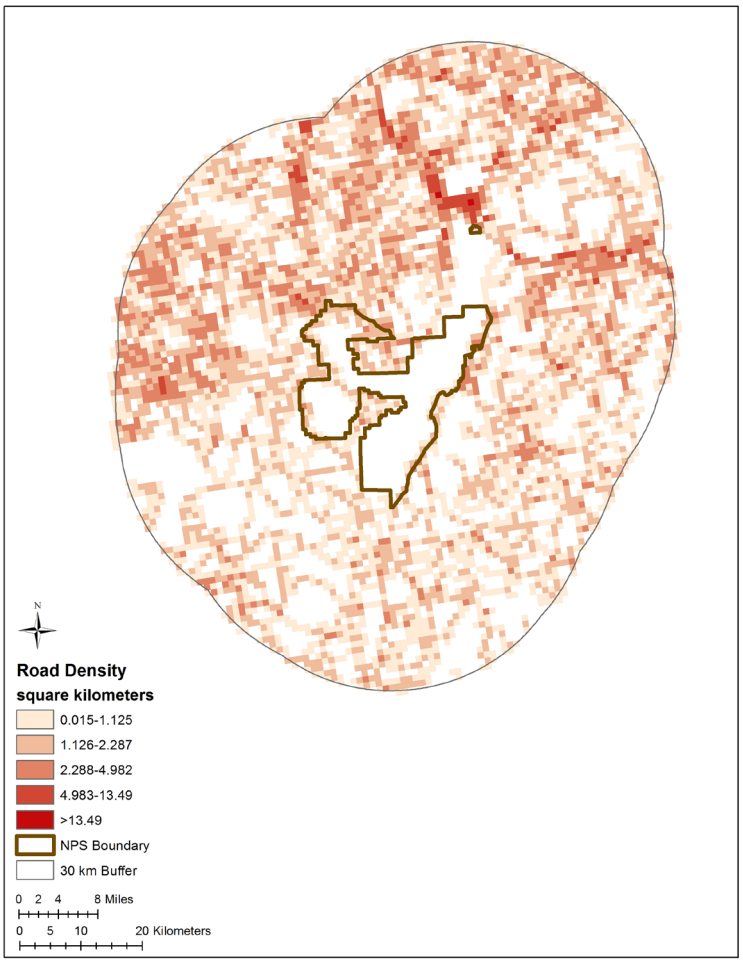


Figure 4.1.4-8. Road density surrounding El Malpais NM. Data sources: NPS (2011b), NPS (2014c), and ESRI (2010).

Table 4.1.4-4. Road density surrounding El Malpais NM (within 30 km of the park).

All Areas		
Density Class	Area (km²)	Percent
0.015 - 1.125	2,189	46.00%
1.126 - 2.287	1,774	37.28%
2.288 - 4.982	722	15.17%
4.983 - 13.49	71	1.49%
> 13.49	2	0.04%
Total Area	**4,758**	
Visible Areas Only		
Density Class	Area (km²)	Percent
0.015 - 1.125	208	50.48%
1.126 - 2.287	146	35.44%
2.288 - 4.982	45	10.92%
4.983 - 13.49	12	2.91%
>13.49	1	0.24%
Total Area	**412**	

Key Uncertainties

How a view is perceived is quite subjective and will always have an element of uncertainty. We have tried to base our assessment on the findings of an extensive body of literature, and have tried to be transparent with our assessment.

Another element of uncertainty is our GIS analysis. This analysis is based on digital elevation models and does not take into account visibility limitations from vegetation, and other variables, and has not been verified in the field. Even with these uncertainties, we have a high level of confidence in this assessment.

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4.2. Night Sky

Indicators/Measures

- Sky Brightness (4 measures)
- Sky Quality (1 measure)

Condition – Trend – Confidence



Good to Moderate - Insufficient Data - High

4.2.1. Background and Importance

Natural dark skies are a valued resource within the NPS, reflected in NPS management policies (NPS 2006), which highlight the importance of a natural photic environment to ecosystem function, and the importance of the natural lightscape for aesthetics. The NPS Natural Sounds and Night Skies Division (NSNSD) makes a distinction between a lightscape—which is the human perception of the nighttime scene, including both the night sky and the faintly illuminated terrain, and the photoic environment—which is the totality of the pattern of light at night at all wavelengths (Moore et al. 2013).

Lightscapes are an aesthetic and experiential quality that is integral to natural and cultural resources (Moore et al. 2013). A 2007 visitor survey conducted throughout Utah national parks found that 86% of visitors thought the quality of park night skies was "somewhat important" or "very important" to their visit. Additionally, in an estimated 20 national parks, stargazing events are the most popular ranger-led program (NPS 2010).

The value of night skies goes far beyond visitor experience and scenery (Figure 4.2.1-1). The photic environment affects a broad range of species, is integral to ecosystems, and is a natural physical process (Moore et al. 2013). Natural light intensity varies during the day-night (diurnal) cycle, the lunar cycle, and the seasonal cycle. Organisms have evolved to respond to these periodic changes in light levels in ways that control or modulate movement, feeding, mating, emergence, seasonal breeding, migration, hibernation, and dormancy. Plants also respond to light levels by flowering, vegetative growth, and their direction of growth (Royal Commission on Environmental Pollution 2009). Given the effects of light on living organisms, it is likely



NPS NATURAL SOUNDS AND NIGHT SKIES DIVISION

Figure 4.2.1-1. CCD camera set-up at Cerro Encierro in El Malpais National Monument.

that the introduction of artificial light into the natural light/darkness regime will disturb the normal routines of many plants and animals (Royal Commission on Environmental Pollution 2009), as well as diminish stargazing recreational opportunities offered to national park visitors.

Approximately 85% of El Malpais National Monument is recommended wilderness and preserving dark night skies is important to maintaining the wilderness character of the national monument. In its foundation document, the development of a dark night skies preservation plan was identified as a priority (NPS 2014). Protecting the night sky resources at El Malpais NM benefits the natural resources, is important for visitor experience, and has cultural significance. El Malpais NM has a unique opportunity to provide educational programs that highlight the cultural significance of night skies to Ancestral Puebloans and their descendants, as well as to provide recreational opportunities for visitors. For centuries people have lived around and sometimes in the lava country. Ancient Indian civilizations crossed the lava flows with trail cairns and related to the landscape with stories and ceremony. Ancestral Puebloans careful observation of the sun, moon and stars was essential for planning festivals and activities such as when to start planting and when to harvest (Aveni 2003).

4.2.2. Data and Methods

The NPS NSNSD goals of measuring night sky brightness are to describe the quality of the lightscape, quantify how much it deviates from natural conditions, and how it changes with time due to changes in natural conditions, as well as artificial lighting in areas within and outside of the national parks (Duriscoe et al. 2007).

Based on new guidance (Moore et al. 2013), the NPS NSNSD recommends the all-sky light pollution ratio (ALR) as the best single parameter for characterizing overall sky condition. However the utility of a single metric limits the ability to fully describe and manage the variations in resource quality that often exists within a park. Therefore, NSNSD recommends using a suite of metrics to describe and manage variations in night sky quality (see Table 4.2.2-1). When available, additional indicators and measures, such as maximum vertical illuminance, should also be considered in an assessment of night sky condition, but the ALR measure is the primary data source for condition assessment.

NSNSD conducted an assessment of the national monument's night sky condition using a CCD camera to assess all-sky light pollution and maximum vertical and horizontal illumination, a sky quality meter to measure sky brightness, and the Bortle Dark Sky Scale, a qualitative assessment commonly used by amateur astronomers to evaluate the sky quality for star gazing. Readings were taken at three locations within El Malpais NM approximately an hour after moonset: Cerro Encierro, the summit of a cinder cone in the middle of the national monument, on April 20, 2012; a meadow below Cerro Encierro on April 20, 2012; and Sandstone Bluffs, located at the northeastern portion of the national monument, on March 16, 2010. The high point at Cerro Encierro allowed

Table 4.2.2-1. Indicators and measures of the night sky and why they are important to resource condition.

Indicator	Measure	Description
Sky Brightness	All-sky Light Pollution Ratio, Vertical Maximum and Horizontal Illuminances and Zenith Sky Brightness	The all-sky light pollution ratio describes light due to man-made sources compared to light from a natural dark sky. Understanding the lightscape and sources of light is helpful to managers to maintain dark skies for the benefit of wildlife and people alike.
Sky Quality	Bortle Scale Class	The Bortle Dark Sky classification system describes the quality of the dark night sky by the celestial bodies and night sky features an observer can see. Observing the stars has been an enjoyable human pastime for centuries.

for unfettered view of city light domes while the lower meadow site effectively blocked light trespass from city light domes, and is considered one of the darkest locations within the national monument.

Indicator/Measures

Sky Brightness (All-sky Light Pollution Ratio, Maximum Vertical Illuminance, Horizontal Illuminance, and Zenith Sky Brightness)

A CCD camera was used to measure both natural and anthropogenic light across the entire hemisphere. From the calibrated images collected by the CCD camera metrics including all-sky light pollution ratio and two measures of integrated sky brightness—horizontal and vertical illuminance—were derived. Ground-based measurements were taken at Cerro Encierro, the meadow below Cerro Encierro, and at Sandstone Bluffs.

The all-sky light pollution ratio (ALR) is the average anthropogenic sky luminance presented as a ratio over natural conditions. It is a useful metric to average the light flux over the entire sky (measuring all that is above the horizon and omitting the terrain). Recent advances in modeling of the natural components of the night sky allow the separation of anthropogenic light from natural features, such as the Milky Way. This metric is a convenient and robust measure. It is most accurately obtained from ground-based measurements with the NPS Night Skies Program's photometric system, however, it can also be modeled with moderate confidence when such measurements are not available.

ALR was modeled for the entire park based on data from the 2001 World Atlas of Night Sky Brightness, which depicts zenith sky brightness (the brightness of the sky directly above the observer). A neighborhood analysis is then applied to the World Atlas to determine the anthropogenic sky brightness over the entire sky. Finally, the modeled all-sky light pollution over the entire sky is presented as a ratio (ALR) over the natural sky brightness (Moore et al. 2013). While modeled data provide useful overall measurements, especially when site visits cannot be made, they are less accurate than ground-based measurements.

Modeled data produced an estimated ALR of 0.17 for the entire national monument. Measurements from Cerro Encierro produced a mean ALR of 0.2, or 20% brighter than average natural conditions, while the meadow below Cerro Encierro produced a mean ALR of 0.09, or 9% brighter than average natural conditions (ground-based data have a 90% confidence level of ±8 nL, or ±0.1 ALR). Sandstone Bluffs produced a mean ALR of 0.35, or 35% brighter than average natural conditions. A summary of all night sky conditions is presented in Table 4.2.2-2.

Vector measures of illuminance (horizontal and vertical) are important in describing the appearance of three-dimensional objects on the landscape and their relative visibility. Vertical illuminance is the integration of all light striking a vertical plane from the point of the observer. In light-polluted areas, maximum sky brightness and maximum vertical illuminance will often measure the same area of sky, typically at the core of urban light domes. Vertical illuminance is an important metric when discussing night sky

Table 4.2.2-2. Night Sky Measurements at El Malpais NM.

Location	All-sky Light Pollution Ratio	Maximum Vertical Illuminance (milli-Lux)	Horizontal Illuminance (milli-Lux)	Zenith Sky Brightness (SQM)	Bortle Scale
Modeled Park-wide	0.17	---	---	---	---
Cerro Encierro	0.20	0.19	0.06	21.74	3
Lower Meadow	0.09	0.08	0.07	21.84	2
Sandstone Bluffs	0.35	0.36	0.09	21.54	4

quality as it is easily noticeable to park visitors (since humans are oriented vertically). Even with dark conditions overhead, high vertical illuminance can hinder or inhibit dark adaptation of the eyes and cast visible shadows on the landscape. This is also an important ecological indicator, as many wildlife species base behavior on visual cues along the horizon. Horizontal illuminance is the amount of light striking a horizontal surface and is an important indicator of sky brightness (Cinzano and Falchi 2014). It is less sensitive in slightly impacted areas. This is because, even though the entire sky is considered, there is a rapid falloff in response to photons near the horizon, owing to Lambert's cosine law. At sites remote from cities, most of the anthropogenic sky glow occurs near the horizon.

Maximum vertical illuminance at Cerro Encierro was measured at 0.19 milli-Lux, or 48% above average natural conditions, while the lower meadow was measured at 0.08 milli-Lux, or 20% above average natural conditions. At Sandstone Bluffs maximum vertical illuminance was measured at 0.36, or 90% above average natural conditions. Horizontal illuminance from anthropogenic sources at Cerro Encierro was measured at 0.06 milli-Lux, or 8% brighter than natural conditions, while the lower meadow was measured at 0.07 milli-Lux, or 8% brighter than natural conditions. Horizontal illuminance at Sandstone Bluffs was measured at 0.09 milli-Lux, or 11% above average natural conditions (Table 4.2.2-2).

Sky brightness describes the amount of light in the night sky. One method of assessing sky brightness uses a Unihedron Sky Quality Meter (SQM) that samples the night sky in a broad spectrum band roughly corresponding to the entire human visual range. The SQM measures an aggregate average brightness for the entire sky that is skewed to zenith brightness over an 80 degree field of view (Moore 2001). Ground-based SQM readings were 21.74 at Cerro Encierro, 21.84 at the lower meadow, and 21.54 at Sandstone Bluffs (Table 4.2.2-2).

Indicator/Measure
Sky Quality (Bortle Dark Sky Scale)

The Bortle Dark Sky Scale (Appendix C) was proposed by John Bortle (Bortle 2001) based on 50 years of astronomical observations. Bortle's qualitative approach uses a nine-class scale that requires a basic knowledge of the night sky and no special equipment (Bortle 2001, Moore 2001, White et al. 2012, Table 4.2.2-3). The Bortle scale uses both stellar objects and familiar descriptors to distinguish among the different classes. Another advantage of the Bortle scale is that it is suitable for conditions ranging from the darkest skies to the brightest urban areas (Moore 2001, Figure 4.2.2-1).

The qualitative Bortle Scale assessment estimated the night sky quality to class 3 at Cerro Encierro and class 2 as observed from the lower meadow. At Sandstone Bluffs observers estimated a Bortle class 4. These observations are consistent with a rural sky at Cerro Encierro, a typical dark sky at the lower meadow, and the transition from rural to suburban skies at Sandstone Bluffs. (Table 4.2.2-2).

4.2.3. Reference Conditions

The ideal night sky reference condition, regardless of how it's measured, regardless of how it's measured, is one devoid of any light pollution. However, results from night sky data collection throughout more than 90 national parks suggest that a pristine night sky is very rare (NPS 2010). El Malpais NM is an NPS unit with significant natural resources including volcanic lava flows, lava tube caves, and unique vegetation associated with the ancient volcanic environment. Approximately 85% of El Malpais National Monument is recommended wilderness. Therefore, the national monument is considered a non-urban NPS unit, or park with at least 90% of its property located outside an urban area (Moore et al. 2013). For non-urban NPS units, the thresholds separating reference of conditions good, moderate, and significant concern are more stringent than those for urban NPS units because these areas are generally more sensitive to the effects of

Table 4.2.2-3. Bortle Dark Sky Scale (White et al. 2012)

Bortle Scale	Milky Way (MW)	Astronomical Objects	Zodiacal Constellations	Airglow and Clouds	Nighttime Scene
Class 1 Excellent Dark Sky Site	MW shows great detail, and appears 40° wide in some parts; Scorpio-Sagittarius region casts an obvious shadow	Spiral galaxies (M33 and M81) are obvious objects; the Helix nebula is visible with the naked eye	Zodiacal light is striking as a complete band, and can stretch across entire sky	The horizon is completely free of light domes, very low airglow	Jupiter and Venus annoy night vision, ground objects are barely lit, trees and hills are dark
Class 2 Typical Dark Site	MW shows great detail and cast barely visible shadows	The rift in Cygnus star cloud is visible; the Prancing Horse in Sagittarius and Fingers of Ophiuchus dark nebulae are visible, extending to Antares	Zodiacal band and gegenschein are visible	Very few light domes are visible, with none above 5° and fainter than the MW; airglow may be weakly apparent, and clouds still appear as dark voids	Ground is mostly dark, but object projecting into the sky are discernible
Class 3 Rural Sky	MW still appears complex; dark voids and bright patches and a meandering outline are visible	Brightest globular clusters are distinct, pinwheel galaxy visible with averted vision	Zodiacal light is easily seen, but band of gegenschein is difficult to see or absent	Airglow is not visible, and clouds are faintly illuminated except at zenith	Some light domes evident along horizon, ground objects are vaguely apparent
Class 4 Rural-Suburban Transition	MW is evident from horizon to horizon, but fine details are lost	Pinwheel galaxy is a difficult object to see; deep sky objects such as M13 globular cluster, Northern Coalsack dark nebula, and Andromeda galaxy are visible	Zodiacal light is evident, but extends less than 45° after dusk	Clouds are just brighter than the sky, but appear dark at zenith	Light domes are evident in several directions (up to 15° above the horizon), sky is noticeably brighter than terrain
Class 5 Suburban Sky	MW is faintly present, but may have gaps	The oval of Andromeda galaxy is detectable, as is the glow in the Orion nebula, Great rift in Cygnus	Only hints of zodiacal light may be glimpsed	Clouds are noticeably brighter than sky	Light domes are obvious to casual observers, ground objects are easily seen
Class 6 Bright Suburban Sky	MW only apparent overhead, and appears broken as fainter parts are lost to sky glow	Cygnus, Scutum, and Sagittarius star fields just visible	Zodiacal light is not visible; constellations are seen, and not lost against a starry sky	Clouds appear illuminated and reflect light	Sky from horizon to 35° glows with grayish color, ground is well lit
Class 7 Suburban-Urban Transition	MW may be just barely seen near the zenith	Andromeda galaxy (M31) and Beehive cluster (M44) are rarely glimpsed	Zodiacal light is not visible, and brighter constellations are easily seen	Clouds are brilliantly lit	Entire sky background appears washed out, with a grayish or yellowish color
Class 8 City Sky	MW not visible	Pleiades are easily seen, but few other objects are visible	Zodiacal light not visible, constellations are visible but lack key stars	Clouds are brilliantly lit	Entire sky background has uniform washed out glow, with light domes reaching 60° above the horizon
Class 9 Inner City Sky	MW not visible	Only the Pleiades are visible to all but the most experienced observers	Only the brightest constellations are discernible	Clouds are brilliantly lit	Entire sky background has a bright glow, ground is illuminated

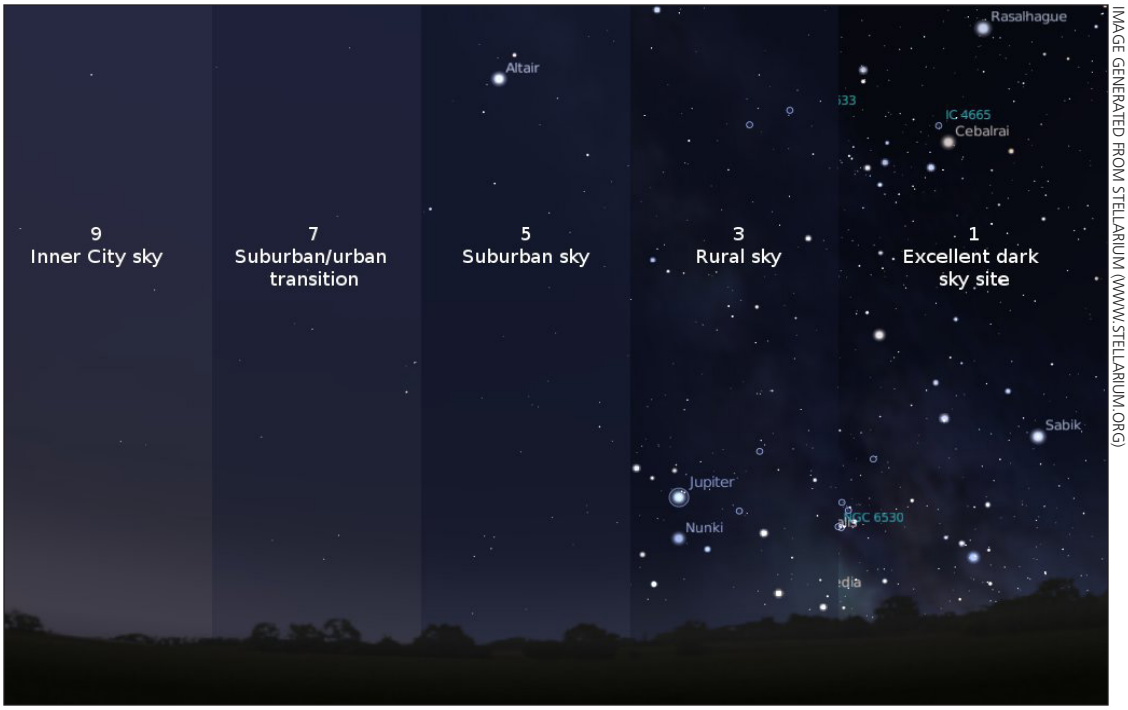


Figure 4.2.2-1. Composite image illustrating the range of night sky conditions based on the Bortle Dark Sky Scale.

light pollution. For a summary of condition assessment categories for all night sky indicators, see Table 4.2.3-1.

All-sky Light Pollution Ratio

A natural night sky has an average brightness across the entire sky of 78 nL (nanolamberts, a measure of luminance), and includes features such as the Milky Way, Zodiacal light, airglow, and other starlight. This is figured into the ratio, so that an ALR reading of 0.0 would indicate pristine natural conditions where the anthropogenic component was 0 nL. A ratio of 1.0 would indicate that anthropogenic light was 100% brighter than the natural light from the night sky. The threshold for night skies in good condition is an ALR <0.33 and the threshold for a moderate condition is ALR 0.33-2.0. An ALR >2.0 suggests significant concern (Moore et al. 2013).

Maximum Vertical Illuminance

The NPS Night Skies Division recommends a reference condition of 0.4 milli-Lux, since the average vertical illuminance experienced under the natural night sky on a moonless night is 0.4 milli-Lux (derived from Jensen et al. 2006, Garstang 1986, and unpublished NPS Night Skies Program data). No thresholds for condition rating have been set at this time. Vertical illuminance can also be expressed as a ratio to natural conditions, similar to ALR.

Horizontal Illuminance

The NPS Night Skies Division recommends a reference condition of 0.8 milli-Lux, since the average horizontal illuminance

Table 4.2.3-1. Night sky condition class summary for non-urban parks (i.e. parks with at least 90% of their property located outside an urban area).

Condition Class	ALR*	SQM	Bortle Scale
Good	ALR <0.33 (<26 nL average all-sky light pollution)	≥21.60	1-3
Moderate	0.33-2.0 (26-156 nL average all-sky light pollution)	21.2-21.59	4
Significant concern	ALR >2.0 (>156 nL average all-sky light pollution)	<21.2	5-9

* At least half of the park's geographic area should meet the standard described.

experienced under the natural night sky on a moonless night is 0.8 milli-Lux (derived from Durisco 2015 [submitted]). No thresholds for condition rating have been set at this time. Horizontal illuminance can also be expressed as a ratio to natural conditions, similar to ALR.

Zenith Sky Brightness

Reference conditions for night sky brightness can vary moderately based on the time of night (time after sunset), time of the month (phase of the moon), time of the year (the position of the Milky Way), and the activity of the sun which can increase "airglow"—a kind of faint aurora. For the minimum night sky brightness measure, the darkest part of a natural night sky is generally found near the zenith. A value of 22.0 magnitudes per square arc second (msa) is considered to represent a pristine sky, though it may vary naturally by more than +0.2 to -0.5 depending on natural conditions (Duriscoe 2013). Lower (brighter) values indicate increased light pollution and a departure from natural conditions. The astronomical magnitude scale is logarithmic, so a change of 2.50 magnitudes corresponds to a difference of l0x (100%); thus a 19.5 msa sky would be 10x brighter than natural conditions. Minimum night sky brightness values of 21.4 to 22.0 msa, are generally considered to represent natural (unpolluted) conditions (Duriscoe et al. 2007).

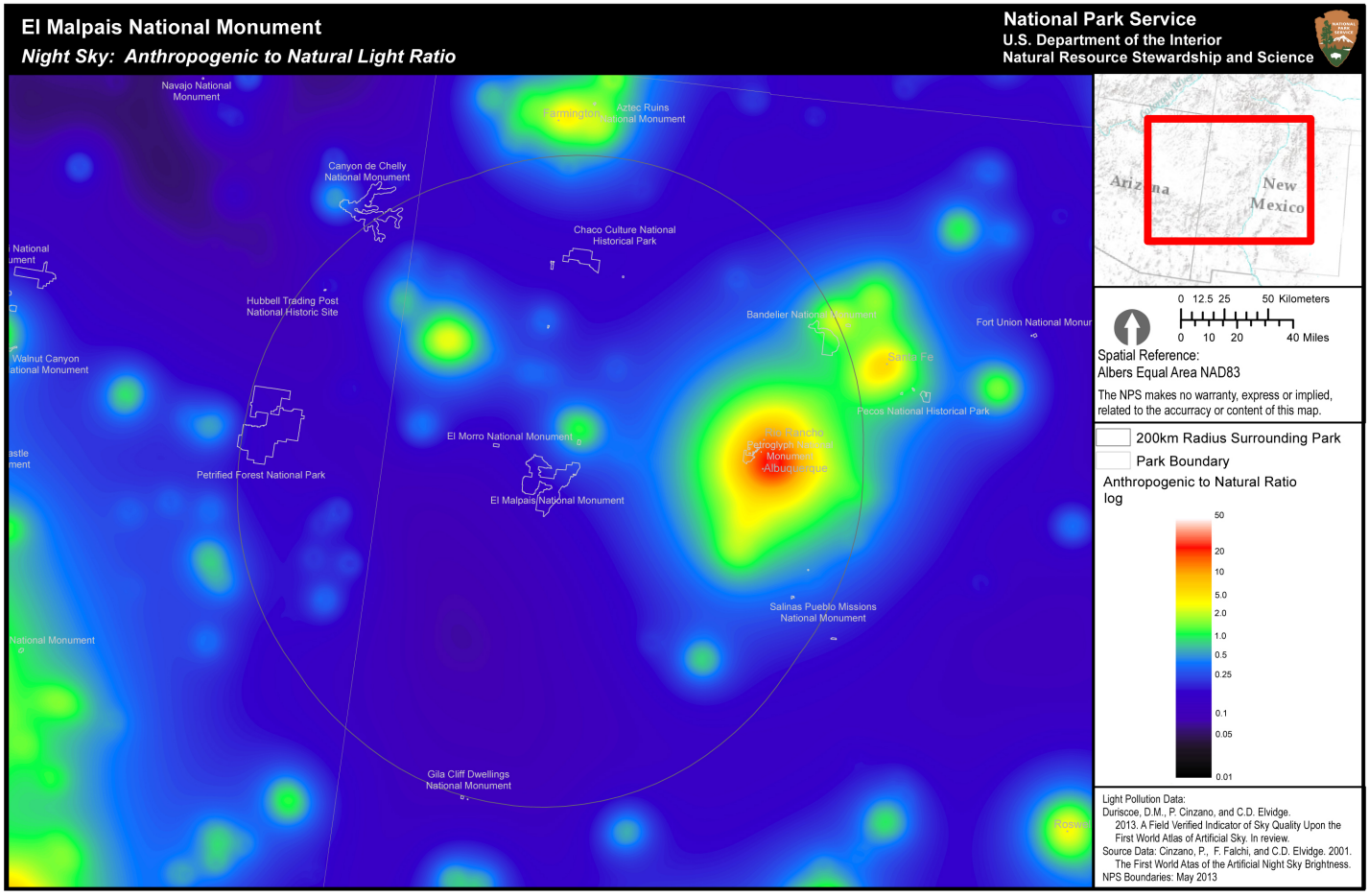
The maximum night sky brightness is often found within the Milky Way of a natural sky. A typical measurement from the Sagittarius region of the Milky Way in a natural sky yields 19.2 msa. Other regions of the Milky Way are somewhat dimmer, or around 20.0-21.0 msa. A value brighter than 19.0 msa will result in impairment to human night vision and may be noticeable by casting faint shadows or causing glare. A value lower (brighter) than 17.0 represents very bright areas of the night sky and would significantly impair human night vision and cast obvious shadows. Values for the brightest portion of the sky are of interest to the NPS because they represent unnatural intrusions on the nightscape, will prevent human dark-adapt vision, and may have effects on wildlife (Duriscoe et al. 2007).

Bortle Dark Sky Scale

A night sky with a Bortle Dark Sky Scale class 1 is considered in the best possible condition (Bortle 2001); unfortunately, a sky that dark is so rare that few observers have ever witnessed it (Moore 2001). Non-urban park skies with a Bortle class 3 or darker are considered to be in good condition, class 4 of moderate condition, and class 5 are considered poor condition. At class 4 and higher, many night-sky features are obscured from view due to artificial lights (either within or outside the park). Skies class 7 and higher have a significantly degraded aesthetic quality that may introduce ecological disruption (Moore et al. 2013). It is important to note that such degraded conditions may be restored toward a more natural state by modifying outdoor lighting, depending on the surrounding conditions that exist outside the national monument.

4.2.4. Condition and Trend

The modeled ALR indicate good night sky conditions for the entire park (Figure 4.2.4-1). This is consistent with ground-based measurements collected at Cerro Encierro and at the lower meadow; however, ALR as measured from Sandstone Bluffs is considered in moderate condition. Although no thresholds have been established for maximum vertical illuminance or horizontal illuminance, both measurements were estimated as good at all three locations except Sandstone Bluffs where maximum vertical illuminance was estimated as moderate (J. White, personal communication, November 2015). The moderate condition for maximum vertical illuminance at Sandstone Bluffs suggests that there is some potential for inhibition of dark adaptation and disruption of natural ecological functions. Ground-based SQM readings indicate good condition at Cerro Encierro and at the lower meadow, and moderate condition at Sandstone Bluffs. The qualitative Bortle Scale assessment indicated good night sky viewing conditions at Cerro Encierro and at the lower meadow, but was only estimated as moderate at Sandstone Bluffs. These data provide baseline information for the national monument. No data on trends were available.

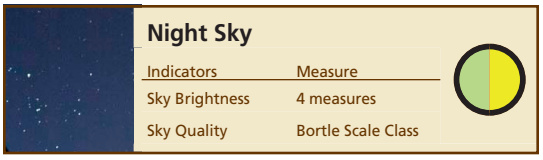


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Figure 4.2.4-1. Modeled ALR map for El Mapais NP. A 200km ring around the park illustrates the distance at which anthropogenic light can impact night sky quality within the park. Photo Credit: NPS Natural Sounds and Night Skies Division.

Local and Regional Context

El Malpais lies within a rural or wilderness setting with few cities that interfere with dark night skies. Albuquerque (population 542,852) to the northeast produces the largest light dome. Santa Fe (population 67,947) north of Albuquerque is faintly visible. The cities of Grants (population 9,182) 36 miles to the northwest and Gallup (population 21,678) 94 miles to the north are also visible from the national monument (U.S. Census Bureau 2010). The light domes from these population centers minimally impact the night sky at Cerro Encierro (Figure 4.2.4-2) and at the lower meadow (Figure 4.2.4-3), but do affect night sky conditions at Sandstone Bluffs (Figure 4.2.4-4).



Overall Condition

Quantitative measures of sky brightness (all-sky light pollution ratio, maximum vertical and horizontal illuminance, and zenith sky brightness) and a qualitative assessment of sky quality (the Bortle Dark Sky Scale) were used to assess the condition of the night sky at El Malpais NM. These indicators are summarized and interpreted in Table 4.2.4-1. The measurements collected from Cerro Encierro and the lower meadow on April 20, 2012 indicates good night sky conditions while data collected at Sandstone Bluffs in the northeast region of the national monument on March 16, 2010 indicate moderate night sky conditions. Overall, the night sky condition at El Malpais is considered good to moderate

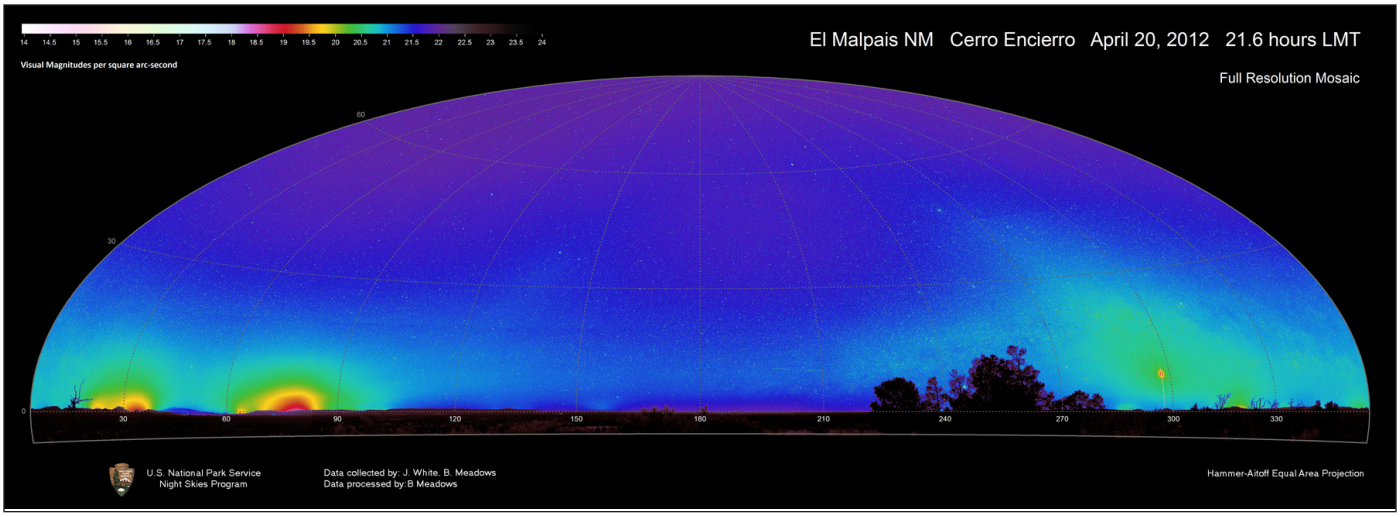


Figure 4.2.4-2. Panoramic all-sky mosaic of all sources of light (natural and anthropogenic) at El Malpais National Monument from Cerro Encierro. Credit: NPS Night Skies and Natural Sounds Division.

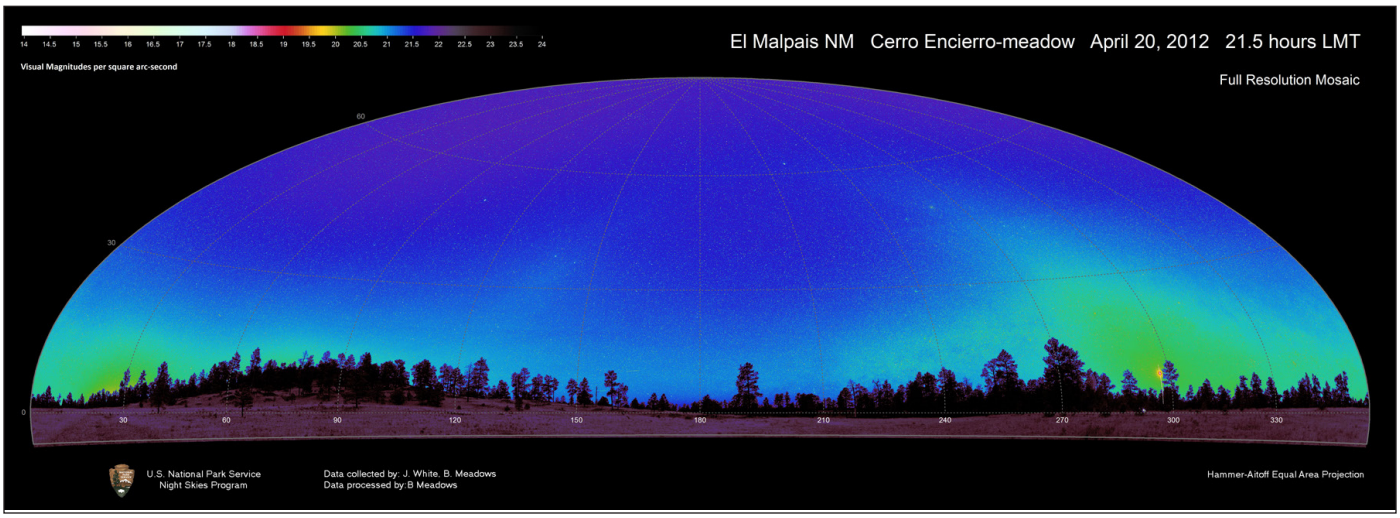


Figure 4.2.4-3. Panoramic all-sky mosaic of all sources of light (natural and anthropogenic) at El Malpais National Monument from lower meadow. Credit: NPS Night Skies and Natural Sounds Division.

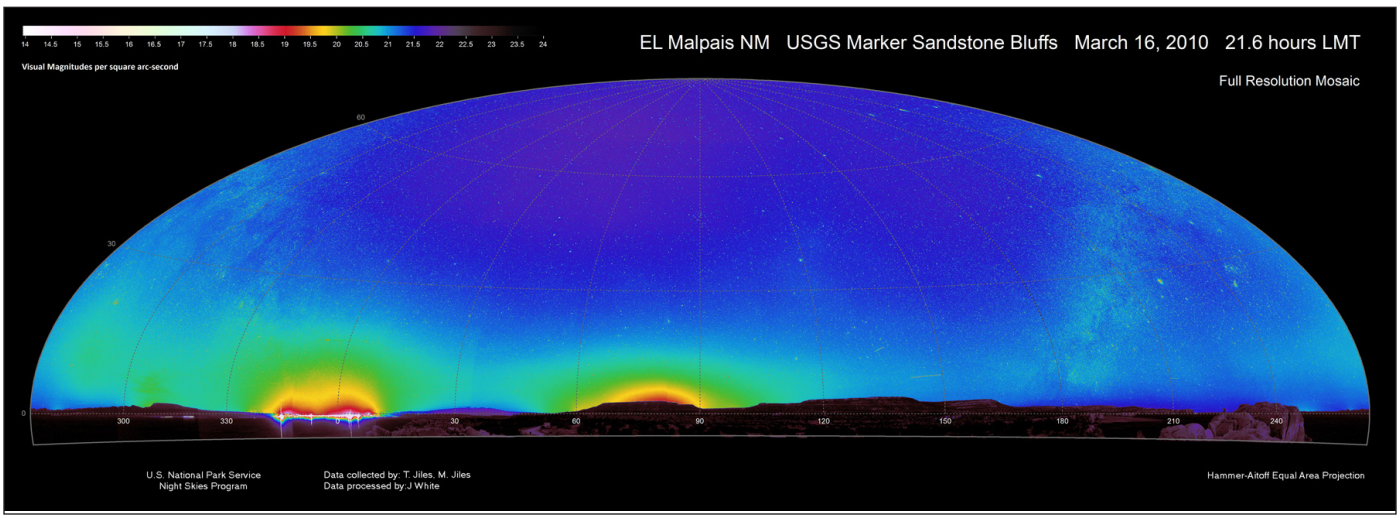


Figure 4.2.4-4. Panoramic all-sky mosaic of all sources of light (natural and anthropogenic) at El Malpais National Monument from Sandstone Bluffs. Credit: NPS Night Skies and Natural Sounds Division.

Table 4.2.4-1. Summary of night sky condition rationale at El Malpais NM.

Indicator	Measure	Condition	Condition Rationale
Sky Brightness	All-sky Light Pollution Ratio	Good/ Moderate	Sky brightness, as measured by ALR, indicates good to moderate condition overall at El Malpais NM. This condition is based on NPS NSNSD benchmarks for non-urban parks, on ground-based measurements taken at three locations within the park, and a modeled estimate for the entire park. Ground-based data from Cerro Encierro (0.20) and the lower meadow (0.09) indicate good condition while data from Sandstone Bluffs (0.35) indicate moderate condition. The modeled ALR, derived from the 2001 World Atlas of Night Sky Brightness, was 0.17 and indicates good condition. Confidence level is high.
	Maximum Vertical Illuminance	Good/ Moderate	Sky brightness as measured by maximum vertical illuminance was 0.19 milli-Lux at Cerro Encierro and 0.08 milli-Lux at the lower meadow. These values reflect a rating of 48% above average natural conditions for Cerro Encierro and 20% above average natural conditions for the lower meadow. At Sandstone Bluffs maximum vertical illuminance was 0.36 milli-Lux, or 90% above average natural conditions. Specific benchmarks for condition classes have not been set; however, condition is estimated as good at Cerro Encierro and the lower meadow, and moderate at Sandstone Bluffs (J. White, personal communication, Nov. 2015).
	Horizontal Illuminance	Good	Sky brightness as measured by horizontal illuminance was 0.06 milli-Lux at Cerro Encierro and 0.07 milli-Lux at the lower meadow. These values reflect a rating of 8% above average natural conditions for both Cerro Encierro and the lower meadow. At Sandstone Bluffs horizontal illuminance produced a value of 0.09 milli-Lux, or 11% above average natural conditions. Specific benchmarks for condition classes have not been set; however, condition is estimated as good for all three locations (J. White, personal communication, Nov. 2015).
	Zenith Sky Brightness	Good/ Moderate	Zenith sky brightness indicates good to moderate condition overall at El Malpais NM. This condition is based on NPS Natural Sounds and Night Skies Division benchmarks for non-urban parks and on ground-based measures of zenith sky brightness at Cerro Encierro (21.74), the lower meadow (21.84), and at Sandstone Bluffs (21.54). Condition is good at Cerro Encierro and the lower meadow, and moderate at Sandstone Bluffs. Confidence level is high.
Sky Quality	Bortle Dark Sky Scale	Good/ Moderate	Sky quality as assessed by the Bortle dark sky scale indicates good to moderate condition overall at El Malpais NM. This condition is based on NPS NSNSD benchmarks for non-urban parks and on the qualitative assessment of Bortle class 3 at Cerro Encierro (good condition), Bortle class 2 at the lower meadow (good condition), and Bortle class 4 at Sandstone Bluffs (moderate condition). These classes are consistent with a rural sky at Cerro Encierro, a typical dark sky at the lower meadow, and the transition from rural to suburban skies at Sandstone Bluffs. Because this measure is qualitative, it has low confidence level.

depending on location within the national monument.

Uncertainties

The Bortle Dark Sky Scale estimates have inherent uncertainties and error. The principle drawback of the Bortle Scale is that it relies upon human visual observers. Differences in visual acuity, experience and knowledge, as well as time and effort expended can influence the estimates (Bortle 2001, Moore 2001). Modeled data are based on 1996 satellite imagery, and ground truthed with NPS ground-based measures. Changes in population levels, private and commercial building growth, and energy development could impact current ALR values.

4.2.5. Sources of Expertise

Chad Moore and Jeremy White, Natural Sounds and Night Skies Division, part of the NPS Natural Resource Stewardship and Science Directorate, provided information pertaining to night sky data collection methodology and interpretation of results. Moore earned a master's degree in earth science in 1996 and began working for the NPS shortly thereafter. Moore is the Night Skies Program manager for a small team of scientists that measure, restore, and promote the proper management of the night sky resource. He and team member Dan Duriscoe have developed an automated all-sky camera capable of precise measurement of light pollution. White earned his Bachelors degree in Ecology and Systematic Biology in 2004 and began working with the NPS in 2005. White is a Physical Scientist with the Night Skies Program responsible for data collection and analysis, interpretation, and public outreach. Since 2001 the team has collected sky quality inventories at over 110 U.S. national parks.

This section was authored by wildlife biologist and writer Lisa Baril.

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4.3. Soundscape

Indicators/Measures

- Sound Level (2 measures)

Condition - Trend - Confidence Level



Good - Insufficient Data - Medium

4.3.1. Background and Importance

Our ability to see is a powerful tool for experiencing our world, but sound adds a richness that sight alone cannot provide. In many cases, hearing is the only option for experiencing certain aspects of our environment, and an unimpaired acoustical environment is an important part of overall National Park Service (NPS) visitor experience and enjoyment, as well as vitally important to overall ecosystem health.

In a 1998 survey of the American public, 72% of respondents identified opportunities to experience natural quiet and the sounds of nature as an important reason for having national parks (Haas and Wakefield 1998). Additionally, 91% of NPS visitors "consider enjoyment of natural quiet and the sounds of nature as compelling reasons for visiting national parks" (McDonald et al. 1995) (Figure 4.3.1-1). Despite this desire for quiet environments, noise continues to intrude upon natural areas and has become a source of concern in national parks (Lynch et al. 2011).

A park's natural soundscape is an inherent component of "the scenery and the natural and historic objects and the wildlife" protected by the Organic Act of 1916. NPS Management Policies (§ 4.9) (2006) require preservation of parks' natural soundscapes and restoration of degraded soundscapes to natural conditions wherever possible. Additionally, NPS is required to prevent or minimize degradation of the natural soundscapes from noise (i.e., any unwanted sound). Although the management policies currently refer to the term soundscape as the aggregate of all natural sounds that occur in a park, differences exist between the physical sound sources and human perceptions of those sound sources. The physical sound



NPS

Figure 4.3.1-1. Elk vocalizations contribute to the natural sounds heard at El Malpais NM.

resources (e.g., wildlife, waterfalls, wind, rain, and cultural or historical sounds), regardless of their audibility, at a particular location, is referred to as the acoustical environment, while the human perception of that acoustical environment is defined as the soundscape. Clarifying this distinction will allow managers to create objectives for safeguarding both the acoustical environment and the visitor experience.

In addition, sound plays a critical role for wildlife communication. Activities such as courtship, predation, predator avoidance, and effective use of habitat rely on the ability to hear with studies showing that wildlife can be adversely affected by intrusive sounds. While the severity of the impacts varies depending on the species and other conditions, documented responses of wildlife to noise include increased heart rate, startle responses, flight, disruption of behavior, separation of mothers and young, and interference with communication (Selye 1956, Clough 1982, USDA 1992, Anderssen et al. 1993, NPS 1994, Dooling and Popper 2007, Kaseloo 2006).

Sound Characteristics

Humans and wildlife perceive sound as an auditory sensation created by pressure variations that move through a medium such as water or air. Sound is measured in terms of frequency (pitch) and amplitude (loudness) (Templeton and Sacre 1997, Harris 1998).

Frequency, measured in Hertz (Hz), describes the cycles per second of a sound wave and is perceived by the ear as pitch. Humans with normal hearing can hear sounds between 20 Hz and 20,000 Hz and are most sensitive to frequencies between 1,000 Hz and 6,000 Hz. High frequency sounds are more readily absorbed by the atmosphere or scattered by obstructions than low frequency sounds. Low frequency sounds diffract more effectively around obstructions, therefore, travel farther.

The amplitude (or loudness) of a sound, measured in decibels (dB), is logarithmic, which means that every 10 dB increase in sound pressure level (SPL) represents a tenfold increase in sound energy. This also means that small variations in SPL can have significant effects on the acoustical environment. For instance, a 6 dB reduction in background noise level would produce a 4x increase in listening area (Figure 4.3.1-2). Changes in the background noise level cause a change in listening opportunity. These lost opportunities will approach a halving of alerting distance and a 75% reduction of listening area for each 6 dB increase in affected band level (Barber et al. 2010).

SPL is commonly summarized in terms of dBA (A-weighted SPL). This metric significantly discounts sounds below 1,000 Hz and above 6,000 Hz to approximate the variation in human hearing sensitivity.

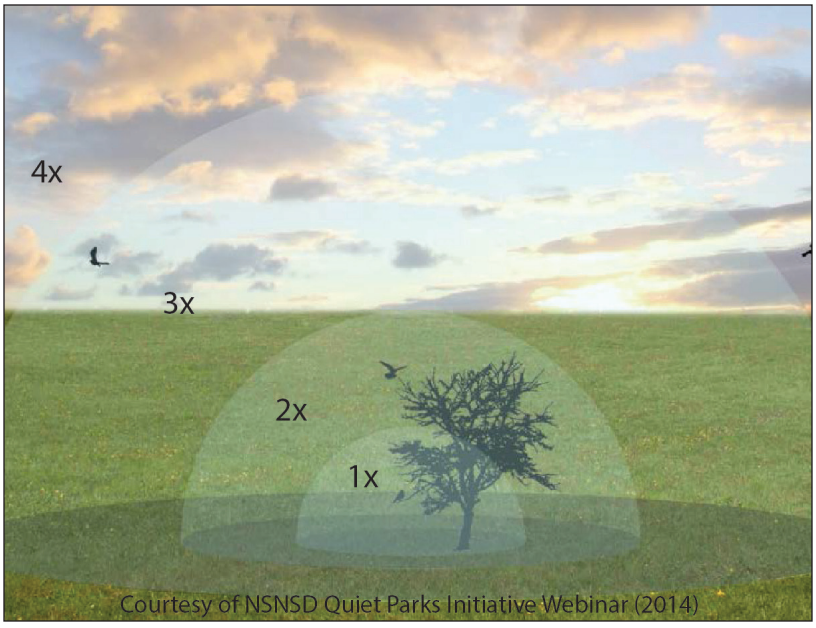


Figure 4.3.1-2. A 6 dB reduction in background noise level would produce a 4x increase in listening area (NPS NSNSD 2014).

4.3.2. Data and Methods

Baseline acoustical monitoring data, including:

- sound level data in the form of A-weighted decibel readings (dBA) every second,
- continuous digital audio recordings,
- one third octave band data every second ranging from 12.5 Hz – 20,000 Hz, and

- meteorological data

were collected by the NPS Natural Sounds and Night Skies Division (NSNSD) scientists during the months of June and July, 2009. Acoustical monitoring systems were deployed for approximately 30 days each at three locations within the national monument: Lost Woman, Sandstone Bluffs, and Lava Falls (Figure 4.3.2-1) .

Sandstone Bluffs and Lava Flows monitoring sites were located on the eastern side of the park close to New Mexico Highway 117. The Lost Woman site was located on the western side of the park farther away from New Mexico Highway 53 than the other two sites were from Highway 117. The characteristics of all monitoring locations are summarized in Table 4.3.2-1.

Table 4.3.2-1. Location characteristics of acoustical monitoring sites at El Malpais National Monument (excerpted from NPS-NSNSD 2009).

Location	Dates Deployed	Vegetation	Elevation (m)
Lost Woman	6/9/2009-7/14/2009	Ponderosa pine	2344
Sandstone Bluffs	6/11/2009-7/15/2009	Pinyon Juniper, High use area	2130
Lava Falls	6/15/2009-7/14/2009	Bare rock/ lava	2170

Indicators/Measures

Sound Level (2 measures)

Sound levels at the monument were evaluated in two ways for the purposes of this condition assessment (1) using the on-site results from the acoustical monitoring effort (NPS NSNSD 2009) to determine percent time above reference sound levels, and (2) using the geospatial sound modeling result for the impact between natural and existing acoustic conditions at the monument (Mennitt et al. 2013).

The geospatial model estimated sound pressure levels for the continental United States by using actual acoustical measurements combined with a multitude of explanatory variables such as location, climate, landcover,

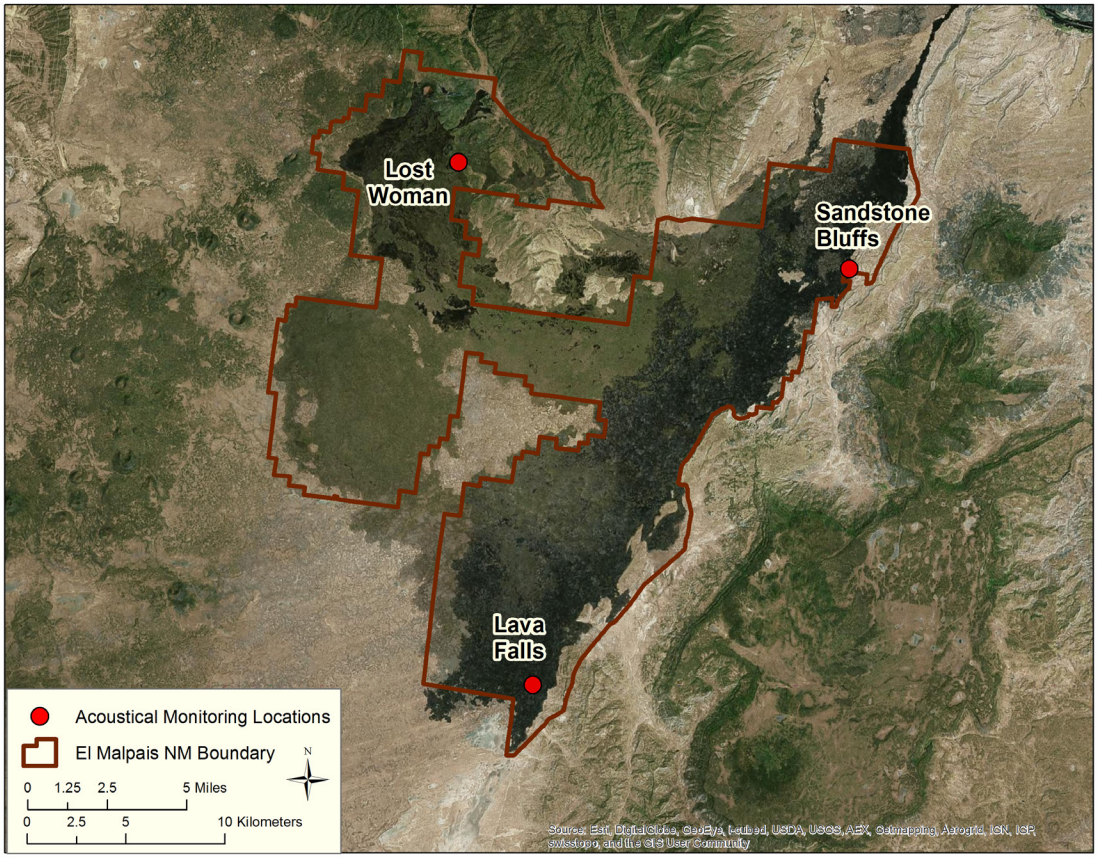


Figure 4.3.2-1. Locations of 2009 acoustical monitoring sites at El Malpais NM.

hydrology, wind speed, and proximity to noise sources (e.g., roads, railroads, and airports). The 270 m resolution model predicts daytime sound levels during midsummer. Each square of color on the map represents 270 m2 and each pixel on the map represents a median sound level (L50). It should be noted that while the model excels at predicting acoustic conditions over large landscapes, it may not reflect recent localized changes such as new access roads or development.

Model parameters useful for assessing a park's acoustic environment include the understanding of a) natural conditions, b) existing acoustic conditions including both natural and human-caused sounds, and c) the impact of human-caused sound sources in relation to natural conditions. The L_{50} impact condition demonstrates the influence of human activities to the acoustic environment and is calculated by subtracting the natural condition from the existing condition. The three models are run separately, and NSNSD "zeroes" out all anthropogenic contributions like roads, development, and cities to predict impact, but the impact stats will not always be exactly equal to existing minus natural (E. Brown, NSNSD pers. comm.).

4.3.3. Reference Conditions

Percent Time Above Reference Sound Levels

Human responses to sound levels can serve as a proxy for potential impacts to other vertebrates because humans have more sensitive hearing at low frequencies than most species (Dooling and Popper 2007). Table 4.3.3-1 summarizes sound levels that relate to human health and speech, as documented in the scientific literature. The first, 35 dBA, is designed to address the health effects of sleep interruption. Recent studies suggest that sound events as low as 35 dBA can have adverse effects on blood pressure while sleeping (Haralabidis, 2008). The second value addresses the World Health Organization's recommendations that noise levels inside bedrooms remain below 45 dBA (Berglund et al., 1999). The third value, 52 dBA, is based on the U.S. EPA's speech interference threshold for speaking in a raised voice to an audience at 10 meters (32.8 ft) (USEPA 1974). This threshold addresses the effects of sound on interpretive presentations in parks. The final value, 60 dBA, provides a basis for estimating impacts on normal voice communications at 1 meter (3.28 ft). Hikers and visitors viewing scenic vistas in the park would likely be conducting such conversations.

L_{50} Impact (Mennitt et al. (2013)

Turina et al. (2013) developed two categories, urban and non-urban, of L_{50} impact reference conditions based on the proximity of a park to urban areas as identified by the U.S. Census Bureau (2010). Non-urban parks had at least 90% of their areas outside designated Urban Areas (Turina et al. 2013).

Sound levels at non-urban parks, such as the monument, most often exhibit less divergence between existing and natural sound levels, making them quieter areas that are more susceptible to noise. Visitors likely have a greater expectation for quiet at non-urban parks and wildlife are likely more adapted to a noise-free environment. Accordingly, the L_{50} impact reference conditions for non-urban parks are more stringent than for urban parks. Reference conditions for both percent time above reference sound levels and L_{50} impact measures are presented in Table 4.3.3-2.

Table 4.3.3-1. Explanation of reference sound level values (NPS 2013).

Sound Levels (dBA)	Relevance
35	Blood pressure and heart rate increase in sleeping humans (Haralabidis et al. 2008)
45	World Health Organization's recommendation for maximum noise levels inside bedrooms (Berglund et al. 1999)
52	Speech interference for interpretive programs (U.S. EPA 1974)
60	Speech interruption for normal conversation (U.S. EPA 1974)

Table 4.3.3-2. Reference conditions used to assess the sound levels at El Malpais National Monument.

Indicator	Measure	Good	Moderate	Significant Concern
Sound Level	% Time Above Reference Sound Levels	The majority of sound levels recorded were <44.99 dBA.	The majority of sound levels recorded were between 45 - 51.99 dBA.	The majority of sound levels recorded were >52 dBA.
	L_{50} Impact	National Park Service Natural Sounds and Night Skies Thresholds for Non-urban Parks in dBA (Turina et al. 2013).		
		≤ 1.5	1.5 - ≤ 3.0	>3

4.3.4. Condition and Trend

Percent Time Above Reference Sound Levels

Figure 4.3.4-1 shows the percent time sound levels were above the reference sound levels at each monitoring location during day (7 a.m. - 7 p.m.) and nighttime (7 p.m. - 7 a.m.) hours. Sound levels mainly exceeded the 35 dBA metric with 13.0 to 44.2% of daytime hours above this level and Lost Woman representing the highest percent time above the reference. Sound levels exceeded the 45 dBA metric 1.2 to 7.5% of the daytime hours, once again with Lost Woman representing the highest percent time above the reference level. Sound levels at all three sites rarely exceeded 52 dBA during day or night.

As would be expected, sounds were lower at night than during the day. Nighttime sound levels only exceeded the 35 dBA reference value 5.7% to 18.2% of the time. During the nighttime hours, sound levels exceeded the 45 dBA reference level for recommended maximum noise levels inside bedrooms only 0.41-0.57% of the time suggesting a quiet environment.

Low frequency sounds (20-800 Hz) of which transportation noises are often a major contributor, comprised more of the sounds heard at the sites during both day and nighttime hours, with the exception of Lava Falls during the night. While the metrics presented in the snapshot report did not fully identify sound sources or the natural ambient conditions, it was noted that the sound sources of interest included small-engine aircraft taking off from a nearby airport (NPS-NSNSD 2009).

Aside from New Mexico State Highways 53 and 117 flanking the northern and eastern boundaries of the monument, respectively, there are very few roads that bisect the park

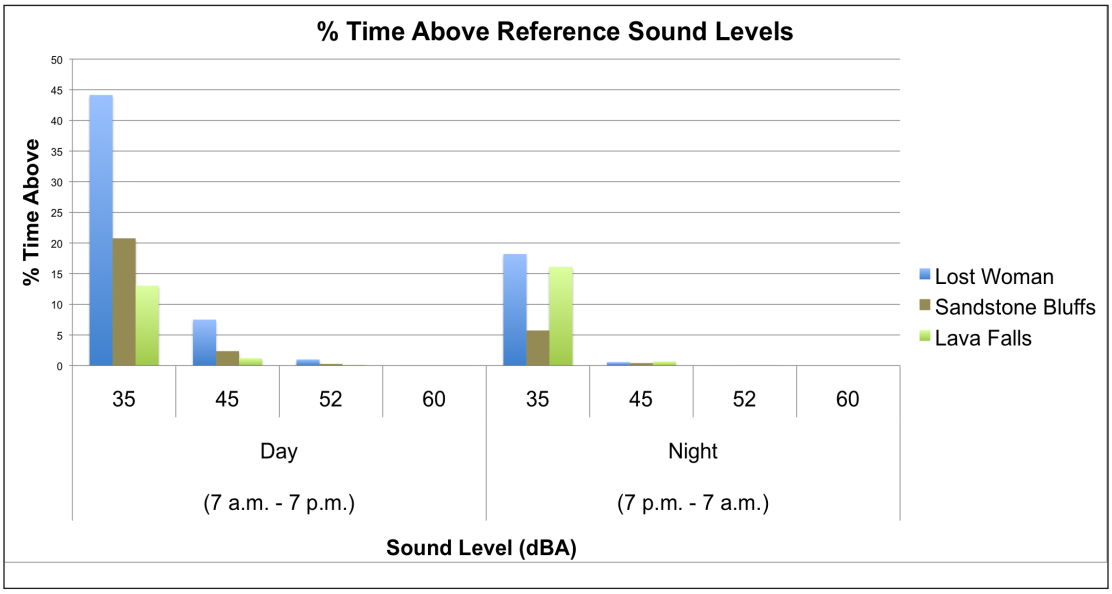


Figure 4.3.4-1. Percent time above reference sound levels within the 12.5-20,000 Hz frequency recorded at El Malpais NM's Lost Woman, Sandstone Bluffs, and Lava Falls acoustical monitoring sites.

(Figure 4.3.4-2; El Morro on the left and El Malpais on the right). In fact most of the park is comprised of an area >100 km^2 without roads (NPS 2014, ESRI 2005). In addition, the monument is primarily surrounded by the even larger El Malpais National Conservation Area, managed by the Bureau of Land Management, which contains two areas of designated wilderness and a third wilderness study area. These protected areas will most likely contribute to maintaining the monument's excellent soundscape condition.

Relative to the percent time above reference sound level measure, all monitoring locations are considered to be in good condition.

L_{50} Impact (Mennitt et al. (2013)

Figure 4.3.4-2 shows the modeled mean impact sound level map for the monument, which was 0.38 decibels (dBA) above natural conditions, ranging from 0 dBA in the least impacted areas to 12.4 dBA in the most impacted areas. The map depicts the area most influenced by human-caused sounds (i.e., lighter colored areas), which is located in Grants, NM. The existing and natural acoustic environment condition maps for the monument are included in Appendix D.

Summary statistics of the L_{50} values for the natural, existing, and impact conditions are provided in Table 4.3.4-1. Average values represent the average L_{50} value occurring within the park boundary and since this value is a mean, visitors may experience sound levels higher and lower than the average L_{50}. A one decibel change is not readily perceivable by the human ear, but any addition to this difference could begin to impact a visitor's listening ability to hear natural sounds or interpretive programs.

Mennitt et al. (2013) suggest that in a natural environment, the average summertime L_{50}, which is the sound level exceeded half of the time (and is a fair representation of expected conditions) is not expected to exceed 41 dBA. They also state that "an impact of 3 dBA suggests that anthropogenic noise is noticeable at least 50% of the hour or more." The modeled results for the monument were well below 41 dBA, and the average impact level was considered to be in good condition according to the reference thresholds developed by Turina et al. (2013).

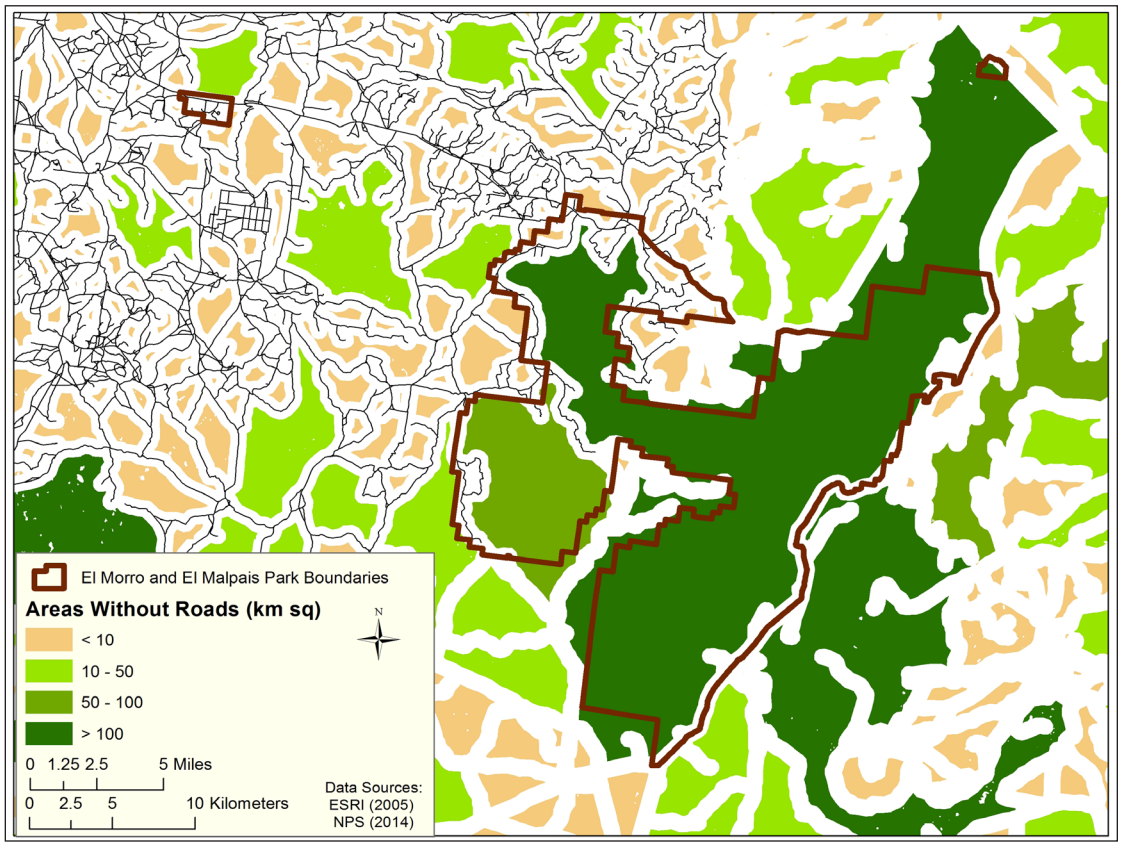


Figure 4.3.4-2. There are very few roads surrounding El Malpais NM, creating relatively large patches without roads. This contributes to the monument's soundscape condition. Data Sources: NPS (2014) and ESRI (2005, 2010).

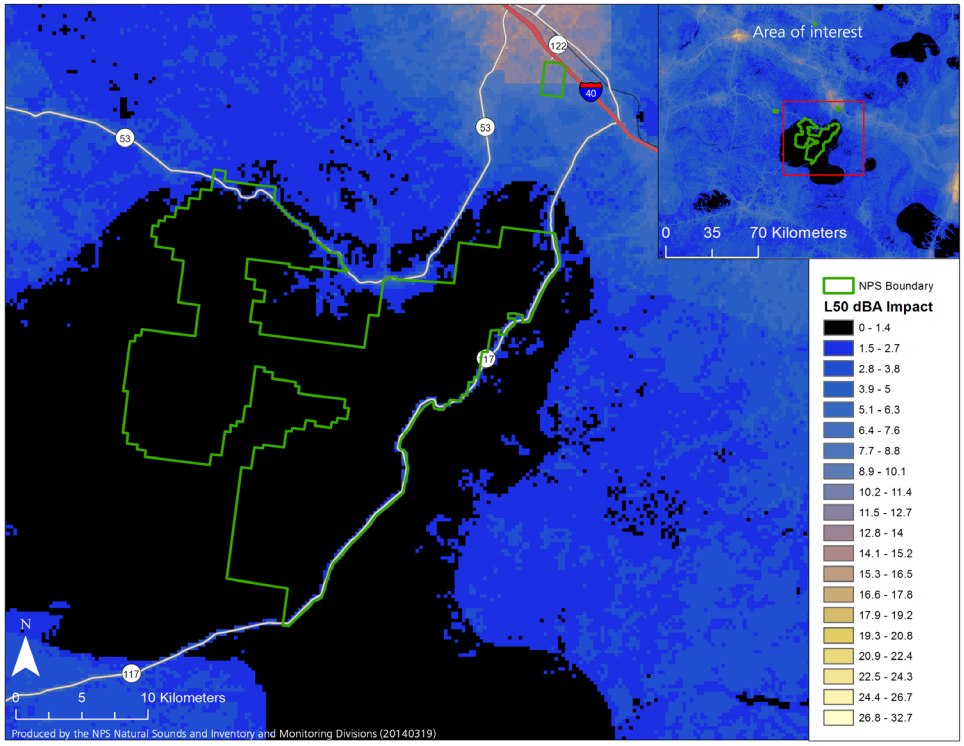
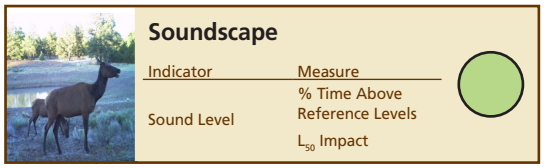


Figure 4.3.4-3. The modeled L_{50} impact sound level at El Malpais NM (Mennitt et al. 2013). Lighter colors represent higher impact areas.



Overall Condition and Trend

For assessing the condition of the national monument's soundscape, we used one indicator with two measures, which are summarized in Table 4.3.4-2. Overall, we consider the soundscape at the national monument to be in good condition, with an unknown trend.

Level of Confidence and Key Uncertainties

Monitoring was only conducted for one season in 2009, and while the results provided more data than what is typically available for most soundscape condition assessments, the information is already six years old and may no longer reflect current condition. Additionally, the information in the monitoring report was a 'snapshot' of the acoustical conditions. Further analysis will provide more information about the types of sounds recorded and an estimate of the natural ambient condition.

4.3.5. Sources of Expertise

The NPS Natural Sounds and Night Skies Division (NSNSD) scientists help parks manage sounds in a way that balances the various expectations of park visitors with the protection of park resources. They provide technical assistance to parks in the form of acoustical monitoring, data collection and analysis, and in developing acoustical baselines for planning and reporting purposes. For more information, see http://nps.gov/nsnsd.

Emma Brown, Acoustical Resource Specialist with the NSNSD, provided an NRCA

Table 4.3.4-1. Values represent the minimum, maximum, and average L_{50} measurements in each acoustic environment (Excel table provided by E. Brown, 2015).

Acoustic Environment Condition	(dBA)		
	Min.	Max.	Avg..
Natural	25.1	29.8	27.8
Existing	24.2	38.7	28.0
Impact	0	12.4	0.38

Table 4.3.4-2. Summary of the soundscape indicator and measures and their contribution to the overall soundscape condition.

Indicators of Condition	Measures	Condition	Rationale for Condition
Sound Level	% Time Above Reference Sound Levels	Good	The majority of existing sound levels heard at all sites were <44.99 dBA, suggesting a relatively quiet environment. We consider this measure to be in good condition.
	L_{50} Impact	Good	The modeled average impact sound level for the national monument of 0.38 dBA, which is considered to be in good condition based on threshold values for non-urban parks (Turina et al. 2013).

soundscape template used to develop this assessment and the sound model statistics and maps.

The NPS NPScape Program provides data and analysis related to resource conservation for parks and partners. The area without roads dataset was obtained from the program's website. For more information, see http://science.nature.nps.gov/im/monitor/npscape/concept.cfm.

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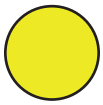
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4.4. Air Quality

Indicators/Measures

- Visibility (1 measure)
- Ozone (2 measures)
- Wet Deposition (3 measures)

Condition – Trend – Confidence



Moderate - Insufficient Data - Medium

4.4.1. Background and Importance

Under the direction of the NPS' Organic Act, Air Quality Management Policy 4.7.1 (NPS 2006), and the Clean Air Act (CAA) of 1970 (U.S. Federal Register 1970), the NPS has a responsibility to protect air quality and any air quality related values (e.g., scenic, biological, cultural, and recreational resources) that may be impaired from air pollutants.

One of the main purposes of the CAA is "to preserve, protect, and enhance the air quality in national parks" and other areas of special national or regional natural, recreational, scenic or historic value. The CAA includes special programs to prevent significant air quality deterioration in clean air areas and to protect visibility in national parks and wilderness areas (NPS-ARD 2012a) (Figure 4.4.1-1).

Different categories of air quality areas have been established through the authority of the CAA: Class I and II. The air quality classes are allowed different levels of permissible air pollution, with Class I receiving the greatest protection and strictest regulation. The CAA gives federal land managers responsibilities and opportunities to participate in decisions being made by regulatory agencies that might affect air quality in the federally protected areas they administer (NPS-ARD 2005).

Class I areas include parks that are larger than 2,428 ha (6,000 acres) or wilderness areas over 2,023 ha (5,000 acres) that were in existence when the CAA was amended in 1977 (NPS-ARD 2015a). Since El Malpais National Monument's wilderness is proposed and not legislated, it is designated as a Class II airshed. However, it is important to note that even though the CAA gives Class I areas the greatest



NPS

Figure 4.4.1-1. El Malpais National Monument is located within a Class II airshed.

protection against air quality deterioration, NPS management policies do not distinguish between the levels of protection afforded to any unit of the National Park System (NPS 2006).

Air Quality Standards

Air quality is deteriorated by many forms of pollutants that either occur as primary pollutants, emitted directly from sources such as power plants, vehicles, wildfires, and wind-blown dust, or as secondary pollutants, which result from atmospheric chemical reactions. The CAA requires the Environmental Protection Agency (EPA) to establish National Ambient Air Quality Standards (NAAQS) (40 CFR part 50) to regulate these air pollutants that are considered harmful to human health and the environment (EPA 2012a). The two types of NAAQS are primary and secondary, with the primary standards establishing limits to protect human health, and the secondary standards establishing limits to protect public welfare from air pollution effects, including decreased visibility, damage to animals, crops, vegetation, and buildings (EPA 2012a).

The NPS' Air Resources Division (NPS-ARD) air quality monitoring program uses EPA's NAAQS, natural visibility goals, and ecological thresholds as benchmarks to assess current conditions of visibility, ozone, and atmospheric deposition throughout Park Service areas.

Visibility affects how well (acuity) and how far (visual range) one can see (NPS-ARD 2002), but air pollution can degrade visibility. Both particulate matter (e.g. soot and dust) and certain gases and particles in the atmosphere, such as sulfate and nitrate particles, can create haze and reduce visibility.

Visibility can be subjective and value-based (e.g. a visitor's reaction viewing a scenic vista while observing a variety of forms, textures, colors, and brightness) (Figure 4.4.1-2) or it can be measured objectively by determining the size and composition of particles in the atmosphere that interfere with a person's ability to see landscape features (Malm 1999). The viewshed section (4.1) of this assessment addresses the subjective aspects of visibility, whereas this section addresses measurements of particles and gases in the atmosphere affecting visibility.

Ozone is a gaseous constituent of the atmosphere produced by reactions of nitrogen oxides (NO_x) from vehicles, powerplants, industry, and fire and volatile organic compounds from industry, solvents,



NPS

Figure 4.4.1-2. A cloudy day at El Malpais NM.

and vegetation in the presence of sunlight (Porter and Wondrak-Biel 2011). It is one of the most widespread air pollutants (NPS-ARD 2003a), and the major constituent in smog. Ozone can be harmful to human health, and it is also phytotoxic, causing foliar damage to plants (NPS-ARD 2003a). The foliar damage requires the interplay of several factors, including the sensitivity of the plant to the ozone, the level of ozone exposure, and the exposure environment. The highest ozone risk exists when the species of plants are highly sensitive to ozone, the exposure levels of ozone significantly exceed the thresholds for foliar injury, and the environmental conditions, particularly adequate soil moisture, foster gas exchange and the uptake of ozone by plants (Kohut 2004).

Ozone penetrates leaves through stomata (openings) and oxidizes plant tissue, which alters the physiological and biochemical processes (NPS-ARD 2012b). Once the ozone is inside the plant's cellular system, the chemical reactions can cause cell injury or even death (NPS-ARD 2012b), but more often reduces the plant's resistance to insects and diseases, reduces growth, and reduces reproductive capability (NPS-ARD 2012c).

Air pollutants can be deposited to ecosystems through rain and snow (wet deposition) or dust and gases (dry deposition). Nitrogen and sulfur air pollutants are commonly deposited as nitrate, ammonium, and sulfate ions and can have a variety of effects on ecosystem health, including acidification, fertilization or eutrophication, and accumulation of mercury or toxins (NPS-ARD 2010, Fowler et al. 2013). Atmospheric deposition can also change soil pH, which in turn, affects microorganisms, understory plants, and trees (NPS-ARD 2010). Certain ecosystems are more vulnerable to nitrogen or sulfur deposition than others, including high-elevation ecosystems in the western United States, upland areas in the eastern part of the country, areas on granitic bedrock, coastal and estuarine waters, arid ecosystems, and some grasslands (NPS-ARD 2015a). Increases in nitrogen have been found to promote invasions of fast-growing annual grasses (e.g., cheatgrass) and exotic species (e.g., Russian thistle) at the expense of native species (Brooks 2003, Allen et al. 2009, Schwinning et al. 2005). Increased grasses can increase fire risk (Rao et al. 2010), with profound implications for biodiversity in non-fire adapted ecosystems. Nitrogen may also increase water use in plants like big sagebrush (Inouye 2006).

According to the EPA (2012a), in the United States, roughly two thirds of all sulfur dioxide (SO_2)and one quarter of all NO_x come from electric power generation that relies on burning fossil fuels. Sulfur dioxide and nitrogen oxides are released from power plants and other sources, and ammonia is released by agricultural activities, feedlots, fires, and catalytic converters. In the atmosphere these transform to sulfate, nitrate, and ammonium and can be transported long distances across state and national borders, impacting resources, including at El Malpais National Monument (EPA 2012b).

Mercury and other toxic pollutants (e.g., pesticides, dioxins, PCBs) accumulate in the food chain and can affect both wildlife and human health. Elevated levels of mercury and other airborne toxic pollutants like pesticides in aquatic and terrestrial food webs can act as neurotoxins in biota that accumulate fat and/or muscle-loving contaminants. Sources of atmospheric mercury include by-products of coal-fire combustion, municipal and medical incineration, mining operations, volcanoes, and geothermal vents. High mercury concentrations in birds, mammals, amphibians, and fish can result in reduced foraging efficiency, survival, and reproductive success (NPS-ARD 2015b).

Additional air contaminants of concern include pesticides (e.g., DDT), industrial by-products (PCBs), and emerging chemicals such as flame retardants for fabrics (PBDEs). These pollutants enter the atmosphere from historically contaminated soils, current day industrial practices, and air pollution (Selin 2009).

4.4.2. Data and Methods

The approach we used for assessing the condition of air quality within the park's airshed was developed by the NPS-ARD

for use in Natural Resource Condition Assessments (NPS-ARD 2015 b,c).

NPS-ARD uses all available data from NPS, EPA, state, and/or tribal monitoring stations to interpolate air quality values, with a specific value assigned to the maximum value within each park. Even though the data are derived from all available monitors, data from the closest stations "outweigh" the rest.

Trends are computed from data collected over a 10-year period at on-site or nearby representative monitors. Trends are calculated for sites that have at least 6 years of annual data and an annual value for the end year of the reporting period.

Indicators/Measures
Visibility (Haze Index)

Visibility is monitored by the Interagency Monitoring of Protected Visual Environments (IMPROVE) Program (NPS-ARD 2010).

NPS-ARD assesses visibility condition status based on the deviation of the estimated current Group 50 visibility conditions from estimated Group 50 natural visibility conditions; (i.e., those estimated for a given area in the absence of human- caused visibility impairment, EPA-454/B003- 005). Group 50 is defined as the mean of the visibility observations falling within the range of the 40th through the 60th percentiles, as expressed in terms of a Haze Index in deciviews (dv). A factor of the haze index is light extinction, which is used as an indicator to assess the quality of scenic vista and is proportional to the amount of light lost due to scattering or absorption by particles in the air as light travels a distance of one million meters (NPS-ARD 2003). The haze index for visibility condition is calculated as follows:

Visibility Condition/Haze Index (dv) =
estimated current Group 50 visibility –
estimated Group 50 visibility
(under natural conditions)

The deciview scale scores pristine conditions as a zero and increases as visibility decreases (NPS-ARD 2015b).

For visibility condition assessments, annual average measurements for Group 50 visibility are averaged over a 5-year period at each visibility monitoring site with at least 3-years of complete annual data. Five-year averages are then interpolated across all monitoring locations to estimate 5-year average values for the contiguous U.S. The maximum value within monument boundaries is reported as the visibility condition from this national analysis.

Visibility trends are computed from the Haze Index values on the 20% haziest days and the 20% clearest days, consistent with visibility goals in the Clean Air Act and Regional Haze Rule, which include improving visibility on the haziest days and allowing no deterioration on the clearest days. Although this legislation provides special protection for NPS areas designated as Class I, the NPS applies these standard visibility metrics to all units of the NPS. If the Haze Index trend on the 20% clearest days is deteriorating, the overall visibility trend is reported as deteriorating. Otherwise, the Haze Index trend on the 20% haziest days is reported as the overall visibility trend.

Indicators/Measures
Level of Ozone (Human Health: Annual 4th-highest 8hr concentration and Vegetation Health: 3-month maximum 12hr W126)

Ozone is monitored across the U.S. through air quality monitoring networks operated by the NPS, EPA, states, and others. Aggregated ozone data are acquired from the EPA Air Quality System (AQS) database. Note that prior to 2012, monitoring data were also obtained from the EPA Clean Air Status and Trends Network (CASTNet) database.

The primary National Ambient Air Quality Standard (NAAQS) for ground-level ozone is set by the EPA, and is based on human health effects. The 2008 NAAQS for ozone was a 4th-highest daily maximum 8-hour ozone concentration of 75 parts per billion (ppb). On October 1, 2015, the EPA strengthened the national ozone standard by setting the new level at 70 ppb. The NPS-ARD assesses the

status for human health risk from ozone using the 4th-highest daily maximum 8-hour ozone concentration in ppb. Annual 4th-highest daily maximum 8-hour ozone concentrations are averaged over a 5-year period at all monitoring sites. Five-year averages are interpolated for all ozone monitoring locations to estimate 5-year average values for the contiguous U.S. The ozone condition for human health risk at the park is the maximum estimated value within park boundaries derived from this national analysis.

Exposure indices are biologically relevant measures used to quantify plant response to ozone exposure. These measures are better predictors of vegetation response than the metric used for the human health standard. One annual index is the W126, which preferentially weighs the higher ozone concentrations most likely to affect plants and sums all of the weighted concentrations during daylight hours (8AM– 8PM). The highest 3-month period that occurs during the ozone season is reported in "parts per million-hours" (ppm-hrs) and used for vegetation health risk from ozone condition assessments. NPS-ARD will begin calculating W126 for April to September for 2014 end year (K. Pugacheva, NPS-ARD, pers. comm.). Annual maximum 3-month 12-hour W126 values are averaged over a 5-year period at all monitoring sites with at least 3 years of complete annual data. Five-year averages are interpolated for all ozone monitoring locations to estimate 5-year average values for the contiguous U.S. The estimated current ozone condition for vegetation health risk at the park is the maximum value within park boundaries derived from this national analysis.

Indicators/Measures

Wet Deposition (Nitrogen, Sulfur, and Mercury)

Atmospheric wet deposition is monitored across the United States as part of the National Atmospheric Deposition Program/ National Trends Network (NADP/NTN) for nitrogen and sulfur wet deposition and at the Mercury Deposition Network (MDN) for mercury wet deposition.

Wet deposition is used as a surrogate for total deposition (wet plus dry), because wet deposition is the only nationally available monitored source of nitrogen and sulfur deposition data. Values for nitrogen (N) from ammonium and nitrate and sulfur (S) from sulfate wet deposition are expressed as amount of N or S in kilograms deposited over a one-hectare area in one year (kg/ha/yr).For nitrogen and sulfur condition assessments, wet deposition was calculated by multiplying nitrogen (from ammonium and nitrate) or sulfur (from sulfate) concentrations in precipitation by a normalized precipitation. Annual wet deposition is averaged over a 5-year period at monitoring sites with at least 3 years of annual data. Five-year averages are then interpolated across all monitoring locations to estimate 5-year average values for the contiguous U.S. For individual parks, minimum and maximum values within park boundaries are reported from this national analysis. To maintain the highest level of protection in the park, the maximum value is assigned a condition status. Wet deposition trends are evaluated using pollutant concentrations in precipitation (micro equivalents/liter) so that yearly variations in precipitation amounts do not influence trend analyses..

Total Mercury

The condition of mercury was assessed using estimated 3-year average mercury wet deposition (ug/m2/yr) and the predicted surface water methylmercury concentrations at NPS Inventory & Monitoring parks. It is important to consider both mercury deposition inputs and ecosystem susceptibility to mercury methylation when assessing mercury condition because atmospheric inputs of elemental or inorganic mercury must be methylated before it is biologically available and able to accumulate in food webs (NPS-ARD 2015c). Thus, mercury condition cannot be assessed according to mercury wet deposition alone. Other factors like environmental conditions conducive to mercury methylation (e.g., dissolved organic carbon, wetlands, pH) must also be considered (NPS 2015b).

Annual mercury wet deposition measurements are averaged over a 3-year period at all NADP-MDN monitoring sites with at least 3 years of annual data. Three-year averages are then interpolated across all monitoring locations using an inverse distance weighting method to estimate 3-year average values for the contiguous U.S. For individual parks, minimum and maximum values within park boundaries are reported from this national analysis.

Conditions of predicted methylmercury concentration in surface water are obtained from a model that predicts surface water methylmercury concentrations for hydrologic units throughout the U.S. based on relevant water quality characteristics (i.e., pH, sulfate, and total organic carbon) and wetland abundance (USGS 2015). The predicted methylmercury concentration at a park is the highest value derived from the hydrologic units that intersect the park.

4.4.3. Reference Conditions

The reference conditions against which current air quality parameters are assessed are identified by NPS ARD (2015c) for NRCAs and listed in Table 4.4.3-1.

Visibility

A visibility condition estimate of less than 2 dv above estimated natural conditions indicates a "good" condition, estimates ranging from 2-8 dv above natural conditions indicate "moderate" condition, and estimates greater than 8 dv above natural conditions indicate "significant concern." The NPS-ARD chose reference condition ranges to reflect the variation in visibility conditions across the monitoring network.

Ozone

The human health ozone condition thresholds are based on the 2015 ozone standard set by the EPA at a level to protect human health: 4th-highest daily maximum 8-hour ozone concentration of 70 ppb. The NPS-ARD rates ozone condition as "good" if the ozone concentrations are less than 54 ppb, which is in line with the updated Air Quality Index (AQI) breakpoints; "moderate" if the ozone concentration is between 55 and 70 ppb; and of "significant concern" if the concentration is greater than or equal to 71 ppb.

The W126 condition thresholds are based on information in EPA's Policy Assessment for the Review of the Ozone National Ambient Air Quality Standards (EPA 2014). Research has found that for a W126 value of:

- ≤ 7 ppm-hrs, tree seedling biomass loss is ≤ 2 % per year in sensitive species; and
- ≥13 ppm-hrs, tree seedling biomass loss is 4–10 % per year in sensitive species.

ARD recommends a W126 of < 7 ppm-hrs to protect most sensitive trees and vegetation and is considered good; 7-13 ppm-hrs to be in "moderate" condition; >13 ppm-hrs is considered to be of "significant concern" (NPS-ARD 2015b).

Wet Deposition

The NPS-ARD selected a wet deposition threshold of 1.0 kg/ha/yr as the level below which natural ecosystems are likely protected from harm, based on studies linking early

Table 4.4.3-1. Reference conditions for air quality parameters (NPS-ARD 2015c).

Air Quality Indicator	Significant Concern	Moderate	Good	Very Good
Visibility (dv)	>8	2-8	< 2	n/a
Ozone: Human Health (ppb)	≥ 71	55-70	≤ 54	n/a
Ozone: Vegetation Health (ppm-hrs)	>13	7-13	<7	n/a
Total N and Total S Wet Deposition (kg/ha/yr)	>3	1-3	< 1	n/a
Mercury Wet Deposition (µg/m2/yr)	≥ 9 and < 12	≥ 6 and < 9	≥ 3 and < 6	< 3
Predicted Methylmercury Concentration (ng/L)	≥ 0.075 and < 0.12	≥ 0.053 and < 0.075	≥ 0.038 and < 0.053	< 0.038

Table 4.4.3-2. Mercury condition assessment matrix (NPS-ARD 2015b).

Predicted Methylmercury Concentration Rating	Mercury Wet Deposition Rating				
	Very Low	Low	Mod-erate	High	Very High
Very Low					
Low					
Moderate					
High					
Very High					

Condition: Green = Good, Yellow = Moderate, Red = Significant Concern

stages of aquatic health decline correlated with 1.0 kg/ha/yr wet deposition of nitrogen both in the Rocky Mountains (Baron et al. 2011) and in the Pacific Northwest (Schibely et al. 2014). Parks with less than 1 kg/ha/yr of atmospheric wet deposition of nitrogen or sulfur compounds are assigned "good" condition, those with 1-3 kg/ha/yr are assigned "moderate" condition, and parks with depositions greater than 3 kg/ha/yr to be of "significant concern."

Mercury

Ratings for mercury wet deposition and predicted methylmercury concentrations can be evaluated using the mercury condition assessment matrix shown in Table 4.4.3-2 to identify one of three condition categories. Condition adjustments may be made if the presence of park-specific data on mercury in food webs is available and/or data are lacking to determine the wet deposition rating (NPS-ARD 2015b).

4.4.4. Condition and Trend

The values used to evaluate conditions for all air quality indicators and measures are listed in Table 4.4.4-1.

Visibility

The estimated 5-year (2009-2013) value (4.1 dv) for the park's visibility condition fell within the moderate condition rating, which indicates visibility is degraded from the good reference condition of <2 dv above the natural condition (NPS-ARD 2015c). For 2004–2013, the trend in visibility at El Malpais NM improved on the 20% clearest days (Figure 4.4.4-1) and remained relatively unchanged (no statistically significant trend) on the 20% haziest days (Figure 4.4.4-2) (IMPROVE Monitor ID: BALD1, AZ). The Clean Air Act visibility goal requires visibility improvement on the 20% haziest days, with no degradation on the 20% clearest days (excerpted from NPS-ARD 2015a).

Visibility impairment primarily results from small particles in the atmosphere that include natural particles from dust and wildfires and anthropogenic sources from organic compounds, NO_x and SO_2. The contributions made by different classes of particles to haze on the clearest days and on the haziest days are shown in Figures 4.4.4-3 and - 4, respectively, using data collected at Mount Baldy, Arizona's IMPROVE monitoring location.

The primary visibility impairing pollutants on both the clearest and haziest days from 2004-2013 were ammonium sulfate and organic carbon (NPS-ARD 2015a). Ammonium sulfate originates mainly from coal-fired

Table 4.4.4-1. Condition and trend results for air quality indicators at El Malpais National Monument (NPS-ARD 2015a).

Data Span	Ozone: Human Health (ppb)	Ozone: Vegetation Health (ppm-hrs)	Visibility (dv)	Total N (kg/ha/yr)	Total S (kg/ha/yr)	Mercury (µg/m2/yr)	Mercury (ng/L)
Condition: 2009-2013 2011-2013 for Mercury	Moderate (67.3)	Moderate (12.4)	Moderate (4.1)	Moderate (1.6)	Good (0.8)	Moderate (5.1-7.5)	Moderate (0.07)
Trend: 2004-2013	The trend in visibility at El Malpais NM improved on the 20% clearest days and remained relatively unchanged (no statistically significant trend) on the 20% haziest days (IMPROVE Monitor ID: BALD1, AZ) (text excerpted from NPS 2015a).						

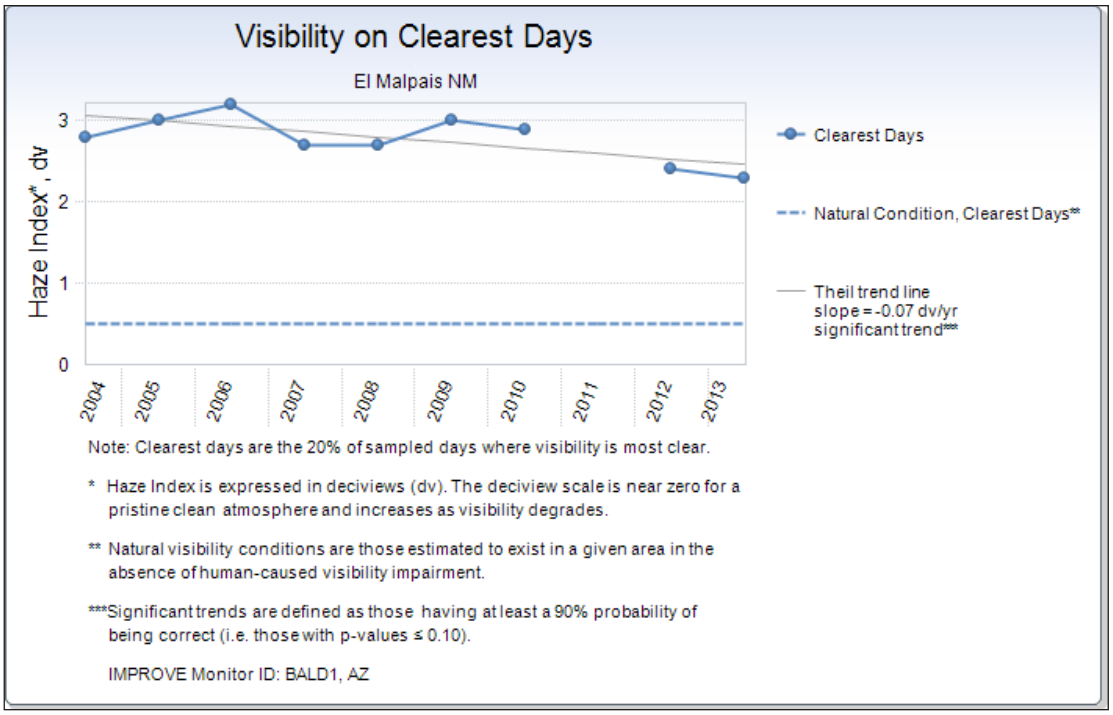


Figure 4.4.4-1. For 2004–2013, the trend in visibility at El Malpais NM improved on the 20% clearest days. Credit: NPS-ARD 2015a.

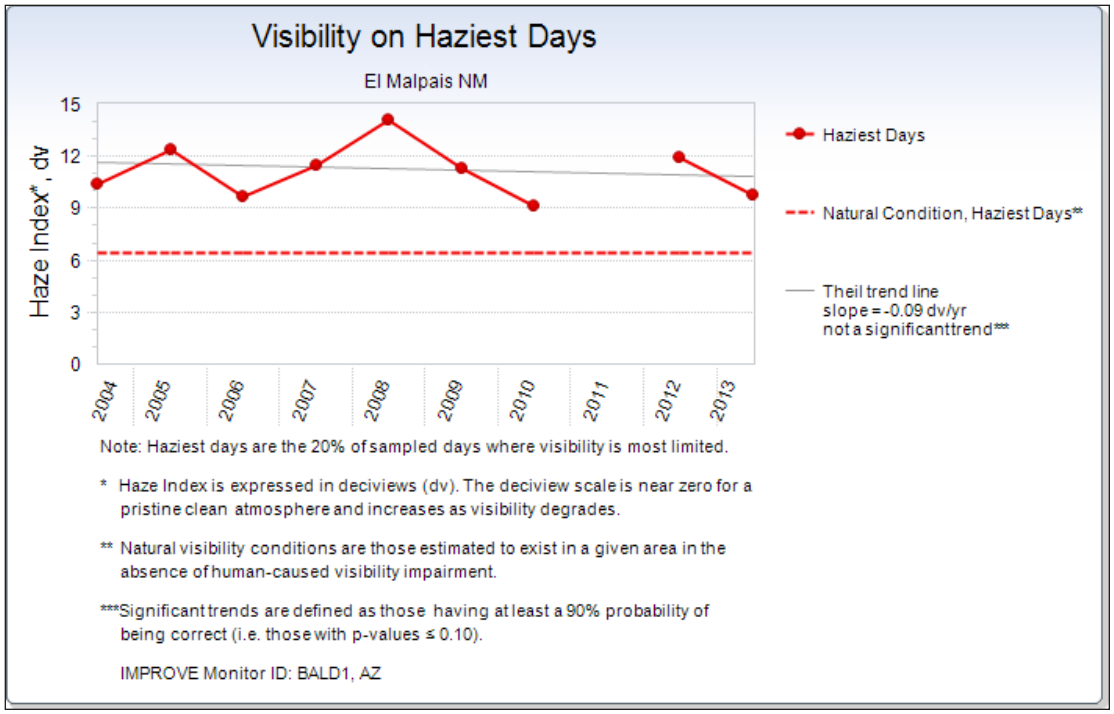


Figure 4.4.4-2. For 2004–2013, the trend in visibility at El Malpais NM remained relatively unchanged (no statistically significant trend) on the 20% haziest days. Credit: NPS-ARD 2015a.

power plants and smelters and organic carbon originates primarily from combustion of fossil fuels and vegetation.

In 2013, the clearest days occurred during the winter months (Dec.-Feb.) (Figure 4.4.4-5) while the haziest days occurred during the spring/summer months (May, June, and August) (Figure 4.4.4-6).

Ozone

Ozone data used for the condition assessment were derived from estimated five-year (2009-2013) values of 67.3 parts per billion for the 4th highest 8-hour average and 12.4 parts per million-hours for the W126 Index, which resulted in a moderate condition rating for both human and vegetation health (NPS-ARD 2015a).

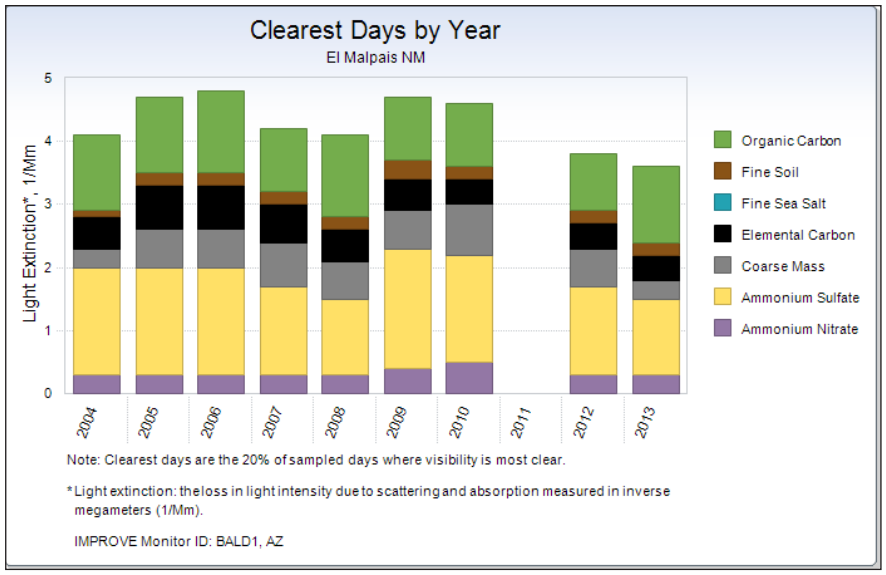


Figure 4.4.4-3. Visibility data collected at BALD1, AZ IMPROVE station showing the composition of particle sources contributing to haze during the clearest days by year from 2004-2013. Credit: NPS-ARD 2015a.

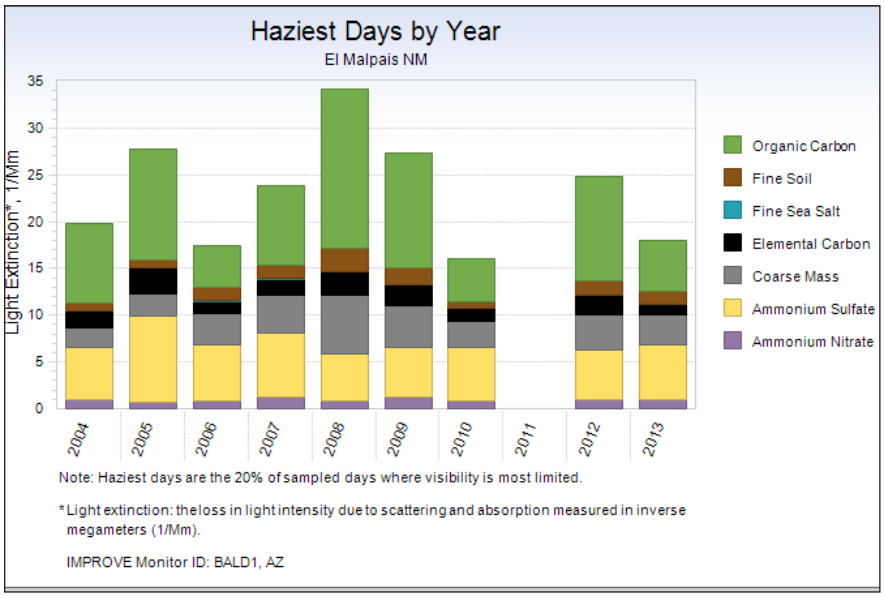


Figure 4.4.4-4. Visibility data collected at BALD1, AZ IMPROVE station showing the composition of particle sources contributing to haze during the haziest days by year from 2004-2013. Credit: NPS-ARD 2015a.

An ozone risk assessment was conducted by Kohut (2004, 2007) for Southern Colorado Plateau parks, concluding that plants in the monument were at low risk of foliar ozone injury. However, ozone concentrations and cumulative doses at the park are high enough to induce foliar injury to sensitive vegetation under certain conditions (NPS-ARD 2015b). The three plants identified as ozone sensitive at the park during the Kohut (2004) effort are listed in Table 4.4.4-2. An additional four plants have also been identified as ozone sensitive at the park and are listed in Table 4.4.4-2 (Bell, in review). Of the seven ozone-sensitive plant species, six (85.7%) are bioindicators, which can reveal ozone stress in ecosystems by producing distinct visible and identifiable injuries to plant leaves (NPS-ARD 2006). These species are noted the table.

Wet Deposition

Wet N deposition data used for the condition assessment were derived from estimated five year average values (2009-2013) of 1.6 kg/ha/yr, which resulted in a moderate condition rating (NPS-ARD 2015a). Wet S deposition data used for the condition assessment were derived from estimated five year average values (2009-2013) of 0.8 kg/ha/yr, which resulted in a good condition rating (NPS-ARD 2015a). No trends could be determined given the lack of nearby monitoring stations.

Sullivan et al. (2011a), studied the risk from acidification for acid pollutant exposure and

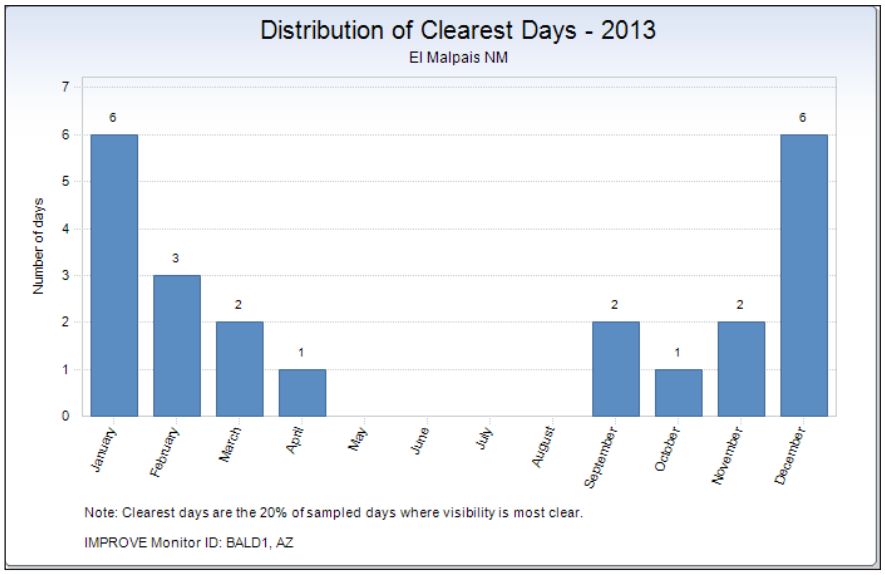


Figure 4.4.4-5. Visibility data collected at BALD1, AZ IMPROVE station showing the distribution of clearest days by month for 2013. Credit: NPS-ARD 2015a.

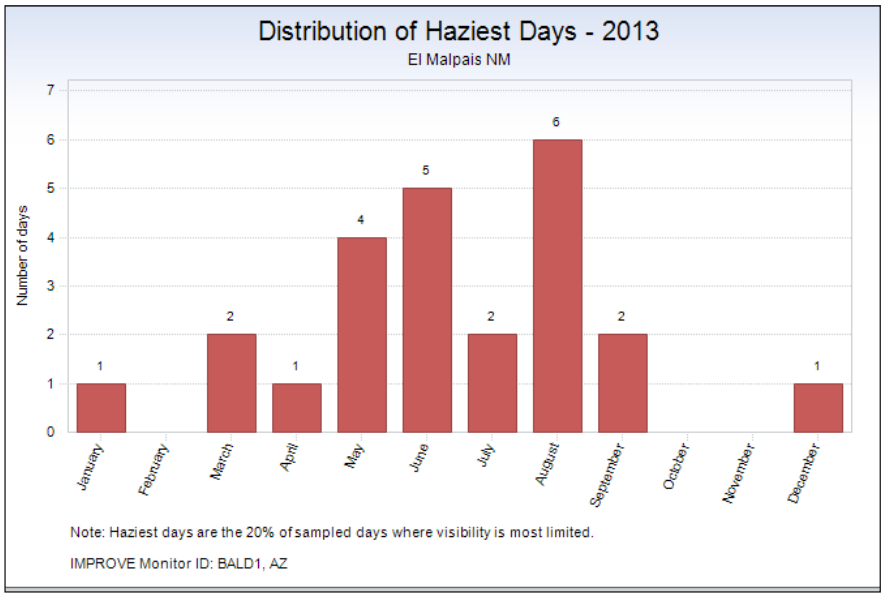


Figure 4.4.4-6. Visibility data collected at BALD1, AZ IMPROVE station showing the distribution of haziest days by month for 2013. (Credit: NPS-ARD 2015a.

Table 4.4.4-2. Ozone sensitive plants found at El Malpais National Monument (Bell, in review; Kohut 2004).

Scientific Name	Common Name	Bioindicator
Artemisia ludoviciana	White sagebrush	Yes
Mentzelia albicaulis	White blazingstar	Yes
*Parthenocissus quinquefolia**	Virginia creeper	No
*Pinus ponderosa**	Ponderosa pine	Yes
Populus fremontii	Cottonwood	Yes
*Populus tremuloides**	Quaking aspen	Yes
Salix scouleriana	Scouler's willow	Yes

*These species only were identified by Kohut (2004) as ozone sensitive at El Malpais NM.

ecosystem sensitivity for Southern Colorado Plateau parks, which included the national monument. Pollutant exposure included the type of deposition (i.e., wet, dry, cloud, fog), the oxidized and reduced forms of the chemical, if applicable, and the total quantity deposited. The ecosystem sensitivity considered the type of terrestrial and aquatic ecosystems present at the parks and their inherent sensitivity to the atmospherically deposited chemicals. These risk rankings were considered low for acid pollutant exposure at the park, low for ecosystem sensitivity, and high for park protection to acidification.

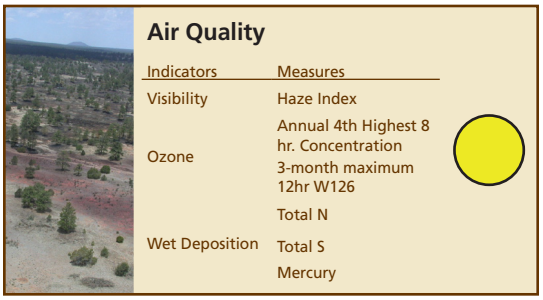
Sullivan et al. (2011b), also developed risk rankings for nutrient N pollutant exposure and ecosystem sensitivity to nutrient N enrichment. These risk rankings were considered low for pollutant exposure at the park, low for ecosystem sensitivity, and high for park protection, with an overall summary risk of low for the park.

Using three data sets, Landscape Fire and Resource Management Planning Tools Project (LANDFIRE), National Wetlands Inventory, and National Land Cover Data, nitrogen-sensitive vegetation for the monument was identified (E&S Environmental Chemistry, Inc. 2009). The LANDFIRE data set was the only one that contained N sensitive communities, including arid, semi-arid, grasslands, and meadows for the monument and locations are shown in Figure 4.4.4-7.

In general, nitrate, sulfate, and ammonium deposition levels have changed over the past 20 years throughout the United States (Figure 4.4.4-8). Regulatory programs mandating a reduction in emissions have proven effective for decreasing both sulfate and nitrate ion deposition primarily through reductions from electric utilities, vehicles, and industrial boilers, although a rise in ammonium ion deposition has occurred in large part due to the agricultural and livestock industries (NPS-ARD 2012d). A study conducted by Lehmann and Gay (2011), indicated a statistically significant decrease in sulfate concentrations from 1985-2009 in the area surrounding the monument, but an increase in nitrate concentrations, although not statistically significant. It seems reasonable to expect a continued improvement in sulfate deposition levels because of Clean Air Act requirements, however, at this time, ammonium levels are not regulated by the EPA and may continue to rise as a result (NPS-ARD 2010).

The 2011–2013 estimated wet mercury deposition is moderate at the park, ranging from 5.1 to 7.5 micrograms per square meter and predicted methylmercury concentrations in surface waters is moderate, at 0.07 nanograms per liter. Based on these levels, the condition for mercury deposition warrants moderate concern.

The degree of confidence in the mercury/toxics deposition status is low because wet deposition and methylmercury concentration estimates are based on interpolated or modeled data rather than in-park studies.



Overall Condition and Trend

For assessing the condition of air quality, we used three air quality indicators. Our indicators/measures for this resource were intended to capture different aspects of air quality, and a summary of how they contributed to the overall condition is summarized in Table 4.4.4-3.

We consider the overall condition of air quality at El Malpais National Monument to be of moderate condition, with a medium confidence level for ozone and wet deposition because estimates are based on interpolated data from more distant monitors and high for visibility based on the IMPROVE monitoring station, BALD1, at Mount Baldy, Arizona.

The trend in visibility at El Malpais NM improved on the 20% clearest days and remained relatively unchanged (no statistically significant trend) on the 20% haziest days (IMPROVE Monitor ID: BALD1,

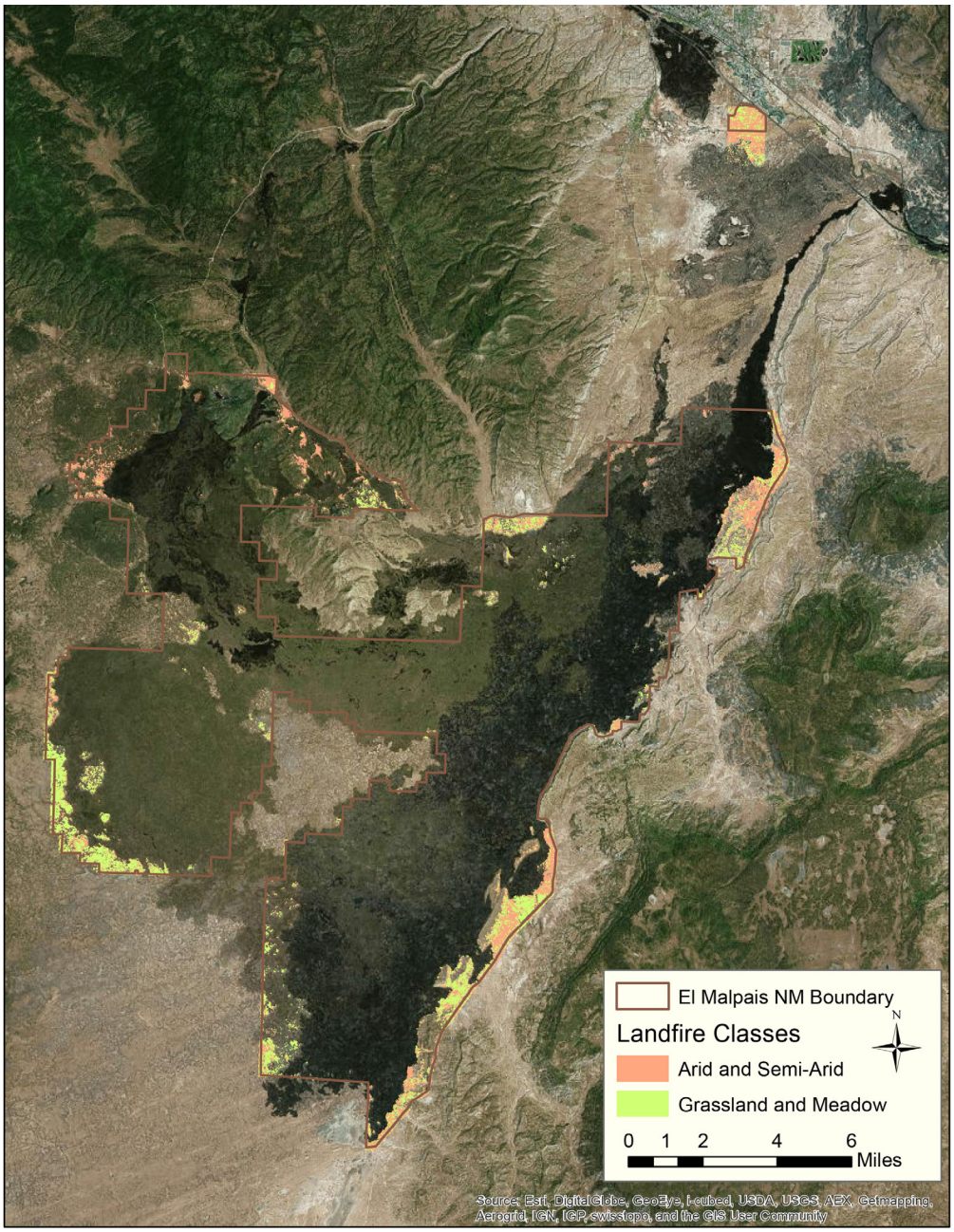


Figure 4.4.4-7. Locations of nitrogen sensitive vegetation at El Malpais National Monument using LANDFIRE data (E&S Environmental Chemistry, Inc. (2009).

AZ) (extracted from NPS 2015a). Trends for the remaining indicators cannot be derived f since no monitoring sites are located near enough to be representative of the conditions at the park and on-site monitoring does not occur.

Level of Confidence/Key Uncertainties/ Threats

A key uncertainty of the air quality section is knowing the effect(s) of air pollution, especially nitrogen deposition, on ecosystems at the parks.

4.4.5. Sources of Expertise

The National Park Service's Air Resources Division oversees the national air resource management program for the NPS. Together with parks and NPS regional offices, they monitor air quality in park units; provide air quality analysis and expertise related to all air quality topics. Ksienya Pugacheva, Natural Resource Specialist with Air Resources Division, provided expertise and an air quality resource condition review from which this assessment was based upon. Section was written by Kimberly Struthers, Science Writer at Utah State University.

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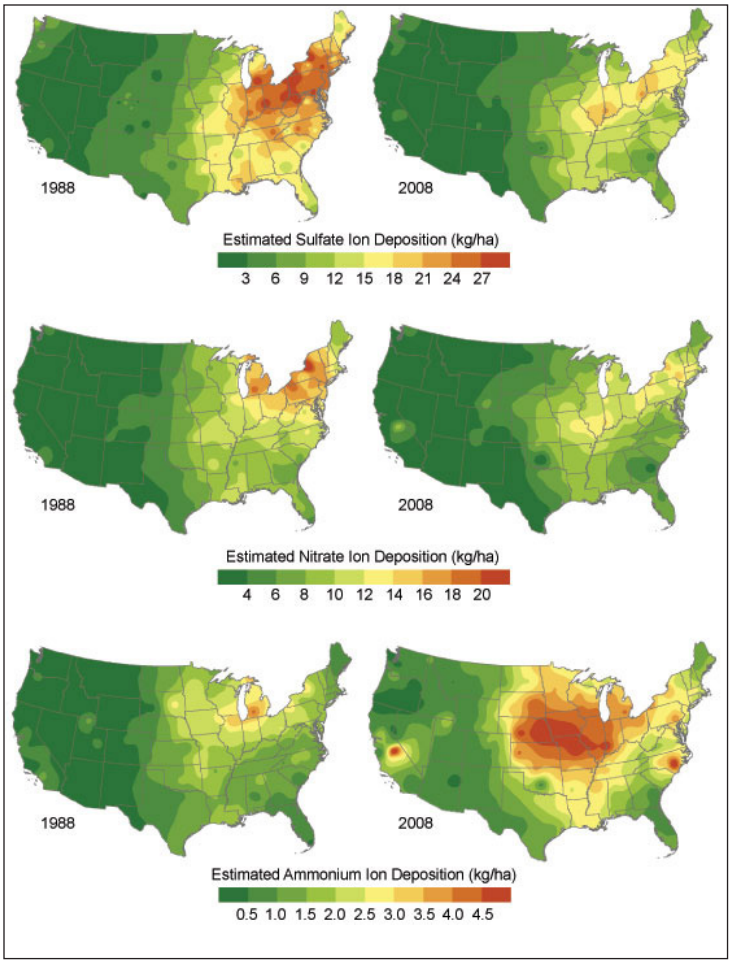


Figure 4.4.4-8. Change in wet deposition levels From 1988-2008 throughout the United States.

Table 4.4.4-3. Summary of the air quality indicators/measures and their contributions to the overall air quality NRCA (excerpted from NPS-ARD 2015a).

Indicator	Measure(s)	Condition	Condition Rationale
Visibility	Haze Index	Moderate	Visibility warrants moderate concern at El Malpais NM. This status is based on NPS Air Resources Division benchmarks and the 2009–2013 estimated visibility on mid-range days of 4.1 deciviews (dv) above estimated natural conditions. For 2004–2013, the trend in visibility at El Malpais NM improved on the 20% clearest days and remained relatively unchanged (no statistically significant trend) on the 20% haziest days (IMPROVE Monitor ID: BALD1, AZ). The Clean Air Act visibility goal requires visibility improvement on the 20% haziest days, with no degradation on the 20% clearest days. The degree of confidence at El Malpais NM is high because there is an on-site or nearby visibility monitor.
Level of Ozone	Human Health: Annual 4th-Highest 8-hour Concentration	Moderate	Human health risk from ground-level ozone warrants moderate concern at El Malpais NM. This status is based on NPS Air Resources Division benchmarks and the 2009–2013 estimated ozone of 67.3 parts per billion (ppb). No trend information is available because there are not sufficient on-site or nearby ozone monitoring data. The degree of confidence at El Malpais NM is medium because estimates are based on interpolated data from more distant ozone monitors.
	Vegetation Health: 3-month maximum 12hr W126	Moderate	Vegetation health risk from ground-level ozone warrants moderate concern at El Malpais NM. This status is based on NPS Air Resources Division benchmarks and the 2009–2013 estimated W126 metric of 12.4 parts per million-hours (ppm-hrs). The W126 metric relates plant response to ozone exposure. A risk assessment concluded that plants in at El Malpais NM were at low risk for ozone damage (Kohut 2007; Kohut 2004). No trend information is available because there are not sufficient on-site or nearby ozone monitoring data. The degree of confidence at El Malpais NM is medium because estimates are based on interpolated data from more distant ozone monitors.
Wet Deposition	Total N in kg/ha/yr	Moderate	Wet nitrogen deposition warrants moderate concern. This status is based on NPS Air Resources Division benchmarks and the 2009–2013 estimated wet nitrogen deposition of 1.6 kilograms per hectare per year (kg/ha/yr). Ecosystems in the park were rated as having low sensitivity to nutrient-enrichment effects relative to all Inventory & Monitoring parks (Sullivan et al. 2011c; Sullivan et al. 2011d). No trend information is available because there are not sufficient on-site or nearby deposition monitoring data. The degree of confidence at El Malpais NM is medium because estimates are based on interpolated data from more distant deposition monitors.
	Total S in kg/ha/yr	Good	Wet sulfur deposition is in good condition. This status is based on NPS Air Resources Division benchmarks and the 2009–2013 estimated wet sulfur deposition of 0.8 kilograms per hectare per year (kg/ha/yr). Ecosystems in the park were rated as having low sensitivity to acidification effects relative to all Inventory & Monitoring parks (Sullivan et al. 2011a; Sullivan et al. 2011b). No trend information is available because there are not sufficient on-site or nearby deposition monitoring data. The degree of confidence at El Malpais NM is medium because estimates are based on interpolated data from more distant deposition monitors..

Table 4.4.4-3. Summary of the air quality indicators/measures and their contributions to the overall air quality NRCA (continued).

Indicator	Measure(s)	Condition	Condition Rationale
Wet Deposition *continued*	Mercury	Moderate	The 2011–2013 estimated wet mercury deposition is moderate at the park, ranging from 5.1 to 7.5 micrograms per square meter.
	Predicted Methylmercury Concentration	Moderate	The predicted methylmercury concentrations in surface waters is moderate, at 0.07 nanograms per liter.

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4.5. Surface Geology

Indicators/Measures

- Surface Lava Flow Features (1 measure)
- Volcanic Vents and Edifices (1 measure)
- Paleontological Resources (2 measures)
- Disturbed Lands (1 measure)

Condition – Trend – Confidence



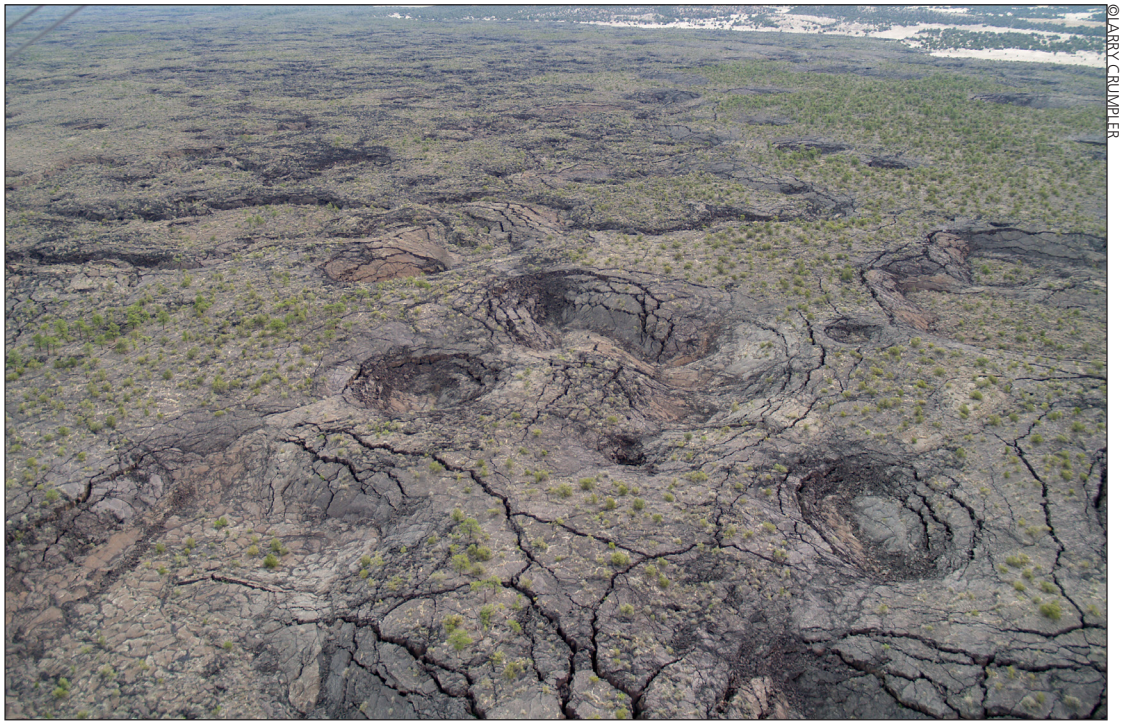
Moderate - Stable - High

4.5.1. Background and Importance

Geologic resources are literally the bedrock of units in the National Park System. They make up the scenery and the landscape that is integral to the significance of most natural areas within the system (Figure 4.5.1-1). Paleontological resources are irreplaceable records of past life and are protected by the Paleontological Resources Preservation Act of 2009. Geologic processes continue to shape park landscapes, impact park ecosystems, and may present hazards to park infrastructure and human safety.

Geology serves as the foundation of ecosystems and is a major determinant of topography, water and soil chemistry, fertility of soils, stability of hillslopes, and flow regimes of surface water and groundwater. These factors, in turn, influence biology, including the distribution of habitats and the locations of threatened and endangered species. Geology also influences human settlement patterns and how people use natural resources—for farming, ranching, industry, construction, hunting, fishing, and recreation.

Geologic resources make up our geoheritage. The National Park Service defines geoheritage as "the significant geologic features, landforms, and landscapes characteristic of our nation which are preserved for the full range of values that society places on them, including scientific, aesthetic, cultural, ecosystem, educational, recreational, tourism, and other values" (NPS 2013).



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Figure 4.5.1-1. Lava flow surface features are one of El Malpais' fundamental resources and values (NPS 2014). The monument's geologic features, especially the McCartys Flow, including the lava rise pits shown here, have great research and educational significance serving as an analog for volcanic features on Mars and the Moon.

Lava flow surface features are one of El Malpais NM's fundamental resources and values (NPS 2014). The monument, especially the McCartys Flow, has great research and educational significance (Larry Crumpler, personal communication, 2015). Research into the McCartys Flow emplacement via inflation processes has provided new understanding into lava flow dynamics (see Appendix E) (Crumpler et al. 2013) and is part of a larger project to understand whether lava flows on Mars or the Moon may have undergone inflation (Zimbelman et al. 2012). Inflation is an emplacement process for basaltic lava flows first identified in Hawaii in 1991 (Walker 1991).

By serving as an analog for lava flows on other planetary bodies, McCartys Flow is allowing researchers to identify and map specific surface features such as lava rise pits and flow margin terraces that may be found in inflated planetary lava flows (Zimbelman et al. 2013). This research to understand inflation processes and their morphological characteristics at the McCartys Flow is supported by NASA and is ongoing (Larry Crumpler, personal communication, 2015). Additionally, the McCartys Flow meets the criteria of a scientifically and educationally significant geoheritage site per the Geological Society of America definition (Geological Society of America 2012).

Surface Geology Overview

The landscape within El Malpais National Monument is dominated by young volcanic features produced during recent eruptions from the Zuni-Bandera Volcanic Field. The Zuni-Bandera field is notable for its lava flows of unusually large length and large volume and for its diversity of vent types and lava flow morphologies (Theilig 1990).

The volcanic terrain of the Zuni-Bandera field has also shaped nearly every aspect of the monument's natural and cultural history. Older rocks exposed in El Malpais include Precambrian igneous and metamorphic rocks that are mostly exposed north of the monument, but minor outcrops occur on the north boundary (KellerLynn 2012). Older sedimentary rocks are exposed in the monument in areas that were not buried by young lava flows (Figure 4.5.1-2). These areas are either on the outside margins of the lava flows, or as islands of older rocks , known as kipukas, that were not buried by lava flows. Kipukas in El Malpais NM have sedimentary substrates or consist of lava flows older than the surrounding flow (KellerLynn 2012).

Appendix E provides further information about El Malpais' surface geology.

Zuni-Bandera Volcanic Field

The most recent phase of volcanic activity in the Zuni-Bandera Volcanic Field, known as the El Malpais phase, occurred during the last 60,000 years. Five young lava flows were emplaced in the monument. From oldest to youngest, these flows are the El Calderon, Twin Craters, Hoya de Cibola, Bandera and McCartys (Table 4.5.1-1) (Figure 4.5.1-3).

Mildly explosive eruptions also formed cinder cones such as Bandera Crater, Twin Craters, and El Calderon. Hoya de Cibola is a shield volcano that was formed from the buildup of lava flows that erupted effusively. The vent area for the McCartys Flow is a thick flow accumulation topped by a small scoria cone (Crumpler et al. 2013). Cinder fields surrounding cinder cones were mapped for El Calderon and Bandera Crater (Figure 4.5.1-3) (Maxwell 1986 and KellerLynn 2012). Although they are not an edifice like a cone, cinder fields present an environment and are landscape features akin to cinder cones as they are both made up of accumulations of mostly loose cinders. Some plant species such as *Phacelia serrate* (cinders phacelia)

Table 4.5.1-1. The young lava flows of the Zuni-Bandera Volcanic Field exposed within El Malpais NM.

Flow	Age (years before present)
McCartys Flow	3,900
Bandera Flows	11,000
Hoya de Cibola Flows	>11,000
Twin Craters Flows	18,000
El Calderon Flows	<60,000

After KellerLynn (2012) and Dunbar (2010). Young basaltic lava flows are notoriously hard to date by available techniques, and the errors for these values are relatively large.

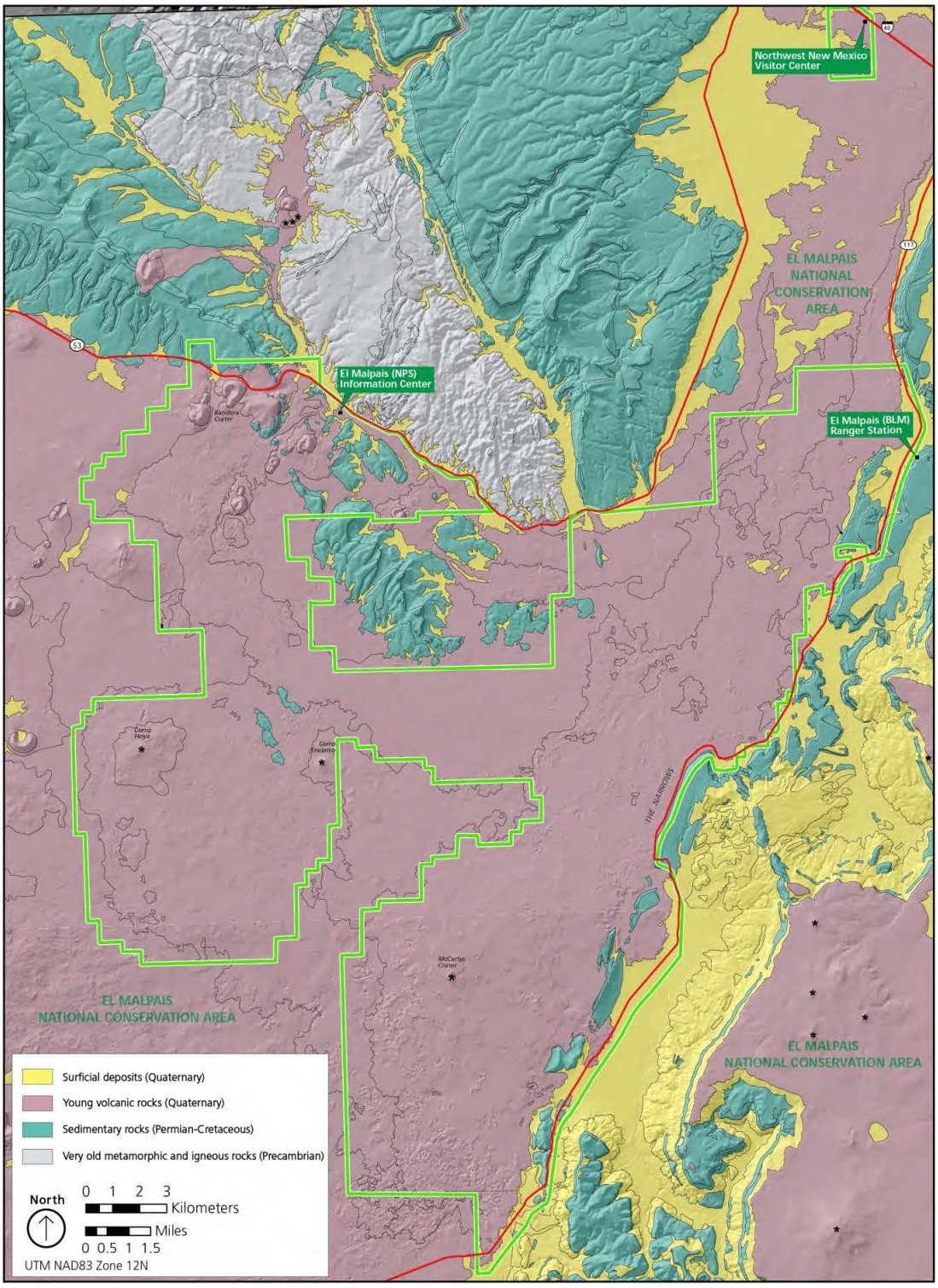


Figure 4.5.1-2. Generalized geologic map of El Malpais NM showing areas of surficial deposits, Quaternary volcanic rocks, sedimentary rocks, and Precambrian igneous and metamorphic rocks. Quaternary volcanic rocks include the young lava flows, cinder cones and cinder fields of the El Malpais period of volcanism that took place within the last 60,000 years and the previous phases of volcanism. Given that the monument is situated over the five youngest lava flows of the Zuni-Bandera Volcanic Field and the abundance of older volcanic rocks, sedimentary rocks are very rare within monument boundaries. Significant exposures of sedimentary rocks occur just north and east of monument boundaries. Map from KellerLynn (2012); NM Guidebook (2010).

grow exclusively or preferentially in cinder substrates (Bleakly 1997).

Two previous periods of basaltic volcanism occurred in the Zuni-Bandera field. The first phase of volcanism began 700,000 years ago and erupted a series of fluid lava flows (Laughlin et al. 1993), mapped as old basalt flows (Maxwell 1986). The second period of volcanism, at approximately 150,000 years before present, produced a series of cinder cones known as the Chain of Craters, mostly to the west of monument boundaries, and associated lava flows (KellerLynn 2012). Cerro Bandera, the northern-most cinder cone in the Chain of Craters, is within monument boundaries (KellerLynn 2012).

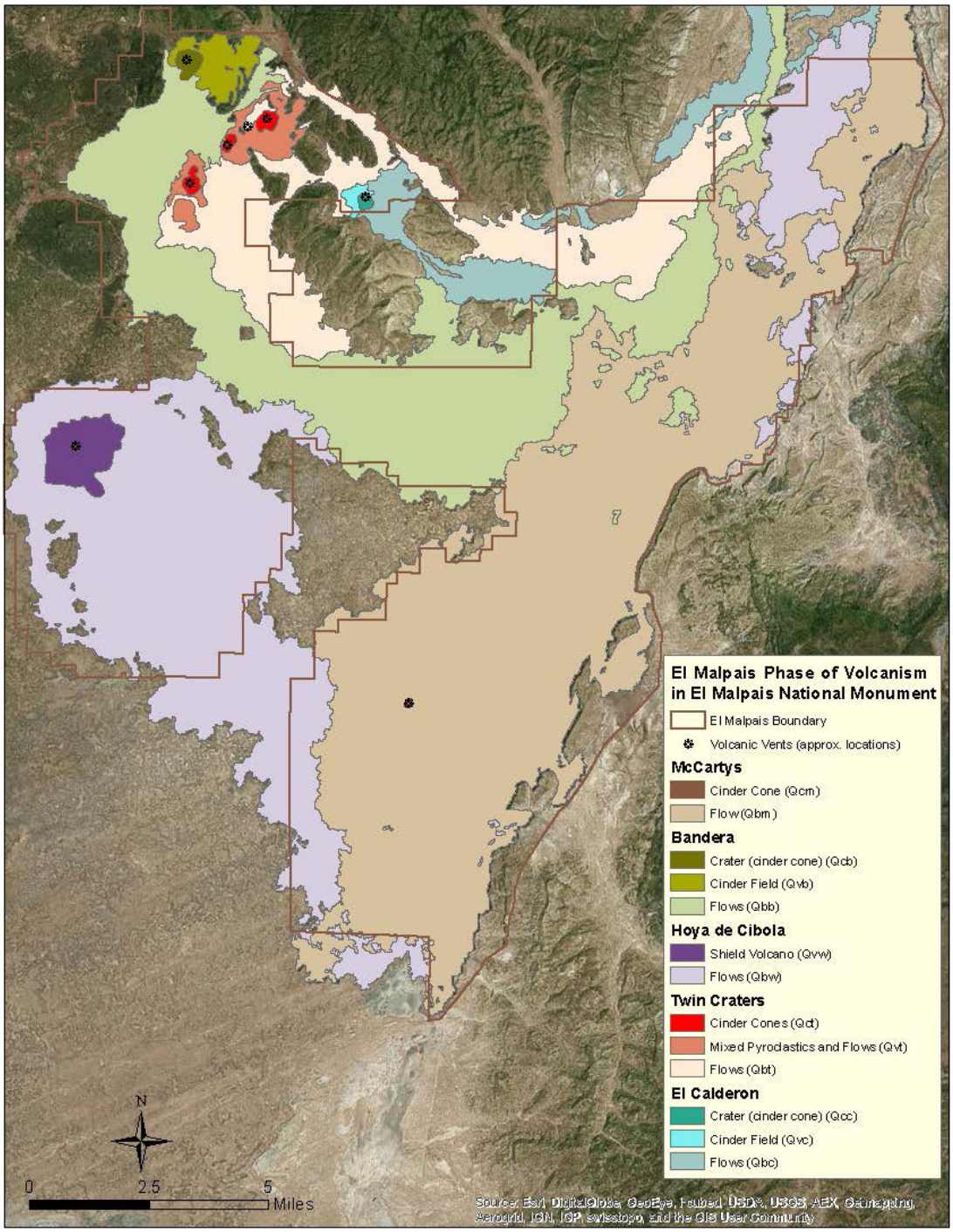


Figure 4.5.1-3. The young lava flows, vents, cinder cones and cinder fields of the Zuni-Bandera Volcanic Field found with El Malpais monument boundaries (Maxwell 1986 and KellerLynn 2012).

4.5.2. Data and Methods

We used four indicators to assess the current condition and trend for surface geology at El Malpais NM (Table 4.5.2-1). Three indicators, with one measure each, evaluated the condition of lava flow surface features, volcanic vents and edifices, and disturbed lands. The paleontological resources indicator had two measures: freeze-thaw index and human impacts.

Indicator/Measure
Lava Flow Surface Features (Lava flow intactness)

The lava flow intactness measure evaluated whether lava flow surfaces features were in natural condition. Lava flows are the predominant physical features of El Malpais landscape, and are exposed at the surface in most areas of the monument.

Information on lava flow surface features is provided in the El Malpais Geologic Resources Inventory (KellerLynn 2012), the original geology map of the El Malpais lava field (Maxwell 1986), volcanological research and reports by Crumpler et al. (2013), Zimbelman et al. (2010, 2012, and 2013), Crumpler (2011), Garry et al. (2011), and Dunbar and Phillips (2004). Most of this research has been into the emplacement of the McCartys Flow and analysis of the flow's inflation structures. Dunbar and Phillips (2004) provided the geochronology of the Zuni-Bandera field, and Dunbar (2015) provided a virtual field trip to El Malpais.

Table 4.5.2-1. The indicators and measures used to assess surface geology condition at El Malpais NM.

Indicator	Measures
Lava Flow Surface Features	Lava Flow Intactness
Volcanic Vents and Edifices	Vent and Edifice Intactness
Disturbed Lands	Abandoned Mineral Lands (AML) Prioritization Ranking
Paleontological Resources	Freeze-Thaw Index
	Human Impacts

Only the youngest lava flow in El Malpais, the McCartys Flow, retains its glassy rind on the upper few millimeters of the surface (Dunbar and Phillips 2004). Delicate surface features such as tachylite (glass) are more susceptible to disturbances.

Indicator/Measure
Volcanic Vents and Edifices (Vent and edifice intactness)

The vent and volcanic edifice intactness measure evaluated whether volcanic vents and edifices were in natural condition. Information on vent and volcanic edifices is provided in the El Malpais Geologic Resources Inventory (KellerLynn 2012), the original geology map of the El Malpais lava field (Maxwell 1986), work deciphering the volcanic history of the cinder cones associated with the Twin Craters flows (Cascadden et al. 1997), and the geochronology of the field (Dunbar and Phillips 2004).

Volcanic vents and edifices in El Malpais NM include cinder cones, a shield volcano, the elevated vent platform for the McCartys Flow, plus a few vents from earlier phases of volcanism in the Zuni-Bandera field. The volcanic vents and edifices indicator also included the Bandera and El Calderon cinder fields and the mixed Twin Craters lava flow and pyroclastic deposit geologic map unit, as these units are found only in the close proximity of vents and were deposited either predominantly or in part via fallout from pyroclastic eruptions. These vents and edifices and their impacts are summarized in Table 4.5.2-2.

World War II Bombing Range Impacts to Lava Flow and Cinder Cone Conditions

Between late 1942 and May 1944, a 23-km^2 (9-mi^2 square mile) area of lava flow around McCartys Crater was used as the Kirtland Demolition Bombing Range for training using live munitions from the Kirtland Army Airfield (Bering Sea Environmental 2015). The McCartys Crater target area is designated as a High Explosive Bombing Range.

When El Malpais NM was established in 1987, the lands within the former World

Table 4.5.2-2. Known volcanic vents and edifices in El Malpais NM.

Vent	Type	Notes
McCartys Vent (Qcm)	Elevated flow accumulation with small cinder cone	The cinder cone has been impacted as its use as a target in the World War II bombing range. Small explosive craters give it a "lumpy" appearance and it is littered with sharp metal fragments.
Bandera Crater (Qcb)	Cinder cone	The largest cinder cone in El Malpais NM, and a classic example of a breached cinder cone.
Bandera Cinder Field (Qvb)	Cinder field	The Bandera cinder field includes 4 AML sites.
Hoya de Cibola (Qvw)	Shield volcano	Small shield volcano with vent at the summit.
Cerro Candelaria (Qct)	Cinder cone	Large cinder cone.
Lava Craters (Qct)	Cinder cone	Small breached spatter cone.
Twin Craters (Qct)	Cinder cones	A series of three small cinder cones over a fissure-like vent with a northeastern trend.
Lost Woman Crater (Qct)	Cinder cone	Large cinder cone with a smaller subsidiary cone to the north.
Twin Crater Mixed Pyroclastics and Flow (Qvt)	Mixed cinders and flows	Area mapped as cinder deposits and lava flows undifferentiated. May include additional vent areas.
El Calderon Crater (Qcc)	Cinder cone	Breached cinder cone. An AML site for a former cinder quarry is on the northeast side of the cinder cone.
El Calderon cinder field (Qvc)	Cinder field	Cinder field preserved in areas not covered by the El Calderon Flow on mostly the west side of the cinder cone.
Cerro Bandera (Qc)	Cinder cone	Part of the Chain of Craters eruptive phase.
Cerro Encierro (Qb)	Cinder cone	Formed a low edifice in what is now the northwestern part of the Hole-in-the-Wall kipuka.
Unnamed vent (Qb)	Unknown	No edifice.

War II bombing range were incorporated in the national monument. In the late 1980s, several 45-kg (100-pound) general purpose bombs (Figure 4.5.2-1) and a bomb tail fuse were blown in place by US Army Explosive Ordnance Disposal specialists (Bering Sea Environmental 2015). In 1994 and 1995, two additional bomb removal actions were taken on behalf of the US Army Cops of Engineers in a 2.6-km^2 (1-mi^2) area around McCartys Crater and in six 1.3 km (0.5-mile) grids northeast and southeast of the crater. During these actions, 25 general purpose bombs and 38 nose/tail fuses were destroyed on site, and 1900 pounds of inert debris were removed (Bering Sea Environmental 2015).

In 2006, a subcontractor for the US Army Corps of Engineers conducted a field inspection of the Kirtland Demolition Bombing Range and did not observe any "Munitions and Explosives of Concern" (e.g., unexploded ordinance, discarded military munitions, or munition components) within the response site. However, munitions debris and expended fuses were observed. Additionally, ten surface soil samples were analyzed for explosives, but only an explosives-related chemical was only detected in one sample at a level well below screening criteria (Bering Sea Environmental 2015).

The Technical Project Planning Memorandum for Meeting No. 1, Kirtland Demolition Bombing Range Cibola County, New Mexico,



Figure 4.5.2-1. A bomb found in the Kirtland Demolition Bombing Range on McCartys Flow in 1984 (Crumpler et al. 2013).

in support of Remedial Investigation/ Feasibility Study (Bering Sea Environmental 2015) was used to evaluate the condition of the geologic surface features and McCartys crater for the impact of the bombing range.

Additional information about the impact of the World War II bombing range on El Malpais surface geology is available in Crumpler et al. (2013). The "somewhat lumpy" appearance of the McCartys scoria cone (Figure 4.5.2-2) results from small detonation craters from explosives. The area is also littered with small pieces of shrapnel.

Indicator/Measure
Disturbed Lands (Abandoned Mineral Lands ranking)

Information on Abandoned Mineral Lands (AML) sites in El Malpais were available in the NPS AML Inventory and Assessment Report, a comprehensive inventory and assessment of AML sites in the National Park System (Burghardt et al. 2014) and database (National Park Service 2015a). Six sites are in El Malpais NM containing a total of 28 features (Burghardt et al. 2014 and NPS 2015a). The Geologic Resources Inventory indicated that there are four additional sites within the monument that are not part of the NPS AML database (KellerLynn 2012).

Burghardt et al. (2014) listed criteria used to prioritize AML features for remedial action. Each site was assigned rankings for hazards, access, resource significance, and resource impacts. Table 4.5.2-3 provides these rankings for El Malpais' six sites using additional information from the NPS service-wide AML database (NPS 2015a).

The hazard and access elements were assigned numeric rankings between 0 and 5 (low to high) by the NPS AML program based on the presence of identifiable characteristics, such as a highwall which is a vertical wall formed from excavation into a hillside (hazard element), or the AML site being accessible by a good road leading to it (access element). The resource significance and resource impact rankings had possible values of 0, 2 or 4 for low, medium and high.

The NPS prioritization system for sites that need mitigation was based on the severity of public safety hazard and the level of impact on park resources (Burghardt et al. 2014). Sites with a hazard level of at least 3, or a resource impact level of 4, are assigned as high priority. Medium priority AML have either a hazard



Figure 4.5.2-2. Small craters from the detonation of general purpose bombs dropped during training exercises from the Kirtland Army Air Base during World War II are visible on the sides and in the crater of McCartys Crater. The entire area around McCartys vent and the surrounding lava flow has been impacted by these ordnance explosions.

Table 4.5.2-3. Prioritization rankings for Abandoned Mineral Lands at El Malpais NM.

Site	Number of Features*	Hazard Rating	Hazards	Access Rating	Access	Resource Significance Rating	Resource Significance	Resource Impact Ranking	Resource Impact	Priority Ranking
Calderon	4	2 (Medium)	Highwalls	4 (High)	Improved Dirt Road	0 (Low)	Unknown impact to biological resources	2 (Medium)	Moderate visual impact	**Medium**
Candelaria 1	3	2 (Medium)	Highwall	4 (High)	Improved Dirt Road	0 (Low)	Unknown impact to biological resources	4 (High)	High visual impact	**High**
Candelaria 2	6	2 (Medium)	Highwalls	5 (High)	Paved Road	0 (Low)	Unknown impact to biological resources	2 (Medium)	Moderate visual impact	**Medium**
Candelaria 3	5	1 (Low)	Highwalls	5 (High)	Paved Road	0 (Low)	Unknown impact to biological resources	2 (Medium)	Moderate visual impact	**Medium**
Candelaria 4	1	2 (Medium)		5 (High)	Paved Road	0 (Low)	Unknown impact to biological resources	2 (Medium)	Moderate visual impact	**Medium**
ELMA Quarry	8	3 (High)	Highwall	5 (High)	Paved Road	0 (Low)	Unknown impact to biological resources	2 (Medium)	Moderate visual impact	**High**

* Number of features only includes features that need remedial action. The ELMA Quarry site includes one additional feature that does not need mitigation.
Data are from Burghardt et al. 2014 and NPS 2015a.

level or resource impact level of 2. All other AML features are considered low priority.

The six AML sites in El Malpais were all surface mines (quarries) (NPS 2015a). Five of the sites were mined for cinders or "lava rock," and the other site, which is off of New Mexico 117, was quarried for sandstone. The Calderon AML site is on the northeast flank of the El Calderon cinder cone (Figure 4.5.2-9), the Candelaria 1 - 4 sites are on the Bandera cinder field, and the ELMA Quarry is in the Dakota Sandstone in the southeastern portion of the monument.

Indicator/Measure
Paleontological Resources (Two measures)

We used two measures to evaluate the condition of paleontological resources. The freeze-thaw index measured the impact that frost weathering may have on fossils. Human impacts evaluated whether there are inadvertent or intentional impacts caused by humans on paleontological resources. Overall, these two measures determined whether paleontological resources remained in natural condition. Information was derived mostly from the NPS Southern Colorado Plateau Inventory and Monitoring Network paleontological inventory and monitoring report (Tweet et al. 2009). Additional information was used from the Geologic Resource Inventory (KellerLynn 2012) and the geologic map of the El Malpais lava field and surrounding areas (Maxwell 1986).

NPS Management Policies (NPS 2006) do not allow for intervention in natural processes such as weathering and erosion except in special situations. Therefore, the impact of natural weathering and erosion on El Malpais' fossils was not considered in this assessment.

Freeze-Thaw Index

The impact of frost weathering on paleontological resources was measured via the freeze-thaw index. The freeze-thaw index is the number of 24-hour periods per year when temperatures pass across the freezing threshold (Santucci et al. 2009). If climate change would cause an increase in the freeze-thaw index, it would have a negative impact on paleontological resources If it decreases the freeze-thaw index, then the rate of weathering and erosion due to physical factors theoretically should be decreased.

The Period of Record Daily Climate Summary for the Grants Municipal Airport weather station, a National Weather Service cooperative station that is closest to El Malpais NM, provides average daily maximum and minimum temperatures for the period of record from 1953 to 2012 (Western Regional Climate Center 2015). The 30-Year Daily Temperature and Precipitation Summary provides average daily maximum and minimum temperatures for 1981 to 2010.

Using average daily high and low temperatures for the period of record, 193 days per year had temperatures that crossed the freezing threshold for the period of record. For the 1981 to 2010 interval, there were 183 days per year when the average temperature crossed the freezing point (Western Regional Climate Center 2015) (Table 4.5.2-4).

The climate change exposure brief for El Malpais NM (Monahan and Fisichelli 2014) provided information on the climate-change exposure by evaluating 25 climate variables, including temperature, that experienced "extreme" values in the past 10-30 years relative to the historical range of variability. "Extreme" conditions are defined as exceeding 95% of the historical range.

4.5.3. Reference Conditions

Geologic resources can be sensitive or robust depending on how easily they may be damaged, and some types of resources may be more vulnerable to damage than others (Gray 2005). The reference conditions by which surface geology conditions were assessed are listed in Table 4.5.3-1.

Surface geology features that had no concerns or issues and are in a natural state and do not present a hazard were considered to be in good condition. If there were some areas of moderate concerns related to impacts and pose some hazards, the condition was considered to be moderate. A condition of significant concern existed when significant impacts to features have been identified and posed hazards.

Our reference conditions for the Abandoned Mineral Land prioritization ranking measure were based on the system used in the NPS AML Inventory and Assessment Report (Burghardt et al. 2014) and data available in the AML database (NPS 2015a). AML sites that were assigned a low priority for mitigation are considered to be in good condition. Sites with a medium priority were considered to be in moderate condition, and high priority AML sites were considered to be of significant concern. AML sites that do not require mitigation were also considered to be in good condition.

Paleontological resources that have no concerns or issues and are in a natural state related to them were considered to be in good condition. If there are some areas of moderate concerns related to impacts to paleontological resources, the condition was considered to be moderate. A condition of significant concern existed when impacts or potential impacts to fossil resources have been identified.

Table 4.5.2-4. Freeze-Thaw Index for Grants Municipal Airport.

Interval	Number of days average daily temperatures cross freezing threshold
Period of Record	193
1981-2010	183

Data from Western Regional Climate Center (2015).

4.5.4. Condition and Trend

We used four indicators with a total of five measures to assess the condition of geologic resources at El Malpais NM as summarized in Table 4.5.4-1.

The surface geology features of El Malpais area have had a long history of human use. Most uses, including grazing, logging and travel corridors like the Zuni-Acoma Trail, have had relatively minor impacts to surface geologic resources. However, cinder, "lava rock," and sandstone surface mining and quarrying and the use of the McCartys crater and lava flow as an aerial bombing range during World War II have had significant impacts on the geologic features in what is now El Malpais NM.

Lava Flow Surface Features

In general, most lava flow surface features are robust and not sensitive to many types of potential impacts. Delicate surface features such as tachylite (glass) are more susceptible to disturbances. Only the McCartys Flow retains its glassy rind (Dunbar and Phillips 2004). While the lava flows are mostly intact, the Lava Falls Trail area on the McCartys Flow is experiencing heavy use and the flow surface in that area is becoming worn (Larry Crumpler, personal communication, 2015).



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Figure 4.5.2-3. Tree mold in the El Calderon lava flow.

Because the lava flow surface features are largely intact and in natural condition, we considered this indicator to be in good condition.

Volcanic Vents and Edifices

At least eight volcanic vents for the El Malpais phase are found within monument boundaries (Figure 4.5.1-3). An additional three vents from earlier phases of volcanism in the Zuni-Bandera field are also present in the monument (Maxwell 1986 and KellerLynn 2012).

Cinder cones are very sensitive to disturbances. For example, quarry sites on cinder cones are difficult to recontour (NPS 2015a). An additional example of the sensitivity of cinder cones to human disturbances is the closure of Sunset Crater Volcano to hiking since 1973 (NPS 2015b). Cinder cones, like many other geologic resources, are nonrenewable parts of the planet's geodiversity and geoheritage, and damage to or loss of cinder cones may lead to loss of important volcanological information (Gray 2004).

Hoya de Cibola, Lost Woman Crater, Twin Craters, Lava Crater, and Cerro Candelaria are in natural condition.

Several of the volcanic vents and edifices in El Malpais NM have been adversely impacted by human activities. The El Calderon cinder cone is the site of a former cinder quarry with two vertical cuts into the side of the cone that is visible from a considerable distance (NPS 2015a) (Figure 4.5.4-1). The Bandera Cinder Field was also the site of cinder surface mines and contains four AML sites (NPS 2015a). The impacts of quarrying on these cinder cones will be discussed under the AML measure.

Because some of the volcanic vents and edifices have been impaired by human activities prior to the establishment of El Malpais NM, and others are in natural condition, we consider this measure to be in moderate condition.

World War II Bombing Range Impacts to Lava Flow and Cinder Cone Conditions

The use of McCartys Crater and the surrounding McCartys Flow in World War II as an aerial bombing range (well prior to the establishment of the national monument) adversely impacted the scoria cone and surface of the surrounding lava flow. McCartys Crater is pocked by explosive depressions (Figure 4.5.4-1), and metal fragments (e.g., bomb debris) are common in the area (Crumpler et al. 2013).

Explosive Ordinance Disposal specialists undertook several bomb removal actions and clean up of ordinance debris in the 1980s and 1990s in the Kirtland Demolition Bombing Range (Bering Sea Environmental 2015). However, given the extremely rough nature of the surface of the lava flows in El Malpais, especially the McCartys Flow in and around

Table 4.5.3-1. Reference conditions used to assess the current condition of geology for each indicator.

Indicator	Measure	Good	Moderate Concern	Significant Concern
Lava flow surface features	Lava flow intactness	No concerns or issues about lava flow surface features have been identified. Lava flows are in a generally natural state and function.	Some areas of moderate concern related to impacts to lava flow surface features.	Areas of concern have been identified that have the potential to impact lava flow surface features.
Volcanic vents and edifices	Vent and edifice intactness	No concerns or issues about volcanic vents and edifices have been identified. Vents and edifices are in a generally natural state and function.	Some areas of moderate concern related to impacts to volcanic vents and edifices exist.	Areas of concern have been identified that have the potential to impact volcanic vents and edifices.
Disturbed lands	Abandoned Mineral Lands Prioritization Ranking	AML sites that require mitigation are ranked as low priority by the NPS AML Program.	AML sites that require mitigation are ranked as medium priority by the NPS AML Program.	AML sites that require mitigation are ranked as high priority by the NPS AML Program.
Paleontological resources	Freeze-Thaw Index	The average number of days per year that go through the freeze-thaw cycle decrease or remain constant compared to the period of record and is not an area of concern related to paleontological resources.	The average number of days per year that go through the freeze-thaw cycle increase slightly compared to the period of record and is an area of slight to moderate concern related to paleontological resources.	The average number of days per year that go through the freeze-thaw cycle increase compared to the period of record and is an area of concern related to paleontological resources..
	Human Impacts	No concerns or issues about human impacts to paleontological resources have been identified. Paleontological resources are in a generally natural state and function.	Some areas of moderate concern related to human impacts on paleontological resources exist.	Areas of concern have been identified about human impacts that have the potential to impact paleontological resources.

the bombing range, it is likely that "Munitions and Explosives of Concern" remain in El Malpais NM. For example, in 2010, military Explosive Ordnance Disposal specialists destroyed a 45-kg (100-pound) general purpose bomb that had been located on the Bandera Flows approximately 10.7 km (6.6 mi) north of McCartys Crater, well outside of the Kirkland Demolition Bombing Range.

The access to the McCartys Crater target area of the bombing range is very difficult given the extremely rugged terrain. Visitation levels to the World War II bombing range are very low, minimizing the risk that unexploded ordinance will be encountered.

In late 2014, a remedial investigation and feasibility study was initiated by the US Army Corps of Engineers at the Kirtland Demolition Bombing Range as part of a program to address formerly used defense sites that may contain munitions and explosives of concern (Bering Sea Environmental 2015). The investigation uses existing data and collection of additional field data to characterize munitions contamination, prepare a site prioritization protocol, prepare a plan, and submit a decision document for the site. The objectives of the study are to determine the presence, extent and nature of munitions and explosives of concern and munitions components at the High Explosive Bombing Range at the McCartys Crater target area (Bering Sea Environmental 2015).

Paleontological Resources

Paleontological resources may be body fossils, which are the actual remains of organisms, or trace fossils, which are evidence of biological activity, such as tracks or burrows. In situ paleontological resources can be impacted by

Table 4.5.4-1. Indicator, measure, and rationale of surface geology condition.

Indicator of Condition	Measure	Condition	Rationale for Condition
Lava flow surface features	Lava flow intactness	Good	The lava flow surface features are largely intact; e.g., in natural condition, in El Malpais NM. Heavy use in the Lava Falls area of the McCartys flow has impacted the surface of the flow there. Additionally, detonations in the Kirkland Demolition Bombing Range have impacted the surface of the flow, especially in the vicinity of the vent. Unexploded ordinance and munitions may remain in the area.
Volcanic vents and edifices	Vent and edifice intactness	Moderate	Overall, volcanic vents and edifices are in moderate condition. While some edifices such as Hoya de Cibola and the vents that produced the Twin Craters Flows are in natural condition, others have been significantly impacted by human activities prior to the establishment of El Malpais NM. The McCartys Crater was used as a range for aerial bombing in World War II, and metal bomb fragments and small craters from explosions remain. Cinder quarrying occurred at El Calderon and in the Bandera Cinder Field.
Disturbed lands	Abandoned Mineral Lands Prioritization Ranking	Significant Concern	Two AML sites in El Malpais are ranked as high priority for mitigation by the NPS AML program because of their hazards or high resource impact and easy access for visitation. Four additional sites are assigned a moderate priority for mitigation by the NPS AML program.
Paleontological resources	Freeze-Thaw Impact	Good	The freeze-thaw index is decreasing because of fewer number of days per year that go through the freeze-thaw cycle. A lower freeze-thaw index should mean that frost weathering has less of an impact on fossils.
	Human Impacts	Unknown	The monument's fossil resources are poorly known and are not being monitored. However, tree mold fossils, while rare and unusual, would be difficult to remove from the encompassing lava flow, and most caves in El Malpais are closed to visitation, protecting the fossils therein.

natural processes, accelerated erosion due to climate change, and human activities, such as illegal collection.

Most of the rock units exposed in El Malpais are volcanic in origin (Maxwell 1986 and KellerLynn 2012). Fossils are generally rare in volcanic rocks. Tree molds (Figure 4.5.2-2) are one of the few types of fossils that may be common in basaltic lava flows and are the most significant paleontological resources at El Malpais (KellerLynn 2012). Appendix E provides further information on El Malpais fossil resources.

Human Impacts

With the exception of the tree molds that have been documented in the park's geodatabase, fossil locations in El Malpais are not well known. Paleontological resources in El Malpais are not being monitored (David Hays, personal communication, 2015). It is, therefore, not known if vandalism or theft of fossils is occurring. The impact of human activities on paleontological resources within El Malpais is unknown, although tree mold fossils would likely be very difficult to remove from the encompassing lava flows. Further, most caves in El Malpais are closed to visitation, protecting the paleontological resources within them from potential vandalism or theft, although it is likely that fossil sites in caves may be very susceptible to potential disturbances. Because the impact of human activities on fossils is unknown, this measure is in unknown condition.

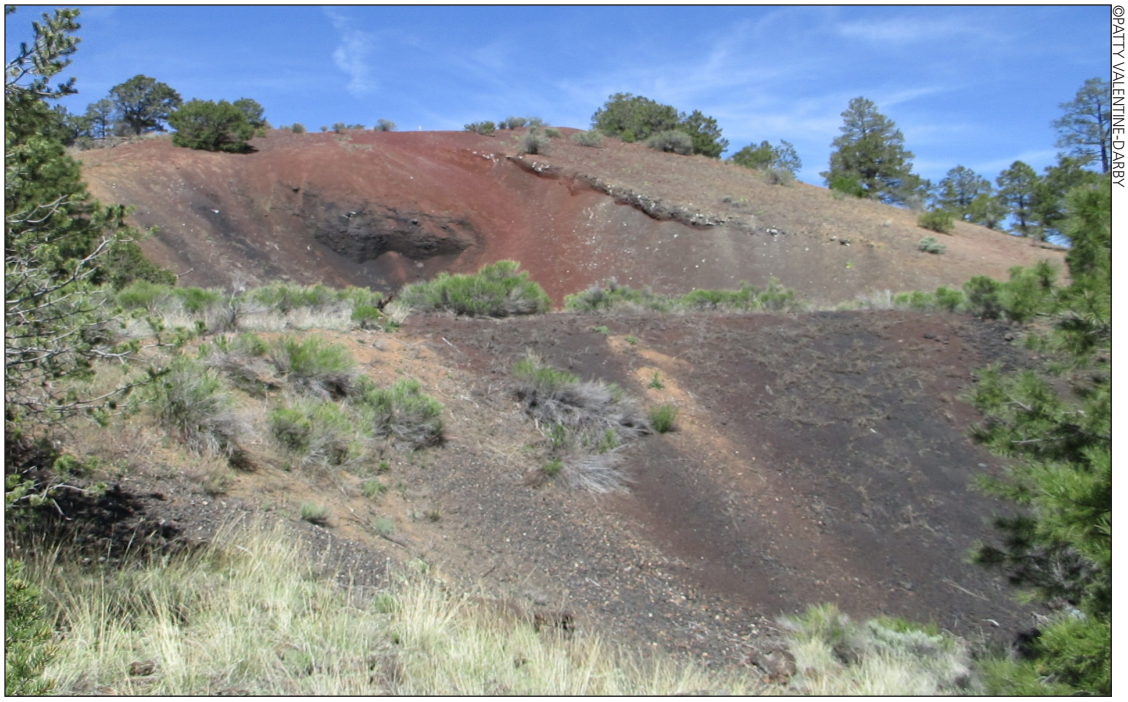

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Figure 4.5.4-1. The vertical cut in the quarry on the El Calderon cinder cone.

Freeze-Thaw Index

Diurnal and annual changes in temperatures that fluctuate above and below the freezing temperatures cause increased weathering and erosion of geologic features. Frost weathering includes mechanical processes that disintegrate, split and breakup rock via the great pressure caused by freezing water in rock pore spaces or in cracks (Jackson 1997).

The impact of frost weathering on paleontological resources was assessed using the freeze-thaw index. The average daily high temperature at the Grants Municipal Airport weather station is above freezing, while winter lows are typically below freezing (Western Regional Climate Center 2015). Therefore, any change in the freeze-thaw index is dependent on the average number of days per year that the low temperature is below freezing. The climate change exposure brief for El Malpais NM (Monahan and Fisichelli 2014) also indicated that the mean temperature of the coldest quarter has gotten significantly warmer compared to historical conditions.

The average number of days that experienced a freeze-thaw cycle in the period of record (1953-present) was 193, and between 1981 and 2010, it was 183. Therefore, the freeze-thaw index for El Malpais NM has decreased, and the condition of fossils for this measure is good.

Climate change predictions for the Colorado Plateau include warmer winter temperatures (BLM 2014), which would further decrease the freeze-thaw index. Winter temperatures are estimated to increase approximately 2.5°C (4.2°F) by 2050 and 3.0°C (5.4°F) by 2090 (BLM 2014), meaning fewer low temperatures below freezing.

AML Prioritization Ranking

AML sites are locales that contain facilities, structures, and disturbances associated with past mineral exploration, extraction, processing, and transportation for which the NPS takes action to mitigate, reclaim, or restore in order to reduce hazards and impacts to park resources (Burghardt et al. 2014).

The Calderon AML site covers 2 acres, and has four features (a surface mine, a highwall, a loading area, and a road). The highwall presents a medium hazard rating due to the potential for falls. The site has a high access rating, and a moderate resource impact rating due to its moderate visual impact (NPS 2015a).

The Candelaria 1 contains four sites that are on private lands within monument boundaries

and are east of Bandera Crater. These four sites cover a total of 8.1 hectares (20 acres) and are all quarry sites for cinders and/or "lava rock," containing features such as surface mines and waste rock piles. Candelaria 1 and 3 also include highwalls, although the highwall in Candalaria 3 is assigned a low hazard rating (NPS 2015a).

Candelaria 1 is assigned a high prioritization rating because it has high resource impact ranking (4), and the other three sites are assigned medium prioritization because of moderate resource impact (2) (Burghardt et al. 2014).

ELMA Quarry is a sandstone surface mine site covering 10 acres adjacent to New Mexico 117 near the Lava Falls area. The site contains nine features including the quarry itself, two historic structures, and waste rock consisting of large sandstone blocks and gravel piles (NPS 2015a). The quarry presents a highwall with a hazard rating of 4 (high) and moderate resource impact ranking (2). The historic structures may have cultural resource significance since the structures apparently date from the 1940s (NPS 2015a).

El Malpais contains six inventoried AML sites with a total of 28 features. Twenty-seven of these features require mitigation (NPS 2015a). Two AML sites, Candelaria 1 and ELMA quarry, are assigned a high priority for mitigation by the NPS AML program (Burghardt et al. 2014). Two additional sites have moderate priority for mitigation. Because the AML sites in El Malpais have high and moderate priority rankings, we consider that AML site prioritization ranking measure is in the condition of significant concern.



Geology

Indicators	Measures
Lava Flow Surface Features	1 Measure
Volcanic Vents & Edifices	1 Measure
Paleontological Resources	2 Measures
Disturbed Lands	1 Measure



Overall Condition

Of the four indicators for the assessment of geologic resources at El Malpais, one was in good condition (lava flow surface features), one was in moderate condition (volcanic vents and edifices), one in a condition of significant concern (disturbed lands), and one was unknown (paleontological resources). The overall condition of surface geology features at El Malpais is considered to be moderate.

Trend

The trend of the condition of geologic resources in El Malpais is generally stable. NPS Management Policies (NPS 2006) prohibit human activities such as mining and aerial bombing that impacted surface geology features prior to the establishment of El Malpais NM. However, the impacts of those past activities linger. Quarry sites on cinder cones are difficult to mitigate (KellerLynn 2012), and mitigation of the impairment of the McCartys Crater vent area from aerial bombing has not been proposed (Bering Sea Environmental 2015).

Volcanologist Larry Crumpler of the New Mexico Museum of Natural History and Science, who has been studying the McCartys Flow for many years, has noticed impacts from recreational use in the Lava Falls area (Larry Crumpler, personal communication, 2015). The glassy rind (tachylite) that has been retained on the surface of the McCartys Flow is more susceptible to trampling than the surfaces of the older lava flows. Likewise, cinder cones and other cinder landscape features are more susceptible to damage from recreational activities such as hiking because they are mostly made up of loose material that does not withstand disturbance well. The trend of sensitive geologic resources such as cinder cones may be more likely to be unstable than the trend of more robust ones like tree mold fossils.

Level of Confidence/Key Uncertainties

We have a high level of confidence in this condition assessment because a number of recent reports and datasets by the NPS and partners were available (e.g., KellerLynn 2012, Burghardt et al. 2014, and Tweet et al. 2009) for this assessment. Further, the McCartys Flow has been the subject of recent and ongoing recent research into its emplacement via inflation (Crumpler et al.

2013, Zimbelman et al. 2010, 2012, 2013, and Garry et al. 2011).

Key uncertainties include the condition of paleontological resources, and whether recreational use will continue to impact lava flow surfaces features such as in the Lava Falls area of the McCartys Flow (Larry Crumpler, personal communication, 2015), and on cinder cones.

4.5.5. Sources of Expertise

Allyson Mathis is a science writer for Utah State University and a geologist by training. Larry Crumpler, Research Curator Volcanology and Space Sciences at the New Mexico Museum of Natural History and Science, provided invaluable information about the research into the emplacement of the McCartys lava flow via inflation processes, on the location of tree molds, and on the condition of the McCartys Flow and gave permission to use numerous photographs. Eric Weaver is acting Chief of Natural Resources at El Malpais NM. David Hays was the Chief of Natural Resources at El Malpais NM until March 2015.

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Zimbelman, J. R., W. B. Garry, J. E. Bleacher, L. S. Crumpler, S. Self, J.C. Aubele, S.M. Baloga, L.S. Glaze, and R.A. Schultz. 2013. Inflation processes at the McCartys lava flow field, New Mexico, with application to identifying inflated lava flows on planetary surfaces. 44th Lunar and Planetary Science Conference. Available at http://www.lpi.usra.edu/meetings/lpsc2013/pdf/2120.pdf (accessed April 14, 2015).

4.6. Caves and Cave Ice

Indicators/Measures

- Cave Meteorology (2 measures)
- Perennial and Seasonal Ice (1 measure)
- Direct Visitor Impacts (1 measure)
- Stability-Breakdown (no measure)
- Rare Minerals (no measure)

Condition – Trend – Confidence



Unknown - Unknown - Unknown

4.6.1. Background and Importance

Subsurface features, especially lava tube caves (Figure 4.6.1-1), are included in El Malpais NM's fundamental resources and values (NPS 2014). El Malpais contains among the longest lava tube systems in the world, with a cumulative length of more than 95 km (60 mi) (Marinakis 1997). The monument also contains the southernmost ice caves on the continent.

Caves are protected by the Federal Cave Resources Protection Act (1998), which protects and preserves significant caves on Federal lands for "perpetual use, enjoyment, and benefit of all people."

Ice caves contain perennial or seasonal ice, and these ice deposits may be up to a few thousand years old and may provide important paleoclimate information (Dickfoss et al. 1997). Additionally, the ice deposits are frequently associated with cultural resources as they have been utilized by people from prehistoric to historic times.

At El Malpais, lava tube caves are mostly found in the El Calderon, Hoya de Cibola, Twin Craters, and Bandera lava flows, with at least one tube in older volcanic deposits (Figure 4.6.1-2). The lava tube caves are in 15 major cave/lava tube systems (Marinakis 1997). Long sections of collapsed tubes also exist in the monument, and entryways into lava tube caves are often through piles of rubble formed via breakdown.

Lava tube caves reveal important information about the emplacement of fluid lava flows, and may also contain rare secondary minerals. Additionally, lava tube caves



NPS

Figure 4.6.1-1. Big Skylight Cave is one of four lava tube caves open to recreational caving in El Malpais NM.

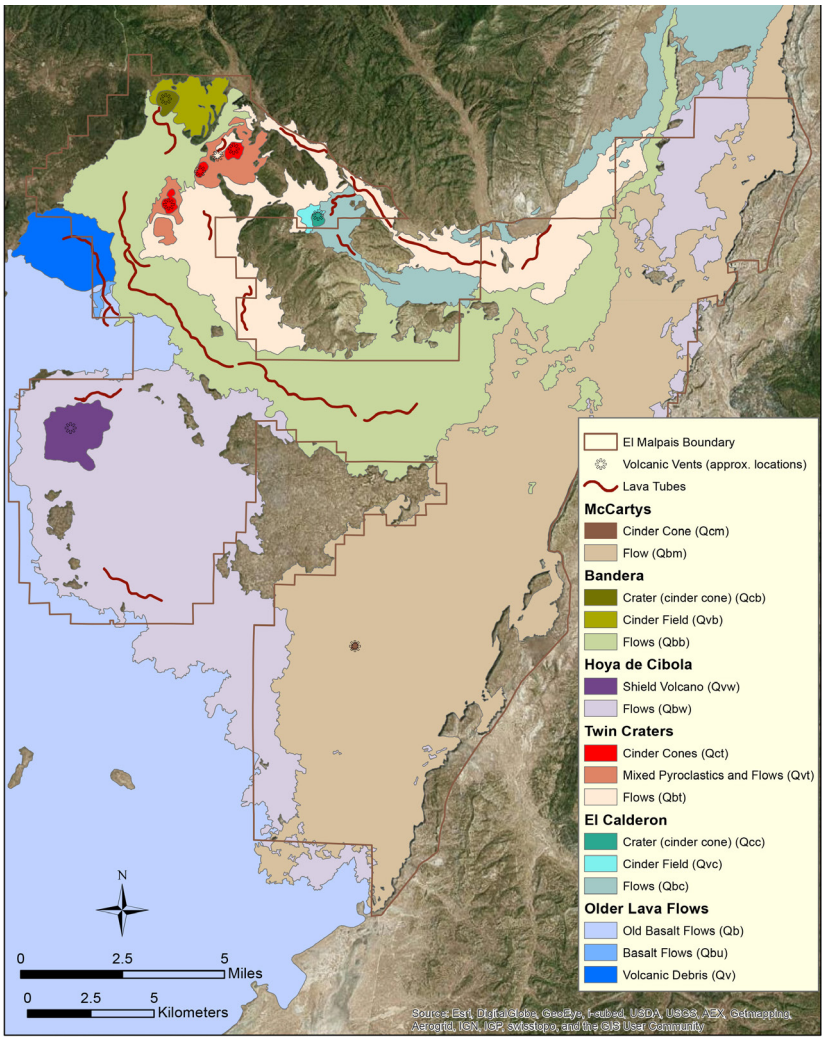


Figure 4.6.1-2. Map showing the major volcanic units of El Malpais NM and the major lava tubes. Geology from KellerLynn (2012).

provide important habitat for bats, cave-dependent organisms, and have unique plant and invertebrate assemblages growing in moss gardens in entrances and skylights (Bleakly 1997, KellerLynn 2012 and Wynne 2013). These entryways and skylights provide distinct microclimates that differ from the rest of the monument and are similar to Arctic climates (KellerLynn 2012). Other microclimates exist in caves including in twilight and dark zones and near ice bodies.

4.6.2. Data and Methods

We used five indicators to assess the current condition and trend for caves and cave ice at El Malpais NM. Measures were developed to evaluate the condition of cave meteorology, perennial and seasonal ice, and direct visitor impact. Measures were not developed for stability-breakdown and rare minerals indicators.

Information about the condition of cave and cave ice was available in a variety of reports and publications, supplemented by information from Eric Weaver, El Malpais Cave Specialist and acting Chief of Natural Resources. Lindsey (1951) provided the first general descriptions of the lava tube caves and ice caves in the El Malpais area. Carlton (1988) provided the first comprehensive resource inventory of El Malpais' lava tube caves. In 1997, Marinakis (1997) prepared a cave inventory and management consulting report that provided comprehensive information on the monument's lava tubes, including information on the status of cave ice. Additionally, information on El Malpais caves is in the park's Geologic Resources Inventory (KellerLynn 2012).

Indicator/Measures
Cave Meteorology (Temperature and Humidity)

Limited information on temperature and humidity condition in El Malpais lava tube caves is available. Ingham et al. (1996 and 2004) presented information from data loggers deployed in two caves between 1993-1995 in a study that was originally geared towards understanding the impact of a planned prescribed fire on lava tube caves (a fire that was never ignited). Beucher and Northup (2011) provided temperature and relative humidity information from microloggers placed in 10 El Malpais caves between late January and late April 2011 as part of an effort to assess whether microclimates in caves used as bat hibernacula were suitable for the growth of *Pseudogymnoascus destructans*, the fungus responsible for White Nose Syndrome. Most of these dataloggers showed diurnal changes in temperature and humidity, although dataloggers in more interior sections of caves (such as in the mud room of Junction Cave) showed less variation than dataloggers in other sections of caves (Beucher and Northup 2011).

Because El Malpais caves are shallow, temperature and humidity conditions inside

caves have a connectivity with atmospheric conditions at the surface, with both annual and diurnal cycles evident (Ingham et al. 2004). Because specific information about temperature conditions inside caves is limited, we used information from the Recent Climate Change Exposure Brief for El Malpais NM (Monahan and Fisichelli 2014) to assess atmospheric conditions that may impact cave meteorology. Figure 4.6.2-1 shows the historical range of variability and the most recent percentile for annual mean temperature with an increase in annual mean temperature since approximately the mid-1980s (Monahan and Fisichelli 2014). The temperature variables of mean annual, mean warmest quarter, mean coldest quarter and mean coldest month were all also "extreme warm," meaning that they were >95th percentiles across 10, 20, and 30-year intervals.

Indicator/Measure

Perennial and Seasonal Ice (Presence/Absence)

This indicator uses the presence/absence of cave ice to provide a limited assessment of the condition of seasonal ice. We chose the presence/absence measure because information on the quantity and other aspects of cave ice is not known.

Perennial or seasonal ice has been documented in at least 40 caves inside of El Malpais NM (Marinakis 1997; NPS 2012; NPS 2015a) (Table 4.6.2-1). Carlton (1988) provided the first systematic inventory of El Malpais caves and included information on the presence and condition of ice; however, his report did not incorporate the cave numbering system currently used to designate El Malpais caves. Marinakis (1997) documented ice in 30 caves, noting general descriptions of the ice. Six caves held significant or massive perennial ice with 24 caves containing amounts of seasonal or perennial ice. One cave that previously held an ice pool no longer contained ice as the pool had been filled by breakdown (Marinakis 1997). Since 1997, monument staff have documented ice in ten additional caves (NPS 2015a), including seven caves not known by Marinakis (1997).

Thirty-four of these ice caves are currently known to monument staff with their locations identified (NPS 2015a). Of these 34 caves, ice was documented as present in 20 of these caves at least once between 2000 and 2008, and ice was absent at least once in four caves.

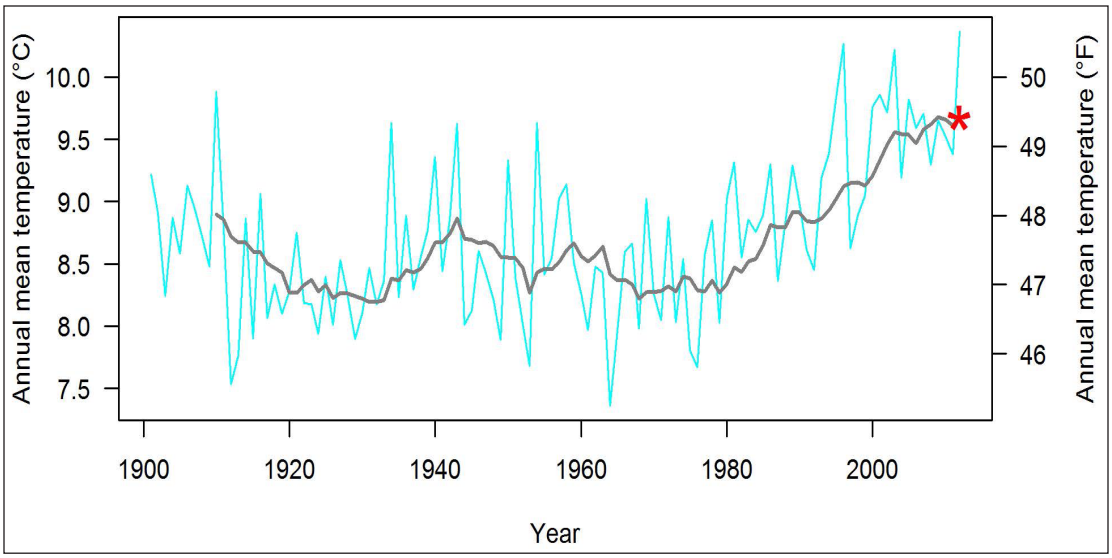


Figure 4.6.2-1. Time series showing the historic range of variability and the most recent percentile for mean annual temperature at El Malpais. The gray line shows temperature averaged over progressive 10-year intervals (10-year moving windows), the blue line shows mean temperature for each year, and the red asterisk show the average temperature of the most recent 10-year interval (2003-2012) (from Monahan and Fisichelli 2014).

Table 4.6.2-1. Known Ice Caves in El Malpais NM.

Cave #	ArcGIS (Yes/No)[1]	Description (Marinakis 1997)	Ice Present (Year)[1]	Ice Absent (Year)[1]	Ice Present 2012[2]	Ice Present 2015[1]
001	Yes	Lesser amounts of seasonal or perennial ice	2001		Unknown	Unknown
002	Yes	Lesser amounts of seasonal or perennial ice	2001		Unknown	Unknown
005	Yes	Lesser amounts of seasonal or perennial ice	2001		Unknown	Unknown
006	Yes	Lesser amounts of seasonal or perennial ice			Yes	Yes
007	Yes	Lesser amounts of seasonal or perennial ice	2001, 2005		Unknown	Unknown
010	Yes	Lesser amounts of seasonal or perennial ice	2001, 2008		Unknown	Seasonal
012	Yes	Lesser amounts of seasonal or perennial ice			Unknown	Seasonal
013	Yes	Lesser amounts of seasonal or perennial ice	2001		Unknown	Unknown
014	Yes	Lesser amounts of seasonal or perennial ice	2001		Yes	Unknown
016	Yes	Lesser amounts of seasonal or perennial ice	2001		Yes	Seasonal
021	Yes	Lesser amounts of seasonal or perennial ice	2001		Unknown	Unknown
023	Yes	Massive perennial ice			Unknown[3]	Seasonal
029	Yes	Massive perennial ice			Yes	Yes, perennial
032	Yes	Lesser amounts of seasonal or perennial ice			No	Unknown
055	Yes	Lesser amounts of seasonal or perennial ice	2001	2000	Unknown	Unknown
056	Yes	Perennial ice			Unknown	Unknown
079	Yes	None reported			Yes	Unknown
092	Yes	Lesser amounts of seasonal or perennial ice			No	Yes; massive perennial ice
093	Yes	Lesser amounts of seasonal or perennial ice	2001		Unknown	Yes, perennial
097	Yes	Lesser amounts of seasonal or perennial ice	2001		Unknown	Unknown
099	Yes	Lesser amounts of seasonal or perennial ice	2001		Yes	Unknown
102	Yes	None reported	2001		Unknown	Unknown
128	Yes	Lesser amounts of seasonal or perennial ice			Unknown	Unknown
143	Yes	Lesser amounts of seasonal or perennial ice	2001		Seasonal	Unknown
147	Yes	Lesser amounts of seasonal or perennial ice	2002		Unknown	Yes, perennial
165	Yes	Lesser amounts of seasonal or perennial ice	2000	2001	Unknown	Unknown
188	Yes	Lesser amounts of seasonal or perennial ice			Unknown	Unknown
233	Yes	N/A	2001		Yes	Yes, perennial
234	Yes	N/A			No	Seasonal
235	Yes	N/A		2001	Unknown	Seasonal
236	Yes	N/A	2001		Yes	Seasonal
250	Yes	N/A	1999	2005, 2010	Unknown	Unknown
455	Yes	N/A			Unknown	Yes, massive perennial
457	Yes	N/A			Unknown	Yes, massive perennial
033	No	Lesser amounts of seasonal or perennial ice			N/A	Unverified
053	No	Significant perennial ice			N/A	Unknown
067	No	Significant perennial ice			N/A	Unknown
070	No	Significant perennial ice			N/A	Unknown
084	No	Former ice pool filled by breakdown			N/A	N/A
094	No	Lesser amounts of seasonal or perennial ice			N/A	Unverified

[1] NPS (2015a)

[2] NPS (2012)

[3] A 2013 monitoring photo showed ice in this cave.

In 2012, an initiative to monitor cave ice evaluated 13 caves (NPS 2012). Perennial ice was found in eight caves, one cave had seasonal ice, and four caves did not contain ice. In 2015, El Malpais staff monitored conditions in 15 caves where ice has been documented (NPS 2015a). Seasonal ice was present in 11 caves and perennial ice was present in four caves.

Repeat photography of ice deposits in caves can provide information on the condition of ice over a period of time (Figure 4.6.2-2). Because of the seasonal variation in the amount of ice in caves (greatest in early spring and lowest in early fall), these comparisons are most useful when the month or season of the photographs are known.

Indicator/Measure
Direct Visitor Impacts (Degree of Impact)

We used the degree of impact measure to assess direct visitor impacts. Four caves (Xenolith, Junction, Big Skylight and Giant Ice Caves) are open to recreational caving with a required permit in El Malpais NM (NPS 2013).

El Malpais NM instituted a cave permitting system in 2013 to provide access to a limited number of caves, while the remaining caves in El Malpais are closed to recreational use (NPS 2013). Prior to 2010, when all El Malpais caves were temporarily closed to recreational caving because of concern related to the spread of White Nose Syndrome, permits were not required to enter caves in the monument. Through October 2015, 838 caving permits had been issued for the year, with 2,865 cavers (Table 4.6.2-2).

Direct visitor impacts to El Malpais caves are known to exist, and in 2015, El Malpais NM resource management staff began implementation of a documentation program to record visitor impacts in caves as mapping is completed (Eric Weaver, personal communication, 2015).

Monitoring and trip reports by NPS staff and the Sandia Grotto of the National Speleological Society have noted visitor impacts when observed.

Direct visitor impacts may include vandalism, dust, lint, trash, food, broken features, polishing or smoothing of surfaces, compacted floors, and footprints. The impact assessment protocol includes visual identification of the amount of trash, evidence of human presence and spray paint or vandalism at monitoring stations (Eric Weaver, personal communication, 2015).

Junction Cave's impact assessment and map shows the majority of the cave with at least some to significant impacts (NPS 2015b) (Figure 4.6.2-3). Monument staff are in the process of conducting an impact assessment for Xenolith Cave in conjunction with building a trail using reflective markers and have started photo-monitoring in Cave 110 (Eric Weaver, personal communication, 2015).

Indicator/Measure
Stability-Breakdown (No measure)

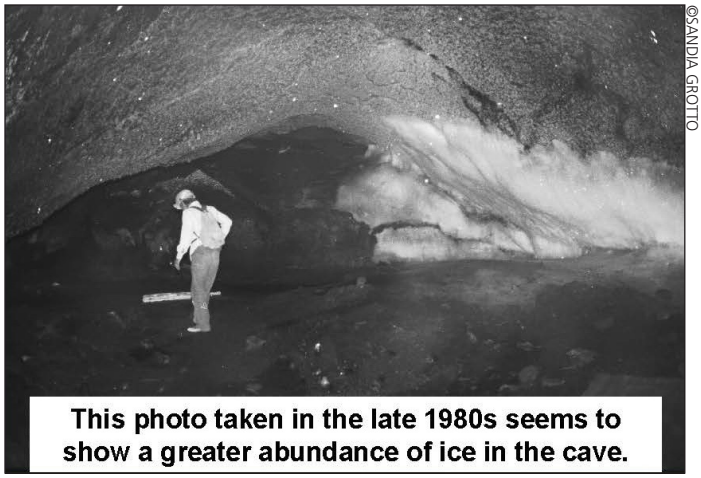
Breakdown refers to both the broken deposits of rock material from the ceiling and walls of caves and the rockfall and other mass wasting processes that deposit them. Breakdown covers the floors of many lava tube caves in El Malpais, and the deposits may be as much as several meters deep in some caves (Rogers and Mosch 1997b).

Cave maps show areas of breakdown, but few El Malpais caves have been mapped, although areas of new breakdown caused by rockfall have been documented by cave researchers (Eric Weaver, personal communication,

Table 4.6.2-2. Number of permitted cavers at El Malpais NM 2013-2015.

Year	No. of Permits	No. of Cavers
2013	338	1219
2014	877	3238
2015*	838	2865

*Data for 2015 are through October 31. Information provided by Eric Weaver, Cave Management Specialist, El Malpais NM.



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Figure 4.6.2-2. Repeat photographs of the thick ice wall in Cave #029. Large amounts of charcoal are present on the floor, likely from fires from early visitors. This cave shows significant impact from human activity (Sandia Grotto 2003). The upper left photo is from the late 1980s, month unknown, and the upper right photo was taken on April 4, 2003. The photo on the left was taken on May 21, 2015. This photo sequence shows an apparent decrease in ice since the late 1980s. Note that the exact date of the 1980s photo is unknown and that the volume of ice in caves is seasonally dependent, so the actual trend of ice in this cave may not be illustrated by this sequence. However, during monitoring in May 2015, El Malpais staff observed markings on the wall of the cave that showed that the ice had receded by approximately 2 m (6.6 ft) (Eric Weaver, personal communication, 2015).

2015). A pool that previously held ice was filled in and that cave (084) no longer contains ice (Marinakis 1997 and Eric Weaver, personal communication, 2015).

Indicator/Measure
Rare Minerals (No measure)

Fourteen secondary minerals or mineraloids have been identified in El Malpais lava tube caves (Rogers and Mosch 1997b). Seven of these minerals are rare in cave environments, and El Malpais has some of the first occurrences of these minerals in caves (Table 4.6.2-3).

These minerals often are part of fragile speleothems such as angel hair, powder, "snowballs," or part of moonmilk, which is white deposit with a cottage cheese-like, tufted or fibrous texture present in a few El Malpais caves (Rogers and Mosch 1997b). Some of these minerals, such as mirabilite, may undergo seasonal changes as Na-sulfate minerals may dissolve under wet conditions (Rogers and Mosch 1997b and McHenry 2008).

4.6.3. Reference Conditions

Reference conditions for caves and cave ice indicators are in Table 4.6.3-1. No reference conditions were developed for stability-breakdown and rare minerals indicators. since no measures were identified.

The reference condition for cave meteorology is whether the temperature and humidity conditions in cave remain within their natural range of variability, and are not being impacted by changes in surface conditions or by human visitation in caves.

The reference condition for cave ice is that ice is present in all caves in which it has been previously documented. Because information on ice occurrence is limited,

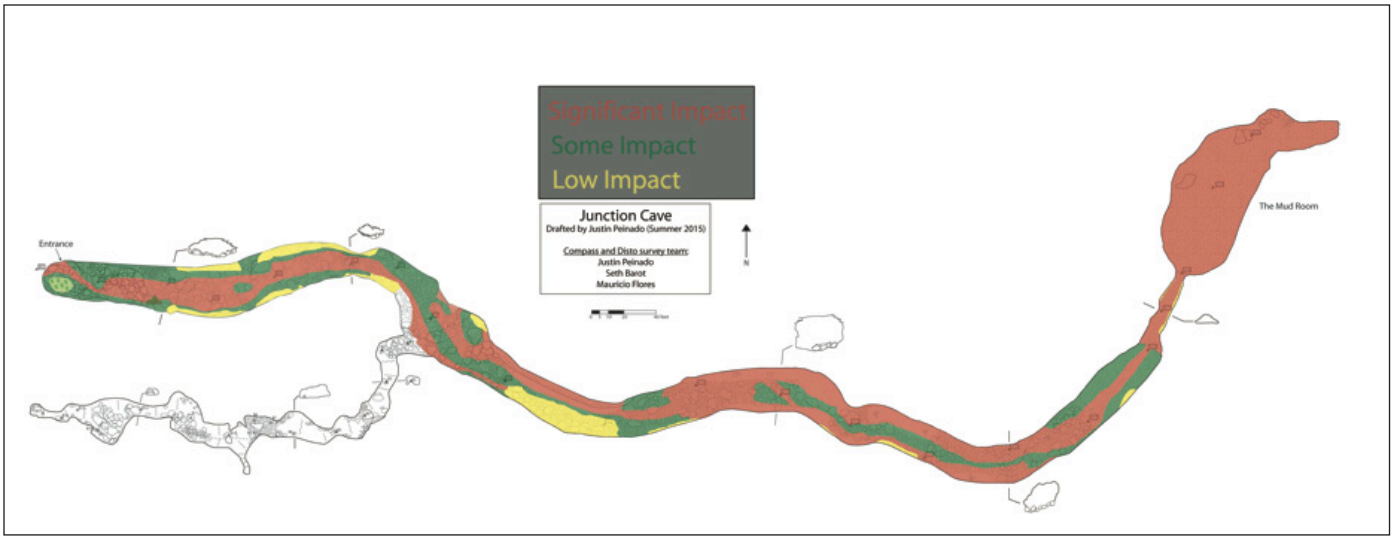


Figure 4.6.2-3. Junction Cave Impact Assessment Map. Map provided by El Malpais NM.

Table 4.6.2-3. Rare cave minerals documented in El Malpais NM (Rogers and Mosch (1997) and Hill and Forti (1997)).

Mineral/Speleothem	Formula	Cave	Notes
Minerals			
Burkeite	$Na_6(CO3)(SO_4)_2$	108	Rare mineral usually found in saline lake deposits. The first known cave occurrence of burkeite was in El Malpais.
Cristobalite	SiO_2		A low temperature form of cristobalite is a component of coralloids with calcite. It is known from lava tube caves in El Malpais and in California.
Epsomite	$MgSO_4 \bullet 7H_2O$	025, 110	Occurs as angel hair deposits and transparent silky crystals.
Glaserite	$(K,Na)Na(SO_4)_2$		Only known from a few caves in El Malpais, Western Australia, Namibia and Sicily.
Mirabilite	$Na_2SO_4 \bullet 10H_2O$	006, 008, 054, 110	Occurs with thenardite in coralloids, angel hair and loose powder. Its occurrence may be seasonal in nature as the mineral dissolves under wetter conditions.
Thenardite	Na_2SO_4	110, 150	Formed from dehydration of mirabilite. Occurs as "snowballs," loose powder or hair.
Trona	$Na_3(CO_3)(HCO_3) \bullet 2H_2O$	038	Only known as a cave mineral from El Malpais and three other lava tube caves in the world.
Speleothem			
Moonmilk	n/a	025, 110	Uncommon speleothem consisting of calcite and other minerals. Bacteria may be involved in its formation.

we did not develop reference conditions beyond the presence/absence measure. The presence/absence measure does not provide information about the quantity of ice or any other variable.

The reference condition for direct visitor impacts is that caves have no impact or a low level of impact and that cave resources cave resources exist in their natural condition and are intact.

4.6.4. Condition and Trend

We used five indicators to assess the condition of caves and cave ice at El Malpais NM as summarized in Table 4.6.4-1.

Cave Meteorology

Temperature and humidity conditions in caves have significant impacts on cave features such as ice deposits, mineral and speleothem condition, and cave ecology and cave organisms. Cave meteorology conditions, especially in the shallow lava tube caves at El Malpais NM, may be sensitive to changes

Table 4.6.3-1. Reference conditions used to assess the current condition of caves and cave ice for each indicator.

Indicator	Measure	Good	Moderate Concern	Significant Concern
Cave Meteorology	Temperature and Humidity	Temperature and humidity conditions in caves are within their natural range of variability.	Temperature and humidity conditions in caves have a slight departure from their natural range of variability.	Temperature and humidity conditions in caves have been altered from their natural range of variability.
Cave Ice	Presence/Absence	Seasonal or perennial ice is present in all caves that have been documented as containing ice.	Seasonal or perennial ice is present in a medium number of caves that have been documented as containing ice.	Seasonal or perennial ice is present in few caves that have been documented as containing ice.
Direct Visitor Impacts	Degree of Impact	Caves have no impact or a low level of impact.	Caves have some impact.	Caves have significant impact.
Stability-Breakdown	n/a			
Rare Minerals				

caused by the presence of people in caves, and to atmospheric conditions at the surface.

Monitoring of two El Malpais caves in the mid-1990s showed that both caves had strong diurnal and seasonal variations in temperature and humidity conditions indicating that conditions inside El Malpais caves are related to conditions at the surface (Ingham et al. 1996 and 2004). Heat from the surface may be transported into El Malpais caves via conduction and via air movement (Ingham et al. 2004). The amount of airflow is dependent on the number of entrances the cave has, barometric pressure, wind and the relative temperature between the surface and interior of the caves. Some caves, especially those with a single entrance caves with a downward slope, are cold traps as more dense cold air is not able to mix with warmer air (Ingham et al. 2004). However, cold traps are not limited to caves with only one entrance, and at least one El Malpais cave with three entrances has a significant cold trap (Eric Weaver, personal communication, 2015).

The deeper sections of a cave have less temperature variation than areas closer to the entrance (Ingham et al. 2004 and Beucher and Northup 2011). Additionally, the presence of a melting ice body in a cave can buffer the temperature nearby as melting ice absorbs heat (Ingham et al. 2004).

Each cave has its own unique microclimate and relationship with conditions at the surface and different sections of a single cave may also have their unique microclimates. Beucher and Northup (2011) present data from 22 microloggers in ten caves for an approximately two month interval. Most dataloggers showed diurnal variation, but some dataloggers recorded nearly constant temperature. Further, the temperatures recorded at some dataloggers showed a seasonal trend and others did not (Beucher and Northup 2011). No current information on cave meteorology conditions were available for this assessment, so the condition of this indicator is unknown.

While little specific information exists on the temperature and humidity conditions inside El Malpais caves, climatic conditions at the surface have a warming trend (Monahan and Fisichelli 2014). The mean annual temperature as measured in progressive 10-year intervals has increased significantly since the early 1980s. Therefore, while the condition of cave meteorology at El Malpais is unknown, the warming conditions at the surface may be causing an increase in temperature in at least some cave as almost all heat in El Malpais caves originates from the surface (Ingham et al. 2004).

Perennial and Seasonal Ice

The condition of permanent and seasonal ice in El Malpais NM is unknown due to limited data. The initial inventories of lava tube caves in El Malpais (Carlton 1988 and Marinakis 1997) documented caves that contained ice. Marinakis (1997) documented a total of

Table 4.6.4-1. Indicators, measures, and rationale used to assess the current condition of caves and cave ice.

Indicator	Measure	Condition	Rationale for Condition
Cave Meteorology	Temperature and Humidity	Unknown	Temperature and humidity conditions in El Malpais caves are unknown. However, because the lava tube caves are shallow and because many caves have more than one opening, there is a connectivity between conditions at the surface and conditions inside caves. The annual mean temperature at El Malpais has risen significantly since the 1980s, suggesting that temperatures inside caves also may be increasing.
Permanent and Seasonal Ice	Presence/ Absence	Unknown	The condition of permanent and seasonal cave ice in El Malpais is unknown. Cave ice has been documented in 40 caves within the national monument. Monitoring in 15 of these caves in 2015 found at least seasonal ice in each cave, but the relative quantity of ice in these caves is not known. Warming climatic conditions at the surface may lead to warmer conditions inside caves, potentially decreasing the amount of cave ice.
Direct Visitor Impacts	Degree of Impact	Unknown	The Impact Assessment Map for Junction Cave showed that the majority of the cave had significant impact. However, the impact assessment for Junction Cave is the only assessment completed to date in El Malpais, and this cave has more visitor impacts than the other lava tubes open to recreational caving (Eric Weaver, personal communication, 2015). Therefore, the condition for direct visitor impact is unknown.
Stability-Breakdown	n/a	Unknown	Breakdown is a common feature of El Malpais caves. Much of the breakdown probably formed during cooling after cave formation, but heavily jointed ceilings and walls can be unstable causing additional breakdown events. Formation of new breakdown has been documented, but the condition of stability-breakdown at El Malpais is unknown.
Rare Minerals	n/a	Unknown	El Malpais contains several minerals that very rarely occur in caves, including burkeite, cristobalite, glaserite, thenardite and trona. Many of these minerals occur as part of fragile speleothems or deposits such as angel hair, loose powder, "snowballs," or moonmilk. The rare minerals in El Malpais caves are not being monitored, so their condition is unknown.

30 ice caves of which 25 caves are in the El Malpais cave database (Eric Weaver, personal communication, 2015). Ice was documented as present at least once by El Malpais NM staff at least once between 2000 and 2008 (NPS 2015a). In 2012, ice was present in five caves, absent in two caves, and in unknown condition in 17 of the ice caves documented by Marinakis (1997) (NPS 2012). In 2015, seasonal or perennial ice was present in the nine caves that were monitored, although one of the caves (029) that had been documented by Marinakis (1997) as having massive perennial ice only held seasonal ice (NPS 2015a).

Since the 1997 inventory conducted by Marinakis (1997), ten additional caves have been documented as containing ice (NPS 2015a). Of the 40 total lava tube caves documented to have contained ice, 15 caves contained ice in 2015, with the presence/ absence of ice in 24 caves being unknown (NPS 2015a). The only documented ice cave known to have completely lost its ice pool is cave 084, where breakdown filled the former ice pool (Marinakis 1997). Although the presence/absence of ice in many caves in 2015 is unknown because they were not monitored, ice was present in all caves that were monitored (NPS 2015a). Whether the relative amount of ice has changed in these caves is unknown, at least one cave (023) apparently had less ice (NPS 2015a). Ice in El Malpais lava tubes can be very sensitive to slight disturbances. The presence of NPS staff in one area of a cave during monitoring in summer 2015 was significant enough to begin melting (Eric Weaver, personal communication, 2015).

Photo monitoring can be an important tool in measuring the vital signs of cave ice, although it is important that repeat photography take place in the same season(s) as ice volume and condition is very sensitive to seasonal conditions (Toomey 2009). A great deal of ice can accumulate over a winter but then disappears via ablation or melting during the summer (Eric Weaver, personal communication, 2015). Although the overall trend of ice in El Malpais lava tube caves is unknown, NPS staff observed that the ice wall in Cave #029 previously was approximately 2 m (6.6 ft) higher than it currently is (Eric Weaver, personal communication, 2015), suggesting that the volume of ice has decreased since the 1980s.However, because the date

of the 1980s photograph is not known, the comparison may not be representative of any long-term trend.

Additionally, the climatic conditions at the surface, including both temperature and precipitation, can impact the amount of ice in caves (Eric Weaver, personal communication, 2015). Winter (November - March) 2014-2015 was significantly warmer than average with near normal amounts of precipitation (Western Regional Climate Center 2015), and even so, at least some ice was present at some point during the year in all monitored ice caves (NPS 2015a).

Additional information about ice caves in the El Malpais region includes long term monitoring of the privately owned Candelaria Ice Cave, revealing that it has had a complex history of accumulation and ablation (Dickfoss et al. 1997). An ice cliff showed significant horizontal ablation, but the ice pool had accumulation during most time intervals. The current condition of Candelaria Ice Cave is not known.

Direct Visitor Impact

The Junction Cave Impact Assessment Map shows significant impacts in most areas of the cave including multiple social trails, some spray paint, mud sculptures and broken glass (Eric Weaver, personal communication, 2015). Junction Cave is the most visited of El Malpais caves and has more direct visitor impacts than the other caves open to recreational caving (Eric Weaver, personal communication, 2015), whereas visitor impact in Big Skylight and Giant Ice Cave is relatively small (Eric Weaver, personal communication, 2015). Junction and Xenolith Caves are more accessible than the other two open caves and, therefore, receive significantly more use. Junction Cave is closed to protect bats during the winter (Eric Weaver, personal communication, 2015).

El Malpais NM staff are in the process of establishing caves in trails using reflective markers (Figure 4.6.4-1) and will assess the effectiveness of established trails on reducing visitor impacts in caves in the future (Eric Weaver, personal communication, 2015.

Direct visitor impacts in lava tube caves at El Malpais NM may be more permanent than impacts in wet limestone caves undergoing active speleogenesis (Eric Weaver, personal communication, 2015). Most of the features in the lava tube caves formed during or immediately after lava flow emplacement, including lava benches, levees, linings, lava balls (Rogers and Mosch 1997a). Lava stalactites, stalagmites and lavacicles also resulted from the formation of lava tubes (Marinakis 1997). Secondary mineral deposits, such as gypsum and other sulfates, also probably formed at the time of eruption (Dillon et al. 2009), although there are different mechanisms by which these mineral deposits my form. But because many key features of lava tube caves are not undergoing active cave processes, they may not be able to heal themselves like those in wet limestone caves.

Additionally, large group sizes may cause additional direct visitor impacts to caves (Eric Weaver, personal communication, 2015). Large school groups have visited El Malpais lava tubes, with groups as large as 80 individuals. Monument staff plan to develop a raised platform through Junction Bridge (a short cave segment immediately adjacent to Junction Cave) to provide a caving experience more appropriate for large groups (Eric Weaver, personal communication, 2015). The overall condition of caves relative to direct visitor impacts is unknown.

Stability-Breakdown

Much of the breakdown at the entrances to and in El Malpais caves and skylights likely formed during initial cooling of the lava flows (Rogers and Mosch 1997a), but the formation of breakdown is an ongoing process. The ceilings and walls of lava tube caves are generally heavily jointed, decreasing their stability, and loose blocks may be found in cave ceilings. Areas of new breakdown have been recorded in El Malpais caves (Eric Weaver, personal communication, 2015).

Because El Malpais caves are not being monitored for stability-breakdown, the condition of this indicator is unknown.

Rare Minerals

The rare minerals in El Malpais caves are not being monitored. However, as part of cave impact assessments and cave mapping, El Malpais staff are inventorying the locations of secondary cave minerals (Eric Weaver, personal communication, 2015). It is usually not possible to differentiate between some of the unusual minerals and more common carbonates and sulfates in the field without using analytical methods. (Eric Weaver, personal communication, 2015).

Many of these minerals occur as components of fragile or delicate speleothems or cave features. Mirabilite may only be seasonally present as it dissolves under wetter conditions. Most of the rare minerals in El Malpais lava tubes are Na-sulfates or Na-carbonates, including burkeite, thenardite and trona. These minerals may also be impacted by seasonal changes in the lava tubes such as those that occur in lava tube caves at Craters of the Moon National Monument (McHenry 2008).



Overall Condition and Trend

The overall condition and trend of the caves and cave ice in El Malpais NM is unknown. Although, areas of concern exist including a warming climate trend and visitor impacts.

4.6.5. Sources of Expertise

Allyson Mathis, a science writer for Utah State University, authored this assessment. Eric Weaver is the Cave Management Specialist and acting Chief of Natural Resources at El Malpais NM and provided information about the park's cave resource management program.

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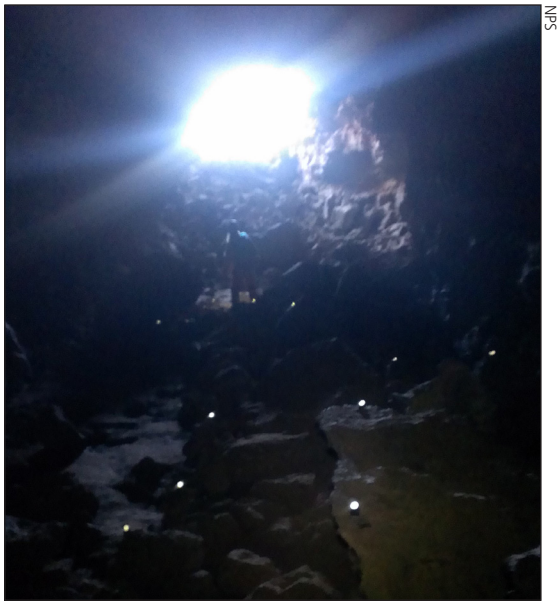

NPS

Figure 4.6.4-1. Reflective trail markers to reduce direct visitor impacts have been installed in Xenolith Cave.

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4.7. Tinajas

Indicators/Measures

- Climate Variables (2 measures)

Condition – Trend – Confidence



Moderate - Insufficient Data - Low

4.7.1. Background and Importance

Ephemeral aquatic habitats at El Malpais National Monument are limited and occur as freshwater rock pools known as tinajas. Globally these pools occur in every biome, varying greatly in size. The interactions between the geology and climate determine the morphology, hydrology, and biology of the pools (Jocque et al. 2010).

Tinajas at El Malpais NM are found in eroded depressions on sedimentary rock substrates found at the eastern side of the park and smaller ones are found on the lava flows (KellerLynn 2012) (Figure 4.7.1-1). These pools are ephemeral and volumes of water held in them is typically low. The source of input to these catchments is meteoric precipitation (Figure 4.7.1-1) and environmental conditions such as high temperature ranges within daily and annual cycles results in extreme fluctuations of water levels in the tinajas. These rapid fluctuations in water availability require a high stress tolerance in species that utilize these habitats.

The organism community structure found in tinajas is typically simple and comprised of aquatic opportunists or specialists with dispersal and recolonizing adaptations necessary for survival (Graham 2002).

There are three types of pool dispersers: passive (such as large branchiopods like *Triops* and fairy shrimp), terrestrial (amphibians and toads), and aerial (insects). Passive dispersers usually travel relatively short distances, relying on wind and/or overflow between pools and exhibit high endemicity. The terrestrial and aerial species are active dispersers and migration usually occurs during their adult phases (e.g, toads vs. tadpoles, insect adults vs. larvae, etc.). In general, a higher number of passive dispersers have been found in North



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Figure 4.7.1-1. Dry tinajas located on top of Sandstone Bluffs at El Malpais National Monument.

American pools; however, this may be a result of a lack of comprehensive research (Jocque et al. 2010).

Tinajas that are intermittently dry usually have lower species richness, contain organisms that can quickly disperse, such as branchiopods with smaller cysts, and have species that can remain dormant for several years. The research suggests that as the diversity of communities decrease with decreasing hydroperiod, biotic interactions become less important (Therriault & Kolasa 2001; Wellborn et al., 1996 as cited in Jocque 2010). Conversely, large rains or multiple rain events provide more opportunity for dispersal as well as organism diversity (Graham 2002).

During Wupatki National Monument's ephemeral pool inventory, no Branchiopoda species were found within the pools that were of similar in size/depth (volumes of 0.09, 0.32, 0.12 m/m^3) to those likely found throughout El Malpais NM (Graham 2002). However, at least one species of *Triops* has been observed throughout some of the tinajas by park and NPS Southern Colorado Plateau Inventory and Monitoring Network (SCPN) staff (D. Hays, Former Branch Chief of NR, pers. comm. 2015), which may suggest that El Malpais represents a higher species richness in similar sized tinajas. Steve Monroe, NPS SCPN Hydrologist, observed several species in the sandstone tinajas along the eastern side of the park, including fairy shrimp, canyon tree frogs (both tadpoles and adults), and springsnails. The latter are particularly significant since there has been discussions of nominating some species of springsnails in New Mexico for endangered status (S. Monroe, SCPN Hydrologist, pers. comm.).

To date, no formal studies have been conducted at the park to determine tinaja community presence, composition, or trends, but Lightfoot et al. (1994) found Canyon Treefrog (*Hyla arenicolor*) to be common in tinajas and stock tanks on the east side of the park. Later, during the park's 2002-2003 herpetofauna inventory, Nowak and Persons (2008) did not locate this species, suggesting that drought conditions during the time of the survey may have been the cause.

4.7.2. Data and Methods

Since species communities are dependent on the length and frequency of pool inundations, the active communities likely reflect the prevailing climate conditions. As such, climate variables of precipitation and Reconnaissance Drought Index (RDI) were used to assess tinaja condition given the lack of survey data.

Indicator/Measure
Climate Variable: Amount of Precipitation

Mean annual precipitation was determined using 1938-2015 data from the El Morro National Weather Service (NWS) cooperative weather station (coop ID 292785). Individual months were not used for annual statistics if more than five days were missing (WRCC 2016).

Indicator/Measure
Climate Variable: Reconnaissance Drought Index

RDI for El Malpais was calculated using 1939-2015 data from the El Morro NWS weather station (coop ID 292785) (WRCC 2015), filtered to remove waters years in which any month was missing seven or more precipitation or temperature values (water years: 1942-43, 1947-50, 1952, 1955, 1965, 2000-01, 2012, and 2014) (Jodi Norris, personal communication, 2016), using the DrinC software package (Tigkas et al. 2013). Annual RDI was estimated using the Thornthwaite method of estimation for potential evapotranspiration, which is based on mean air temperatures (Jodi Norris, personal communication, 2015).

The RDI time scale is yearly and incorporates both precipitation and potential evapotranspiration into its calculations (Tsakaris and Vangelis 2005). The incorporation of potential evapotranspiration provides important advantages over other drought indices and is more suitable in cases of a changing environment (Fuchs 2012), but it does not provide insight into occurrence, frequency, or temporal distribution of intense precipitation events. As such, its use is more appropriate for application at the landscape scale (Stephen Monroe, Hydrologist, Southern Colorado Plateau Network,

National Park Service, review comment included in ELMO historic pool assessment review, 2015).

It's important to note that data from the Grants, New Mexico coop station, which is closer to El Malpais, were not used for either measure. The station had a short data record and was not very consistent with the surrounding stations, whereas the El Morro station record was longer and reasonably consistent with several of the surrounding stations. Also, the El Morro station is close enough to El Malpais to use as a general record of drought stress for El Malpais NM (Jodi Norris, personal communication, 2015).

4.7.3. Reference Conditions

The reference conditions by which tinaja condition was assessed are listed in Table 4.7.3-1.

4.7.4. Condition and Trend

The average annual precipitation for the period of record (1938-2015) was 13.6 inches, with a range of 7.8 - 19.5 inches (Figure 4.7.4-1) (WRCC 2016 - Station #292785). Precipitation was well above average in 2015, with 17.45 inches, which is one of the highest amounts on record, suggesting an improvement in the recent drought conditions that occurred from 2012-2014. The western half of Cibola County New Mexico, where the park is located, is still considered to be abnormally dry (Figure 4.7.4-2) (National Drought Mitigation Center 2016). Taking this into account, along with the high amount of rainfall in 2015, this measure was considered to be in good to moderate condition.

The normalized RDI value for 2015 was 0.25, which indicates near normal conditions (Figure 4.7.4-3) (Nicolas et al. 2011). However, the longer-term trend of RDI in the region for several years preceding 2015 were either negative (i.e., 1999, 2002-2004, 2007-2008, 2011, 2013) or very low (i.e., 2005-2006, 2009-2010), suggesting overall drier conditions, warranting a moderate condition rating.

Table 4.7.3-1. Reference conditions for tinajas.

Indicator	Measures	Good	Moderate	Significant Concern
Climate Variables	Amount of Precipitation	Current rainfall average has remained stable and/or increased compared to the average for the period of record.	Current rainfall average is moderately less than the average for the period of record.	Current rainfall average is significantly less than the average for the period of record.
	Degree of Drought	No recent drought conditions over the period of record.	Abnormally dry to mild drought conditions over the period of record.	Severe to exceptional drought conditions over the period of record.

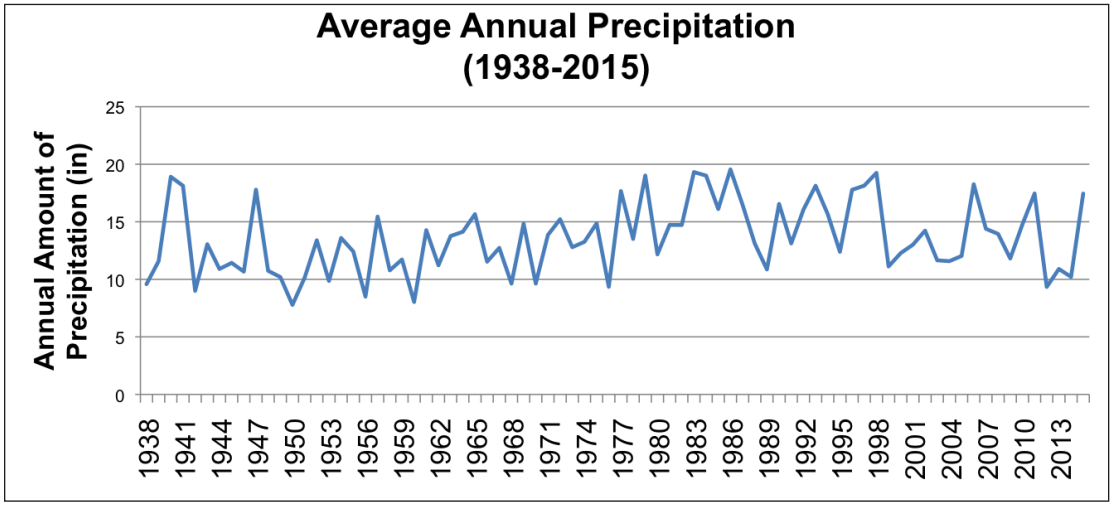


Figure 4.7.4-1. The average annual precipitation from 1938-2015 was 13.6 inches (WRCC 2016 - Station #292785).

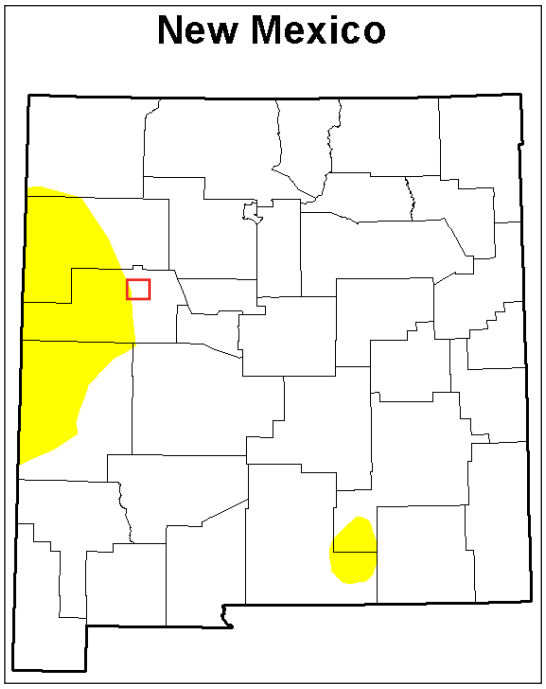
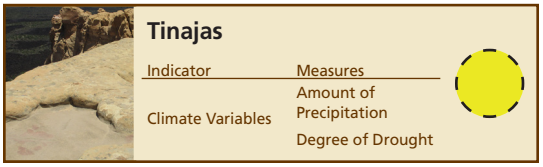


Figure 4.7.4-2. According to the National Drought Mitigation Center (2016), the western half of Cibola County, where El Malpais is located, is still in an abnormally dry condition, although greatly improved during 2015. Rectangle shows approximate location of the park.



Overall Condition

The conditions for both measures are summarized in Table 4.7.4-1, with an overall condition rating of moderate.

Uncertainties

Recent climate change models for the southwestern United States predict possible scenarios ranging from hotter and drier (less frequent, higher intensity rain events); to warm and wet (slight increase in rainfall frequency as well as an increase in the intensity of rain events); or what's known as Feast or Famine (high degree of variability, but increase in intensity of rain events) (Stephen Monroe, Hydrologist, Southern Colorado Plateau Network, National Park Service, review comment included in ELMO historic pool assessment review, 2015), which will influence the water availability in tinajas.

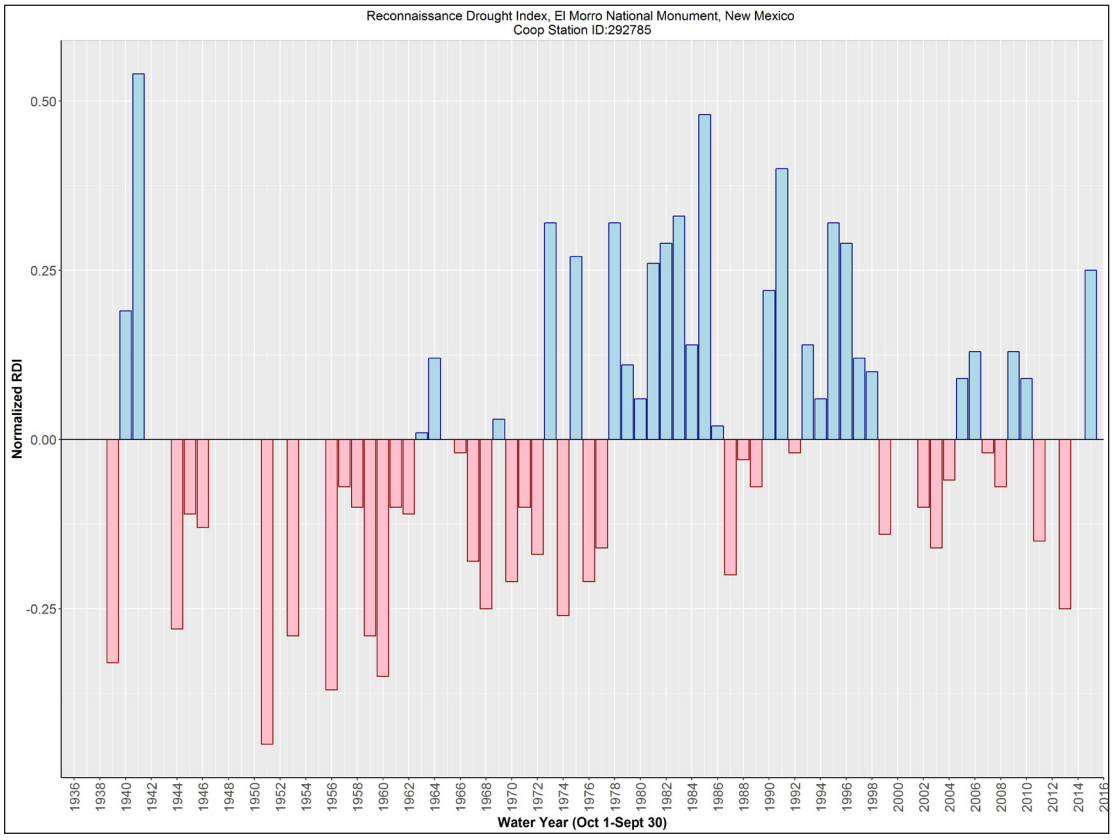


Figure 4.7.4-3. RDI for El Malpais NM using data (1939-2015) from the El Morro National Weather Service station. RDI calculated by Jodi Norris, Landscape and Quantitative Ecologist, SCPN, using the DrinC software package. Figure Credit: Jodi Norris.

Table 4.7.4-1. Summary of tinaja condition rationale.

Indicator of Condition	Measure	Condition	Rationale for Condition.
Climate Variables	Amount of Precipitation	Good to Moderate	Precipitation was well above average in 2015 but below in several of the most recent years, warranting a good to moderate condition rating.
	Reconnaissance Drought Index	Moderate	Even though drought conditions improved in 2015, drought conditions have prevailed in the region most recently, warranting a moderate condition rating.

The confidence level for this assessment is low given the fact that no formal studies have been conducted and that the availability of water is likely variable throughout the park.

4.7.5. Sources of Expertise

Jodi Norris, Landscape and Quantitative Ecologist, Southern Colorado Plateau Network, calculated RDI using data from the El Morro National Weather Service station and prepared Figure 4.7.2-1. Steve Monroe, Hydrologist for the NPS Southern Colorado Plateau Inventory and Monitoring Network, and Joel Wagner, Wetlands Specialist with the NPS Water Resources Division, reviewed this assessment.

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4.8. Vegetation- Piñon and Juniper

Indicators/Measures

- Are the species present and their distributions consistent with supply and demand of light, water, nutrients, and growing space, and within their natural range of variability?
- Are stand densities within their range of natural variability for their growing conditions?
- Are the age class distributions of piñons and junipers consistent with the expected range of variability for this site/ecosystem type?
- Do the trees and understory plants appear vigorous and healthy for this site/ecosystem type?
- Are ecological processes (e.g., fire) operating within a natural range of variability?
- Are the current levels of insects and/or disease within the normal range for this ecosystem type?

Condition – Trend – Confidence



Good – Unchanging – High

4.8.1. Background and Importance

Piñon pine (*Pinus edulis*) and one-seed juniper (*Juniperus monosperma*) (piñon-juniper) is a major habitat type found within the boundaries of El Malpais NM, and it comprises approximately 20% of the total area of the monument according to recent vegetation mapping efforts by Muldavin et al. (2013; Figures 4.8.1-1 and 4.8.1-2). Piñon-juniper habitats have considerable value to wildlife. Piñon-juniper woodlands serve an important role as cover, particularly thermal cover during winter, for large mammals such as mule deer (*Odocoileus hemionus*) and elk (*Cervus elaphus*) (Fairchild 1999; Gillihan 2006). They also provide food sources for many wildlife species.

Piñon nuts are consumed by a variety of both mammal and bird species, and some of these species, such as Piñon Jays (*Gymnorhinus cyanocephalus*), even specialize on this food source (Balda 2002; Figure 4.8.1-3, on left). Juniper berries also provide a food source for a variety of wildlife, such as Townsend's Solitaires (*Myadestes townsendi*; Figure 4.8.1-3, on right), which winter in areas of juniper (Bowen 1997). In addition to providing food, piñons and junipers provide nesting habitat for a variety of species (Gillihan 2006). Because of their food and other values, piñon-juniper woodlands support a higher abundance and diversity of birds than many other forest types, as well as one of the highest proportions of obligate or semi-obligate bird species (Gillihan 2006; Paulin et al. 1999). Also, as noted in Section 4.15 of this report, some bat species at El Malpais NM may use this type of vegetation for roosting (Chung-MacCoubrey 1996).



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Figure 4.8.1-1. Piñon-juniper vegetation atop El Calderon at El Malpais NM.

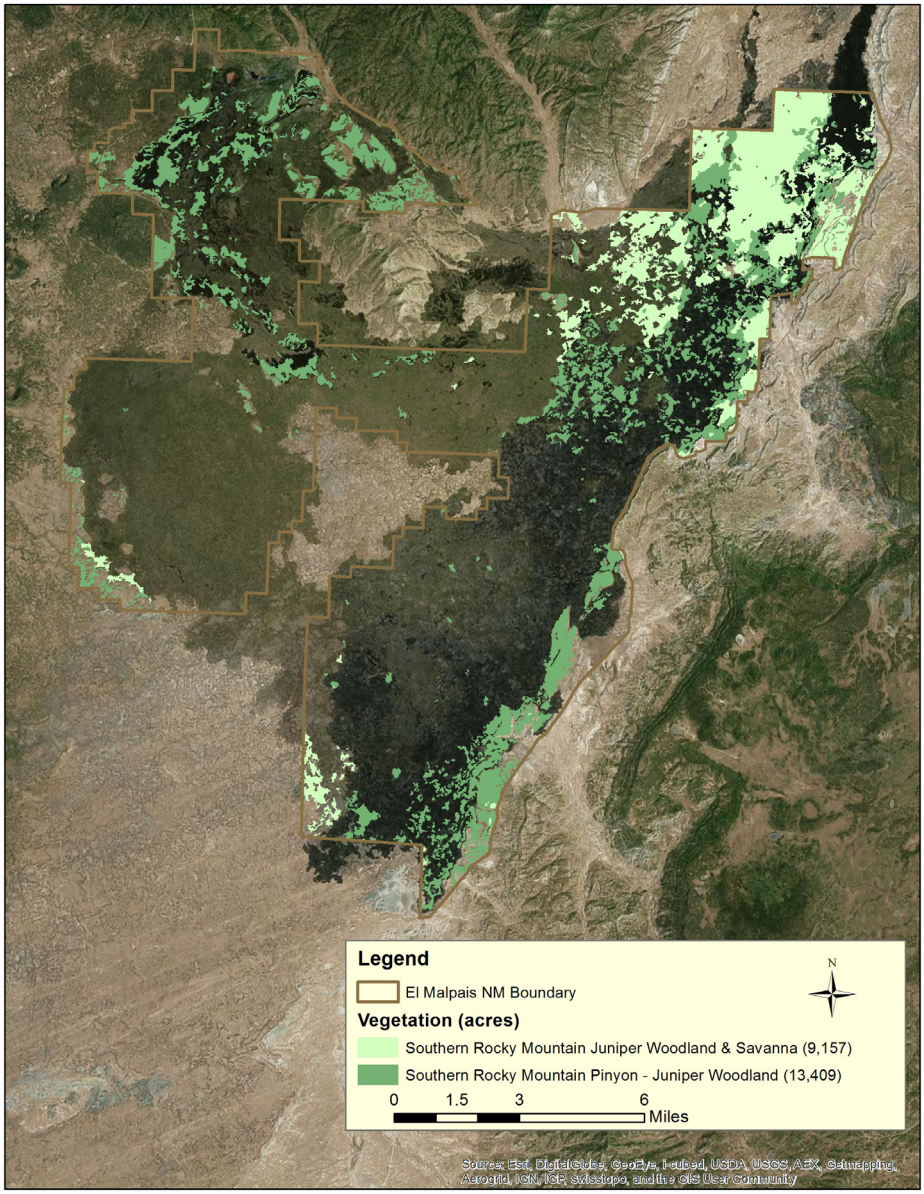


Figure 4.8.1-2. Distribution of the two main categories of Piñon-juniper vegetation at El Malpais NM based on recent vegetation mapping (Muldavin et al. 2013).



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Figure 4.8.1-3. Piñon Jays (on left), specialize on piñon nuts as a food source, and Townsend's Solitaires (on right) eat juniper berries.

4.8.2. Data and Methods

We adapted criteria developed by Edmonds et al. (2011), in consultation with piñon-juniper experts, to evaluate the condition of piñon-juniper habitat at El Malpais NM. Eight indicators were presented by Edmonds et al. (2011), including two that are related to water (aquatic species and clean flows from streams) and do not apply to the monument. One additional indicator, wildlife, was also eliminated (but addressed elsewhere in this assessment), leaving five original indicators. These remaining five were split apart for clarity (into six indicators), and formed the basis of our piñon-juniper indicators/measures. It should be noted that although the "clean flows from streams" indicator was eliminated, it is related to soil erosion, and we report on instances of erosion if they were observed/are known to exist.

Indicators/Measures

- Are the species present and their distributions consistent with supply and demand of light, water, nutrients, and growing space, and within their natural range of variability? (1)
- Are stand densities within their range of natural variability for their growing conditions? (2)
- Are the age class distributions of piñons and junipers consistent with the expected range of variability for this site/ecosystem type? (3)
- Do the trees and understory plants appear vigorous and healthy for this site/ecosystem type? (4)
- Are ecological processes (e.g., fire) operating within a natural range of variability? (5)
- Are the current levels of insects and/or diseases within the normal range for this ecosystem type? (6)

The first indicator/measure assesses whether the species and their distributions are within the natural range expected for the vegetation type (community). The second indicator/measure assesses tree densities within the plant communities, which can provide insight into the dynamics of a community to indicate condition. For example, if trees are more dense than expected, it could mean that conditions are conducive for those species and ecological processes such as fire are absent from the system. Higher than expected tree densities can lead to suppression of understory plant growth and diversity, and to reduced water yield in streams and springs because of increased transpiration by the trees. If trees occur in lower densities than expected, there could be some factor negatively affecting their recruitment or survival (e.g., fire or insects/disease or drought). The third indicator/measure, focusing on age class distribution, can reveal information on natural processes, such as seedling recruitment, fire, or other disturbances, that are characteristic of different types of plant communities. Information obtained under the fourth indicator/measure can indicate whether nutrient cycling, water supply, light supply, etc., are operating within parameters that support the plant communities. The plants' physical appearance can provide information pertaining to this measure. Under the next indicator/measure, fire scars, type of vegetation, age of trees, and even historical photographs to a certain extent, can provide information that helps assess the range of variation for ecological processes. The final indicator/measure focuses on the current condition of infestations from insects or certain diseases that may indicate overall rigor of the system.

Although we generally consider these six measures as falling into two groups, or types of indicators, ecological or vegetation characteristics (1-4 and 6) and ecological processes (5), there is also overlap among them. Therefore, we do not distinguish between the two groups throughout the assessment and treat each measure as having approximately equal weight.

<u>The Field Assessment</u>

This assessment is based on a vegetation field assessment conducted at El Malpais NM on June 2-3, 2015, with piñon-juniper experts William Romme and Brian Jacobs, personnel

from El Malpais National Monument, personnel from the Southern Colorado Plateau Network (SCPN), and one member of the NRCA writing team (these individuals are named in Section 4.8.5 of this chapter and/or Table A.1 of Appendix A). The field assessment report produced by W. Romme and B. Jacobs (i.e., Romme and Jacobs 2015) was used heavily in the following sections.

Areas of the park visited during the two days of field work included the El Calderon area, the western end of the Zuni-Acoma trail, the Sandstone Bluffs overlook area, the Lava Falls area, the west side of the park (and the El Malpais National Conservation Area, managed by BLM) via a drive on unimproved Road 42, and the Cerro Bandera area. Previously existing reports that were used in the assessment are cited as appropriate in the following sections.

4.8.3. Reference Conditions

Based more on ecological processes and dynamics of the vegetation (than on floristic composition and physiognomy, as in the vegetation mapping of Muldavin et al. 2013), Romme and Jacobs (2015) concluded that there are two fundamentally different kinds of piñon-juniper habitats within the national monument: 1) persistent piñon-juniper woodlands, and 2) juniper-piñon savannas (Table 4.8.3-1). These two general habitat types form the basis for the reference conditions used to assess the condition of piñon-juniper habitats throughout the national monument.

Note that Romme and Jacobs (2015) used a functional classification of the vegetation because it is more useful in the context of the condition assessment. The dynamics of

Table 4.8.3-1. Piñon-juniper habitat types used as references (adapted from Romme et al. 2008, 2009). Fire regime information based on several sources (Romme et al. 2007, 2008, 2009; Floyd et al. 2000, 2004; Shinneman and Baker 2009). Reference photos below from Capulin Volcano NM (NPS photos; condition section [Table 4.8.4-1] contains photos for El Malpais NM).

Persistent Piñon-Juniper Woodland	
	**Canopy:** The canopy of persistent piñon-juniper woodlands ranges from sparse stands of scattered small trees growing on poor substrates to relatively dense stands of large trees on more productive sites. The canopy may be dominated by either piñon or juniper or both.
	Understory: The understory of persistent piñon-juniper woodlands can be dominated by shrubs, forbs, or less commonly grasses. However, the understory is typically sparse with extensive areas of bare soil or rock.
	Site Conditions: Persistent piñon-juniper woodlands may occur on a wide variety of substrates and topographic settings but are most commonly associated with rugged uplands with shallow, coarse-textured, and often rocky soils that support relatively sparse herbaceous cover.
	Fire Regime: Stand replacing fires with low frequency and high intensity that most likely vary in size and extent. The fire interval in these stands is typically very long (at least multi-decadal), but more often measured in centuries.
Piñon-Juniper (or Juniper-Piñon) Savanna	
	**Canopy:** The canopy of piñon-juniper savanna is typically characterized by low- to moderate-density within a well-developed grassland matrix. In some areas of the western United States, this type may have dense enough canopy to be considered as a woodland, but the key feature remains the relatively continuous grassland.
	Understory: The understory of piñon-juniper savanna is consistently comprised of grasses.
	Site Conditions: Piñon-juniper savanna typically occurs on moderately deep coarse-to-fine textured soils on gentle upland and transitional valley locations. They are most common in areas where the precipitation is dominated by summer monsoon.
	Fire Regime: The pre-1900 fire regimes in piñon-juniper savanna are not well understood, but are believed to be of lower intensity and more frequent than the woodland fire frequencies (e.g., at intervals of years or decades).

a piñon-juniper stand are more informative than the local species composition, because composition is primarily a reflection of soil and climate conditions and responds slowly to environmental stresses (W. Romme, pers. comm.). On the other hand, components such as tree density and fire frequency respond more quickly to environmental change, and affect the ecosystem as a whole. Their classification still includes species composition, just not as the first step in the classification process.

We considered the condition to be good for a given indicator within each piñon-juniper habitat type if it was consistent with maintaining:

- a fully functioning community of plants (and animals that each piñon-juniper habitat type supports),
- resilience to natural or anthropogenic disturbances that vary in intensity, duration, and size, while maintaining or sustaining the piñon-juniper habitat type's inherent complexity, and
- the natural dynamics of the piñon-juniper habitat type with respect to productivity, nutrient capital, and biodiversity.

We considered the condition to be of moderate concern if there was some departure from the elements listed above for a given indicator, but that the piñon-juniper habitat type was capable of restoring itself to a good condition on its own, or with limited management intervention. Finally, we considered the condition to be of significant concern for a given indicator if there was substantial departure from the elements listed above that were either irreversible or would require substantial management intervention to return the condition to good.

Reference Period

The period of time used as a reference for assessing vegetation at the national monument was the period of several centuries up to around 1880 (Romme and Jacobs 2015). In evaluating ecological change in the Southwest, this pre-1880 time period has often been used. *Note that the remainder of this section (4.8.3) was taken directly from Romme and Jacobs (2015).*

> The several centuries prior to around 1880 was not a time without any human impacts, nor a time without any ecological change. However, the rate and magnitude of human impacts and ecological changes increased dramatically beginning in the late 19th century, with the onset of very heavy livestock grazing, industrial scale logging, and a market economy supported in part by an expanding network of railroads and capital from outside the region. Relative to what would come later, the pre-1880 period can be viewed as a time of comparatively natural ecological characteristics and ecological processes.
>
> Puebloan people (notably Acoma, Zuni, and Laguna) have continuously occupied the area around El Malpais and El Morro National Monuments since at least the 1100s A.D., and Spanish explorers, missionaries, and settlers began to frequent the area in the early 1600s (Weber 2009). Although Puebloan people began raising European livestock as early as the 1600s, the lands within present-day El Malpais NM probably were not heavily influenced by this early grazing, because they were somewhat remote from settlements and lacked water (Grissino-Mayer 1995). It seems likely that early livestock grazing would have had greater impacts on the vegetation within present-day El Morro NM, because that area was closer to Zuni Pueblo, provided a reliable water source, and was situated along a well-used trading route. However, the magnitude of pre-1880 grazing impacts at El Morro NM is not well understood. Puebloan people also harvested trees for construction and fuel, but those

impacts probably were localized and left little lasting impact.

Note that upon park review of the above text from the Romme and Jacobs (2015) report, it was pointed out that some relevant historical information was missing, and so we present it here: Also around the early 1600s, Ramah Navajo began grazing sheep and cattle in the area. They continued to graze sheep in the El Morro area and in El Morro's Box Canyon until the late 1940s/early 1950s (Steve Baumann, Resources Management Chief, El Morro and El Malpais NMs, pers. comm.; Ferguson 2012, Bradford 2013).

Changes after 1880

After the Atlantic and Pacific Railroad arrived at what would become Grants, New Mexico, in 1881, the intensity of livestock grazing in and around the malpais increased dramatically. The town of San Rafael, at the edge of the lava flows, became a center for tens of thousands of sheep that grazed on lands within the future monument (Grissino-Mayer 1995). Large cattle companies also were established in the area, and horses were pastured on some of the kipukas within the malpais. Grazing intensity was greatest during the 1880s, then decreased in the 1890s and through the 20th century, but continues in the areas surrounding the two monuments (Grissino-May 1995).

Importance of Climatic Variation

It is important to recognize that regional climate was not static during the pre-1880 reference period, nor has it been unchanging since that time. A 2,129-year local climate reconstruction, based on tree-rings collected from ancient trees in El Malpais NM (Grissino-Mayer 1995), reveals alternating wet and dry periods throughout the last two millennia. The driest period and the wettest period in the 2,129-year chronology occurred in the late 1500s and in the late 1900s, respectively (Table 4.8.3-2). Indeed, very few portions of that long climate chronology would be described as "normal" or "average." Wet periods generally favored vegetative growth, and severe droughts periodically stressed the vegetation as well as the people eking out a living in western New Mexico. Subsequently, the 20th century has been one of the wettest and warmest centuries in the last millennium. The long-term climate trends documented in the national monument also are seen across much of the Southwest (Swetnam and Betancourt 1998, Gray et al. 2003).

Although the 20th century was a generally wet period overall, its climate also fluctuated, and included some noteworthy drought periods. Grissino-Mayer's (1995) tree-ring based chronology extends only up to 1992. However, instrumental climate records are available for El Morro NM as far back as March of 1938 (http://www.ncdc.noaa.gov/cdo-web/). We calculated average annual precipitation for the entire period of record (1939-2014), and also for individual decades from the 1950s through 2014.....The 1950s and 1960s were dry decades, consistent with the pattern in the tree-ring record. Indeed, many piñon and ponderosa pine trees died during that drought (Breshears et al. 2005).

The 1970s had close to average annual precipitation, and then the 1980s and 1990s were very wet—although a few individual dry years occurred during those two decades of overall moist conditions. The first decade of the 21st century turned relatively dry again, with most years having below-average precipitation even though the decade's total precipitation was only a little below the long-term average as a result of one exceptionally wet year (2006 with 18.26 inches total). The climate since 2010 also has been dry, and the most recent three years

Table 4.8.3-2. Synopsis of climate variability since the late 15th century at El Malpais NM, based on a tree-ring chronology developed by Henri Grissino-Mayer. Adapted from Table 3.15 (pages 108-110) in Grissino-Mayer (1995), and taken from Romme and Jacobs (2015, Table 1a).

Period	Climate Conditions
1483-1540 A.D.	Generally favorable moisture conditions, but numerous drought years interspersed among wet years
1541-1567 A.D.	Great year-to-year variation, with more wet years than dry years
1568-1607 A.D.	The "Great Drought," seen throughout the West, worst short-term drought in the 2,129-year record at El Malpais NM
1608-1656 A.D.	Generally favorable moisture conditions, with a few severe drought years
1657-1723 A.D.	Variable moisture conditions, but few extremely wet or extremely dry years
1724-1790 A.D.	Generally unfavorable moisture conditions, with some wet years but many severe drought years
1791-1829 A.D.	Great year-to-year variation, with numerous very wet years
1830-1889 A.D.	Generally favorable moisture conditions, with many very wet years but also with occasional drought years
1890-1904 A.D.	Generally unfavorable moisture conditions, with many more drought years than wet years; a brief but severe drought from 1891-1893
1905-1943 A.D.	Very wet period, with variation from year to year but no extreme climate years
1944-1963 A.D.	Severe drought period, most years with below-average moisture but no extreme climate years
1964-1992 A.D.	Very favorable moisture conditions overall, but highly variable with some extremely wet and extremely dry years; 1978-1992 saw the greatest precipitation in the 2,129-year record at El Malpais NM

(2012-2014) was the driest three-year period at El Morro NM since the 1950s...Global climate models predict a trend of increasing temperatures and perhaps decreasing precipitation throughout the 21st century (IPCC 2013).

4.8.4. Condition and Trend

The complete field assessment report of Romme and Jacobs (2015) is included on the park's final DVD. Their report also addresses condition of piñon-juniper in El Morro NM and contains more detailed information on some points than what we present here.

Table 4.8.4-1 describes the two types of piñon-juniper habitat at El Malpais NM based on the functional/dynamic classification of forest and woodland vegetation used by Romme and Jacobs (2015). Note that this table is similar to the table shown in the Reference Conditions section, but it presents information specific to the national monument's piñon-juniper vegetation. Persistent piñon-juniper woodlands, usually characterized by centuries-old trees, are found scattered across the national monument landscape, in both small patches and extensive stands, in areas having rocky or thin soil that is unsupportive of abundant herbaceous growth (Romme and Jacobs 2015). They are often found on ridgetops, steep slopes, and cinder cones, but they are also found on flatter topography where soil conditions are better for deep-rooted woody plants compared to herbaceous plants. During the field assessment in June at the national monument, persistent piñon-juniper woodlands were observed on the rim and slopes of El Calderon, on the east side of El Calderon, in Encerrito Kipuka, on the Sandstone Bluffs, east of the Lava Falls parking area, and along Highway 42 (which included areas off the monument; Romme and Jacobs 2015).

The second type of piñon-juniper woodland, juniper-piñon savanna, also described in the table, consists of one-seed juniper and piñon pine trees within a grassland matrix. The tree density varies greatly. At El Malpais NM, these savannas are found around the margins

Table 4.8.4-1. Vegetation types dominated by piñon and/or juniper at El Malpais NM and El Morro NM (adapted from national monument vegetation maps and observations by Romme and Jacobs on June 2-4, 2015). Fire regime information comes from Romme et al. (2009), Jacobs et al. (2008), and Grissino-Mayer (1995). Note that this classification is based on ecological processes and dynamics of the vegetation more than on floristic composition and physiognomy. Table (including photos) from Romme and Jacobs (2015).

Persistent Piñon-Juniper Woodland	
 	**Canopy:** The canopy is composed of *Pinus edulis* and *Juniperus monosperma*, and ranges in density from moderately sparse to moderately dense, depending on local site conditions. Many of the trees are centuries old. Younger trees (<100 yr old) also are numerous, resulting in an all-aged stand structure.
	Understory: Sparse to moderately dense cover of shrubs (e.g., *Atriplex canescens, Rhus trilobata, Forestiera pubescens*) and grasses (e.g., *Bouteloua gracilis, Hesperostipa comata*), usually with much bare ground.
	Site Conditions: Relatively dry sites, often steep and rocky, usually with coarse-textured soils, e.g., cinder cones or limestone kipukas.
	Fire Regime: Lightning-ignited fires occur yearly, but most burn only a single tree and fail to spread. However, spreading canopy fires can occur under very dry, windy conditions, and these are severe, stand-replacing fires. Intervals between stand-replacing fires at the scale of a 1-acre stand may be measured in decades or more likely in centuries.
	Plant associations from Muldavin et al. (2013) likely to be found: *Juniperus monosperma / Muhlenbergia pauciflora* Woodland; *Pinus edulis* - (*Juniperus monosperma*, *Juniperus deppeana*) / *Bouteloua gracilis* Woodland; *Pinus edulis / Achnatherum scribneri* Woodland.
Juniper-Piñon Savanna	
 	**Canopy:** The canopy is composed of *Pinus edulis* and *Juniperus monosperma*, with *Juniperus monosperma* usually the more abundant, within a well-developed grassland matrix. Tree density ranges from sparse to moderately dense. Many of the trees are <100 yr old, representing the process of tree expansion into grasslands that has occurred during the past century.
	Understory: The understory is dominated by grasses. *Bouteloua gracilis* appears to be the major grass species in most areas, but others (e.g., *Hesperostipa comata*) are also found. Sparse shrubs (e.g., *Atriplex canescens*) and cacti (e.g., *Opuntia imbricata*) may be present as well.
	Site Conditions: Relatively deep, fine-textured soils, usually on relatively gentle terrain.
	Fire Regime: The historical fire regime is not well understood, but may have been characterized by spreading fires at intervals of years or decades that burned through the grasses and thinned the trees.
	Plant associations from Muldavin et al. (2013) likely to be found: *Juniperus monosperma / Bouteloua gracilis* Woodland.

of the park where the topography is gentle and soils are relatively deep and fine-textured (Romme and Jacobs 2015). During the June field assessment, juniper-piñon savanna was observed along the El Calderon loop trail in the vicinity of Junction Cave, Double Sinks, and Bat and Xenolith Caves, and along Highways 117 and 42. In the first area, one-seed juniper was the primary tree species and blue grama was the primary grass present.

An important difference between these two piñon-juniper types that Romme and Jacobs (2015) point out is that "many of the savannas we see today probably were nearly treeless grasslands 100+ yrs ago. The relative abundance of trees vs. grasses apparently fluctuates over century-long time scales: grasses predominate during dry periods and after severe fires, whereas trees become increasingly abundant during wet periods and during long intervals between successive fires

(Romme et al. 2009). The 20th century was a relatively wet period with few fires in this area (Grissino-Mayer 1995), and trees have greatly increased as a consequence."

Are The Species Present, And Their Distributions Consistent With Supply And Demand Of Light, Water, Nutrients, And Growing Space, And Within Their Natural Range Of Variability?

Persistent Piñon-Juniper Woodlands

In general, the species present and their corresponding distributions appear to be within their natural range of variability, and therefore, are in good condition. However, although native species predominate in most places visited, some non-native species were observed in specific locations. The main location was the El Calderon cinder cone, where small pockets of mullein (*Verbascum thapsus*) were observed (Figure 4.8.4-1). Also, near the base of the cinder cone under ponderosa pine trees and near persistent piñon-juniper woodland, cheatgrass (*Bromus tectorum*) was observed (W. Romme, pers. comm., July 28, 2015); cheatgrass was also observed in the general area along a dirt trail/road near the parking lot. Overall, however, non-native plants did not appear to be very abundant or widespread in this woodland type. Although these plants are not currently causing direct impacts where they exist, some concern exists over them because both species are capable of expanding substantially, especially after fire. Such an expansion, if it occurred, could potentially threaten the ecological integrity of this community type that is poorly adapted to fire (see discussion in Romme and Jacobs (2015). Although we judge current condition to be good, this would be downgraded if these plants, especially cheatgrass, were to expand due to soil disturbance (for example, from fuel reduction and/or prescribed fire activities). Note that while exotic plants are addressed here to some extent, they are covered more thoroughly in the exotic plants section of the condition assessment (Section 4.13).

Juniper-Piñon Savannas

In juniper-piñon savannas, the species present and their distributions generally appear to be within their natural range of variability and in good condition. The dominant tree species in most of these savannas is one-seed juniper, as was probably the case historically (Romme and Jacobs 2015).



Figure 4.8.4-1. The exotic plant mullein (top) and where it was observed on El Calderon (bottom). This area of El Calderon was mined for cinders in the past (Eric Weaver, El Malpais NM, pers. comm.).

Are Stand Densities Within Their Range Of Natural Variability For Their Growing Conditions?

Persistent Piñon-Juniper Woodlands

The condition for this indicator/measure deviates somewhat from the reference condition, but the persistent piñon-juniper woodlands at El Malpais are still considered to be in good condition for this indicator/measure (Romme and Jacobs 2015; the reason for this judgement is described immediately below). Tree densities are likely greater than before 1900 in most stands due to infill driven by climate, which has occurred in piñon-juniper woodlands throughout the Southwest. It is natural for tree densities to increase and decrease in this vegetation type over century-long time scales. An increase in the tree density "probably is a mostly natural result of favorable climatic conditions for tree establishment and growth during the past century, plus a paucity of fires. Human-caused fire exclusion no doubt contributed to

the lack of fires. However, this vegetation type does not burn frequently in any case because of its inherent fuel structure; we suspect that most of the persistent piñon-juniper woodland in the national monument would have escaped fire in the past century even if humans were not present" (Romme and Jacobs 2015). Importantly, the understory vegetation appears healthy and diverse in the stands observed, so it does not appear that the densification of trees is adversely affecting the understory. The change is not considered to pose a serious threat to ecological integrity, and Romme and Jacobs (2015) do not suggest any management actions to address it. Rather, they point out that climate models indicate that more drought, and therefore fire, may occur in the future than occurred in the 1900s, and that may lead to drought-caused mortality of piñon and juniper.

Note that this paragraph, provided by Dr. Romme during review of this section, describes in more detail how drought conditions affect tree survival.

> Drought can lead to tree mortality both directly and indirectly. Direct drought-caused mortality occurs when trees simply cannot obtain enough moisture from the soil to make up for the water lost in transpiration, and they die. Even if drought is not severe enough to kill a tree outright, drought stress reduces a tree's ability to produce defensive chemicals and resin with which to repel attacks by insects and disease; thus, mortality from insects or disease can be an indirect effect of drought. Dry conditions also allow for fires to burn more frequently and more intensely; thus, fire-caused mortality also can be an indirect effect of drought. This is why this report pays so much attention to climate variation, especially the occurrence and intensity of drought, both historical and future: it is because drought is often the ultimate cause of tree mortality, either directly or via insects, disease, or fire.

Juniper-Piñon Savannas

To address this indicator/measure, Romme and Jacobs (2015) wrote (note that it addresses both El Malpais and El Morro National Monuments):

> "Tree densities probably are greater in most stands than before 1900, and trees also appear to have expanded into former grasslands in many areas. The mechanism driving these processes of infill of pre-existing savannas and expansion into former grasslands is uncertain, but may be the result of a century of fire exclusion as well as the 20th century climate which was favorable for tree establishment and survival. Tree densities naturally wax and wane in this vegetation type over century-long time scales; current densities probably are at or above maximum typical densities. Extreme densification of juniper-piñon savannas potentially may threaten the ecological integrity of affected grasslands, may reduce ground water recharge, and may support high-severity crown fires. These negative changes may be happening in some savannas in eastern New Mexico. However, the current densities and visual impacts on grasslands in El Malpais NM and El Morro NM are much less dramatic than in those other places. Current tree densities do not appear to pose a serious threat to ecological integrity in El Malpais and El Morro.

Although the density of trees within savannas in El Malpais are probably greater than they were prior to the 1900s, they do not appear to be affecting the integrity of the savannas. However, because current densities are probably "at or above the highest typical densities in the juniper-piñon savanna type," we consider current condition under this indicator/measure to be of moderate concern. Condition of grasslands is addressed in a separate section of the condition assessment. It is possible, however, that tree densities may have been similar to those seen today during past periods with moist conditions (e.g.,

the early 1500s, early 1600s, and mid-1800s; Romme and Jacobs 2015, see also Table 4.8.3-2).

Note that there is an interesting and useful discussion of the possible mechanisms for the infill of pre-existing savannas and expansion of savannas into former grasslands in Romme and Jacobs (2015). Basically, the two alternative (or combined) explanations described are that: 1) frequent burning of juniper-piñon savannas may have occurred prior to the 1900s and thinned savannas and prevented establishment of trees in grasslands (i.e., fire exclusion model); and/or 2) climate in the 20th century was favorable for tree establishment and survival in most of the Southwest, and the expansion of juniper and piñon trees was the result (i.e., climate model). Romme and Jacobs (2015) stress that, because data are lacking to test and refine these models, uncertainty exists regarding the causes of tree densification at El Malpais NM.

Are The Age Class Distributions Of Trees Consistent With The Expected Range Of Variability For This Site/Ecosystem Type?

Persistent Piñon-Juniper Woodlands

Although we have limited data that address the age class distribution of piñon-juniper at the national monument, the age classes appear to be within their natural range of variability (Romme and Jacobs 2015). All-aged population structures were observed, which are typical of this woodland type, with centuries-old trees, as well as younger trees <100 years old, present. Based on the information available, therefore, we consider condition to be good for this indicator/measure.

Juniper-Piñon Savannas

Based on limited information, the age classes appear to be approximately within their natural range of variability, and therefore are in good condition. It does, however, appear that a greater proportion of the population is made up of 10- to 100-year-old trees than probably occurred before 1900 (Romme and Jacobs 2015). Some centuries-old trees were observed in savannas that would have been considered savannas before 1900. However, old trees were not observed in areas where one-seed juniper is expanding into former grasslands. Note that this last point may also be addressed in the section in the report on grasslands, depending on the findings of that assessment.

Do The Trees And Understory Plants Appear Vigorous And Healthy For This Site/Ecosystem Type?

Persistent Piñon-Juniper Woodlands

For this piñon-juniper type, most individual trees and understory plants appeared healthy. Dead piñon trees, however, were observed in many areas. The trees appeared to have died within the last 5-10 years, probably due to recent drought conditions. Small-scale events such as this are natural, however, and the situation does not appear to threaten the ecological integrity of this woodland type (Romme and Jacobs 2015). Therefore, we consider condition under this measure to be good.

Juniper-Piñon Savannas

Most trees and understory plants, including grasses and forbs, appeared healthy within the savannas observed. Therefore, condition was considered good for this indicator/measure.

Are Ecological Processes (e.g., Fire) Operating Within A Natural Range Of Variability?

Persistent Piñon-Juniper Woodlands

As described earlier in this section, persistent piñon-juniper woodlands burn rarely, except for single-tree ignitions that fail to spread, with intervals between stand-replacing fires on the order of centuries. It is possible that fire intervals have become somewhat longer due to fire exclusion in the 20th century, but intervals remain within the historical range of variability for this woodland type (Romme and Jacobs 2015). This possible change is not of particular concern, and the condition for this indicator/measure is considered to be good.

Juniper-Piñon Savannas

There is considerable uncertainty in applying this indicator/measure to savannas (Romme and Jacobs 2015). The reason is that historical fire regimes of juniper-piñon savannas are not well understood. With the continuous

fine-fuel cover that grasses provide and the frequency of dry weather, fires that spread may have been relatively frequent. If this was the case, then the infrequency of fires today (essentially no fire) is a substantial departure from the historical fire regime. Note that the increase in density of trees within the savannas at the national monument was discussed above. As also discussed there, Romme and Jacobs (2015) state "...we do not regard the densification of these savannas or the expansion of junipers into former grasslands as serious threats to the ecological integrity of the ...monument. Tree densities naturally wax and wane in this vegetation type over century-long time scales (Romme et al. 2009)." We consider condition for this indicator/measure to be of moderate concern, but we stress that there is more uncertainty in this case than with the other measures.

During the field assessment, some junipers were observed to have been killed by recent prescribed or wild fires.

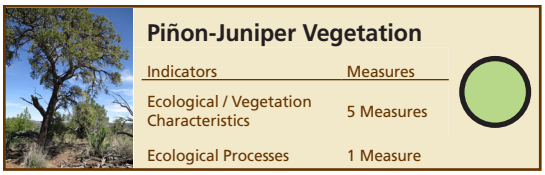
Are the Current Levels of Insects and/or Disease within the Normal Range for this Ecosystem Type?

Persistent Piñon-Juniper Woodlands

We found no evidence that the level of insects and/or disease are outside the normal range for this ecosystem type. During the vegetation field assessment, trees were examined, but there was no evidence of tree mortality or morbidity due to insects or disease (Romme and Jacobs 2015). Insects and disease appear to pose no serious threat at this time, and condition for this indicator/measure is considered to be good.

Juniper-Piñon Savannas

As with the woodland type, during the field assessment we found no evidence that the level of insects and/or disease are outside the normal range for savannas (Romme and Jacobs 2015). Insects and disease appear to pose no serious threat at this time, and condition for this indicator/measure is considered to be good.



Overall Condition

For assessing the condition of piñon-juniper vegetation, we used a variety of indicators/measures that were adapted from Edmonds et al. (2011). Two piñon-juniper experts, as well as additional ecologists with SCPN and park staff participated in the field assessment. All of the indicators/measures for this resource were intended to capture different aspects of the piñon-juniper communities located within the national monument. A summary of the indicators/measures and how they contributed to the overall condition is summarized in Table 4.8.4-2.

As shown in the table, based on our assessment, the overall condition of piñon-juniper communities at El Malpais NM is good, although there are some areas of concern. Of the six indicators/measures for the two vegetation types (12 indicators/measures total), ten are considered to be in good condition. Two (both for juniper-piñon savannas) are considered to be of moderate concern. Overall, the main areas of concern are the increase in density of trees in savannas, as well as the potential change in fire intervals in the savannas. Another area of concern, although we considered the condition good overall for the first indicator/measure, is the occurrence of the exotic plant, cheatgrass, in or near persistent woodlands on El Calderon; the plant's current occurrence appeared to be low, but Romme and Jacobs (2015) considered it of potentially major ecological significance.

The main area of uncertainty with the indicators/measures in this condition assessment is with regards to the possible reduction in fire frequency in the savannas, as described in the next section.

Based on our analysis and the information available, the condition of piñon-juniper vegetation at the national monument appears to have been generally stable over the last half century. Conditions for vegetation have

Table 4.8.4-2. Indicators/measures of piñon-juniper condition for persistent piñon-juniper woodlands and juniper-piñon savannas. Table based on Tables 6a and 6b in Romme and Jacobs (2015).

Community or Overall	Indicator/Measure	Condition	Condition Rationale
Persistent Piñon-Juniper Woodland	Is species presence & distribution consistent with conditions and within natural range of variability?	Good (but some concern exists)	The condition is generally good, but some concern exists due to low levels of exotic species occurring in some locations. Both cheatgrass and mullein were observed, with cheatgrass being of particular concern due to its potential effect on fire frequency. Condition could change if species expand after soil disturbance.
	Are stand densities within their range of natural variability for their growing conditions?	Good	Condition is good, although there has probably been an increase in tree density over the 20th century due to climate conditions conducive to tree establishment/ growth.
	Are age class distributions of trees consistent with expected range of variability?	Good	Although based on limited data, condition appeared good for this indicator. Centuries-old trees are present in most places, along with younger trees <100 yr old, resulting in all-aged population structures which are typical of this vegetation type.
	Do the trees and understory plants appear vigorous and healthy?	Good	Most individual trees and understory plants appeared healthy. However, some dead piñon trees were observed and probably died in the last 5-10 yrs due to drought conditions. Such small-scale mortality events are natural and do not appear to threaten ecological integrity.
	Are ecological processes (e.g., fire) operating within natural range of variability?	Good	Condition is good, although fire intervals may have lengthened somewhat due to 20th century fire exclusion. However, intervals remain within the historical range of variability for this vegetation type as this type rarely burns, with centuries long intervals between recurrent fires.
	Are the current levels of insects/ disease within the normal range?	Good	Condition is good. There was little evidence of tree mortality or morbidity due to insects or disease.
Persistent Piñon-Juniper Woodland Summary	Overall condition based on all six indicators/measures	Good	Overall condition is good, with all of the indicators/measures good. Some concern does exist under the first indicator/measure; although current occurrence appears low, an increase in the exotic species present could increase fire frequency in this vegetation type.
Juniper-Piñon Savanna	Is species presence & distribution consistent with conditions and within natural range of variability?	Good	Species presence and distribution generally appears to be within the natural range of variability, and is in good condition. The dominant tree species in most of these savannas is one-seed juniper, as was probably the case historically.
	Are stand densities within their range of natural variability for their growing conditions?	Moderate	Tree densities probably are greater in most stands observed than before 1900, and trees also appear to have expanded into former grasslands in many areas. The mechanism driving these changes is uncertain, but may be the result of a century of fire exclusion and 20th century climate which was favorable for tree establishment/survival. Tree densities naturally wax and wane in this vegetation type over century-long time scales; current densities probably are at or above maximum typical densities. Condition is considered to be of moderate concern. However, current densities are much less dramatic than in other places in the state and do not appear to pose a serious threat to ecological integrity.

Table 4.8.4-2. Indicators/measures of piñon-juniper condition for persistent piñon-juniper woodlands and juniper-piñon savannas. Table based on Tables 6a and 6b in Romme and Jacobs (2015) (continued).

Community or Overall	Indicator/Measure		Condition	Condition Rationale
Juniper-Piñon Savanna continued	Are age class distributions of trees consistent with expected range of variability?		Good	Condition is good. Based on limited data, the age classes appear to be approximately within their natural range of variability, although 10 to 100-yr-old trees probably constitute a greater proportion of the population than was typical before 1900. Some centuries-old trees are present.
	Do the trees and understory plants appear vigorous and healthy?		Good	Most trees and understory, including grasses and forbs, are healthy in appearance. This is the case even though tree densities are greater than probably existed prior to 1900. Condition is good for this indicator/measure.
	Are ecological processes operating within natural range of variability?		Moderate	Historical fire regimes of juniper-piñon savannas are not well understood. Spreading fires may have been relatively frequent, given the continuous fine-fuel cover (grasses) and frequent occurrence of dry weather. If so, then the modern fire regime (essentially no fire) is quite different. However, empirical data are lacking, which makes this an area of major uncertainty. Based on the available information, we consider condition to be of moderate concern. Some juniper trees have been killed due to recent prescribed and/or wild fires.
	Are the current levels of insects/disease within the normal range?		Good	Condition is good. There was little evidence of tree mortality or morbidity due to insects or disease.
Juniper-Piñon Savanna Summary	Overall condition based on all six indicators/measures		Good	Overall condition is good, with four of the indicators/measures good and two of moderate concern. The increased tree density within savannas could increase the risk of high-severity crown fires under extremely dry and windy conditions.

been, on the whole, largely conducive for tree establishment and survival, although as described, there has been some mortality of trees over the last approximately 5-10 years. At this time, we consider the overall trend in condition as unchanging. However, see one of the points below regarding uncertainty and climate.

Level of Confidence/Key Uncertainties

Overall, our confidence in this assessment is high. However, as is generally the case, there are some uncertainties. One of the key uncertainties in the assessment is that surrounding the historical fire regimes of juniper-piñon savannas. As described in the preceding pages, historical fire regimes in this vegetation type are not well understood. For this reason, relatively more uncertainty exists with our interpretation of the departure from reference conditions for this indicator/measure. Some uncertainty also exists surrounding the mechanisms of increased tree density within the savannas, and the potential effects of this increase.

There is also some uncertainty with the assessment overall, because it is based on a field visit to only some areas of the park. Due to the size and inaccessibility of much of the national monument, it was not possible to visit all areas dominated by the subject vegetation. On the other hand, the areas chosen were considered (by national monument personnel) to be representative of areas within the park.

There is at least one uncertainty regarding trend. Although we considered the trend in condition to be unchanging based on current information, there are predictions for future climate that could lead to a decline

in condition. If El Malpais NM experienced a major drought or extended drought conditions in the future, tree mortality could become more widespread, and the overall condition could decline. Romme and Jacobs (2015) wrote the following in the context of potentially managing the increase in tree densities in the piñon-juniper and ponderosa pine vegetation types at the national monument (which is an important point), but it also applies to this discussion of uncertainty in future conditions.

> ...this increase [in tree densities] is in large part a manifestation of the climate of the 20th century, which was especially favorable for tree establishment and survival. But we are now moving rapidly out of the climate that characterized the 20th century. Higher temperatures, more frequent and severe droughts, and more frequent and difficult to control wildfires are in our future. Worldwide, trees are dying at an accelerated rate, especially old trees (Allen et al. 2010, Anderegg et al. 2013). We see this at El Malpais NM where the venerable 650+ year-old *Pseudotsuga menziesii* named Yoda recently succumbed to the drought of the last several years. Thus, we may find that a new 21st century management priority will be retaining trees in the face of deteriorating climate, rather than the imperative to reduce tree densities that probably made sense back in the climatically benign days of the late 20th century.

Even with these uncertainties, we have high confidence overall in this assessment. The field assessment consisted of two full days at El Malpais NM with two piñon-juniper vegetation experts, two ecologists with SCPN, a biologist/writer, and three personnel from El Malpais NM with a substantial knowledge of the park.

4.8.5. Sources of Expertise

During the course of this assessment, we consulted with the following individuals who provided subject matter expertise and participated in a two-day field assessment at El Malpais:

William H. Romme is Professor emeritus of fire ecology and senior research scientist in the Natural Resource Ecology Laboratory at Colorado State University, Fort Collins, CO. In addition to participating in the field assessment and co-authoring the report upon which this section is based, Dr. Romme reviewed the draft of this section. Brian J. Jacobs is a vegetation ecologist who recently retired from the NPS at Bandelier NM. Both of these subject matter experts have conducted research in the ecology of piñon-juniper ecosystems and are well-published in this topic.

Two individuals with the SCPN also participated in the field assessment at the park, Lisa Thomas, Program Manager for the SCPN, and Jim DeCoster, Plant Ecologist for the SCPN.

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4.9. Vegetation- Ponderosa Pine

Indicators/Measures

- Are the species present and their distributions consistent with supply and demand of light, water, nutrients, and growing space, and within their natural range of variability?
- Are stand densities within their range of natural variability for their growing conditions?
- Are the age class distributions consistent with the expected range of variability for this site/ecosystem type?
- Do the trees and understory plants appear vigorous and healthy for this site/ecosystem type?
- Are ecological processes (e.g., fire) operating within the natural range of variability?
- Are the current levels of insects and/or disease within the normal range for this ecosystem type?

Condition – Trend – Confidence



Good – Unchanging – High

4.9.1. Background and Importance

New Mexico and Arizona contain approximately 6 million acres (2.5 million hectares) of ponderosa pine (*Pinus ponderosa*) forests (Graham and Jain 2005). Areas dominated by ponderosa pine make up a significant proportion of El Malpais NM, or about 56% of the total area of the national monument according to recent vegetation mapping efforts (Muldavin et al. 2013; Figure 4.9.1-1 and 4.9.1-2).

Ponderosa pine habitats are considerably valuable to wildlife. At least 250 species of vertebrates inhabit ponderosa pine forests in the Southwest (Allen et al. 2002). Patton et al. (2014) reported 48 mammals, 111 birds, and 47 amphibians and reptiles, as well as 422 arthropods in their database of species found in Arizona ponderosa pine forests.



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Figure 4.9.1-1. Ponderosa pine vegetation in the El Calderon area at El Malpais NM.

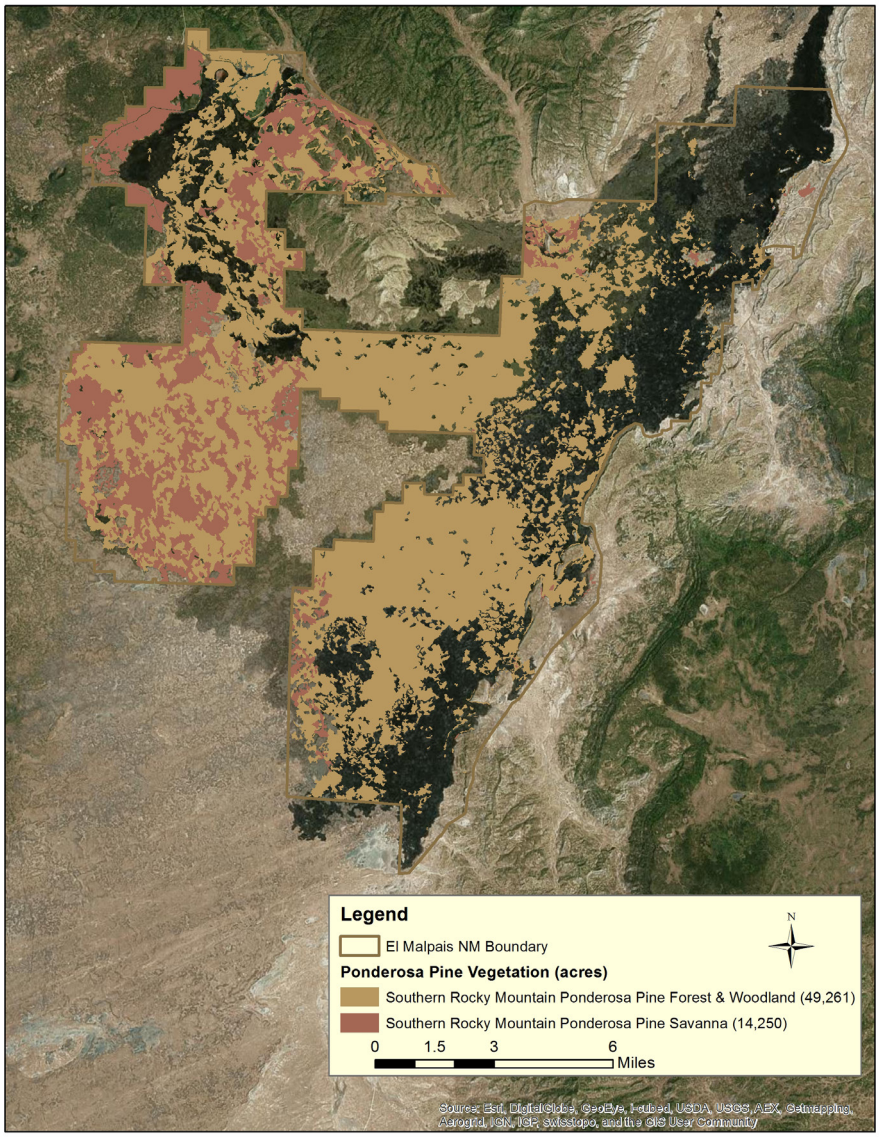


Figure 4.9.1-2. Distribution of the two main categories of ponderosa pine vegetation at El Malpais NM based on recent vegetation mapping by Muldavin et al. (2013).



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Figure 4.9.1-3. Abert's squirrels (*Sciurus aberti*) are a distinctive species of ponderosa pine forests on the Southern Colorado Plateau.

Wildlife species using these habitats include the Abert's squirrel (*Sciurus aberti*), a "distinctive inhabitant" of ponderosa pine forests on the Southern Colorado Plateau (Figure 4.9.1-3; Northern Arizona University 2015). This species of squirrel feeds on ponderosa pine seeds and the tree's cambium layer, and the squirrel uses the tree for shelter and nesting. Among the other species that use these forests are mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), chipmunks, and voles (Northern Arizona University 2015), and bats (Chung-MacCoubrey 1996). Many different bird species also use ponderosa pine habitats, such as Steller's Jay (*Cyanocitta stelleri*), Brown Creeper (*Certhia americana*), White and Red-breasted Nuthatches (*Sitta carolinensis* and *S. canadensis*, respectively), Dark-eyed Junco (*Junco hyemalis*), and

Western Tanager (*Piranga ludoviciana*) (Northern Arizona University 2015), all of which are known to occur at El Malpais NM (Johnson et al. 2007). Ponderosa pine habitats are also valuable for their plant species diversity (Patton et al. 2014).

4.9.2. Data and Methods

We adapted criteria developed by Edmonds et al. (2011), in consultation with vegetation experts, to evaluate the condition of ponderosa pine habitat at El Malpais NM. Eight indicators were presented by Edmonds et al. (2011), including two that are related to water (aquatic species and clean flows from streams) and do not apply to the national monument. One additional indicator, wildlife, was also eliminated (but addressed elsewhere in this assessment), leaving five original indicators. These remaining five were split apart for clarity (creating six indicators), and formed the basis of our ponderosa pine indicators/measures. It should be noted that although the "clean flows from streams" indicator was eliminated, it is related to soil erosion, and we report on instances of erosion if they were observed/are known to exist.

Indicators/Measures

- Are the species present and their distributions consistent with supply and demand of light, water, nutrients, and growing space, and within their natural range of variability? (1)
- Are stand densities within their range of natural variability for their growing conditions? (2)
- Are the age class distributions consistent with the expected range of variability for this site/ecosystem type? (3)
- Do the trees and understory plants appear vigorous and healthy for this site/ecosystem type? (4)
- Are ecological processes (e.g., fire) operating within the natural range of variability? (5)
- Are the current levels of insects and/or disease within the normal range for this ecosystem type? (6)

The first indicator/measure assesses whether the species and their distributions are within the natural range expected for the vegetation type (community). The second indicator/measure assesses tree densities within the plant communities, which can provide insight into the dynamics of a community to indicate condition. For example, if trees are more dense than expected, it could mean that conditions are conducive for those species and ecological processes such as fire are absent from the system. Higher than expected tree densities can lead to suppression of understory plant growth and diversity, and to reduced water yield in streams and springs because of increased transpiration by the trees. If trees occur in lower densities than expected, there could be some factor negatively affecting their recruitment or survival (e.g., fire or insects/disease or drought). The third indicator/measure, focusing on age class distribution, can reveal information on natural processes, such as seedling recruitment, fire, or other disturbances, that are characteristic of different types of plant communities. Information obtained under the fourth indicator/measure can indicate whether nutrient cycling, water supply, light supply, etc., are operating within parameters that support the plant communities. The plants' physical appearance can provide information pertaining to this measure. Under the next indicator/measure, fire scars, type of vegetation, age of trees, and even historical photographs to a certain extent, can provide information that helps assess the range of variation for ecological processes. The final indicator/measure focuses on the current condition of infestations from insects or certain diseases that may indicate overall rigor of the system.

Although we generally consider these six measures as falling into two groups, or types of indicators, ecological or vegetation characteristics (1-4 and 6) and ecological processes (5), there is also overlap among them. Therefore, we do not distinguish between the two groups throughout the assessment and treat each measure as having approximately equal weight.

The Field Assessment

This assessment is based on a vegetation field assessment conducted at El Malpais NM on June 2-3, 2015, with vegetation experts William Romme and Brian Jacobs, personnel from El Malpais NM, personnel from the Southern Colorado Plateau Network (SCPN), and one member of the NRCA writing team (these individuals are named in Section 4.8.5 of this chapter and/or Table A.1 of Appendix A). The field assessment report produced by W. Romme and B. Jacobs (i.e., Romme and Jacobs 2015) was used heavily in the following sections.

Areas of the park visited during the two days of field work included the El Calderon area, the western end of the Zuni-Acoma trail, the Sandstone Bluffs overlook area, the Lava Falls area, the west side of the park (and the El Malpais National Conservation Area, managed by BLM) via a drive on unimproved Road 42, and the Cerro Bandera area. Previously existing reports that were used in the assessment are cited as appropriate in the following sections.

4.9.3. Reference Conditions

Based more on ecological processes and dynamics of the vegetation (than on floristic composition and physiognomy, as in the vegetation mapping of Muldavin et al. 2013), Romme and Jacobs (2015) concluded that there are two fundamentally different kinds of ponderosa pine habitats within the national monument: 1) ponderosa pine-piñon-juniper woodland/savanna, and 2) ponderosa pine-piñon-juniper rocky woodland (Table 4.9.3-1). These two general habitat types form the basis of the reference conditions used to assess the condition of ponderosa pine habitats throughout the national monument.

Note that Romme and Jacobs (2015) used a functional classification of the vegetation because it is more useful in the context of the condition assessment. The dynamics of a piñon-juniper stand are more informative than the local species composition, because composition is primarily a reflection of soil and climate conditions and responds slowly to environmental stresses (W. Romme, pers. comm.). On the other hand, components such as tree density and fire frequency respond more quickly to environmental change, and affect the ecosystem as a whole. Their classification still includes species composition, just not as the first step in the classification process.

We considered the condition to be good for a given indicator within each ponderosa pine habitat type if it was consistent with maintaining:

- a fully functioning community of plants (and animals that each ponderosa pine habitat type supports),
- resilience to natural or anthropogenic disturbances that vary in intensity, duration, and size, while maintaining or sustaining the ponderosa pine habitat type's inherent complexity, and
- the natural dynamics of the ponderosa pine habitat type with respect to productivity, nutrient capital, and biodiversity.

We considered the condition to be of moderate concern if there was some departure from the elements listed above for a given indicator, but that the ponderosa pine habitat type was capable of restoring itself to a good condition on its own, or with limited management intervention. And finally, we considered the condition to be of significant concern for a given indicator if there was substantial departure from the elements listed above that were either irreversible or would require substantial management intervention to return the condition to good.

Reference Period

The period of time used as a reference for assessing vegetation at the national monument was the period of several centuries up to around 1880 (Romme and Jacobs 2015). In evaluating ecological change in the Southwest, this pre-1880 time period has often been used. *Note that the remainder of this section (4.8.3) was taken directly from Romme and Jacobs (2015).*

Table 4.9.3-1. Vegetation types dominated by ponderosa pine at El Malpais NM and El Morro NM (adapted from national monument vegetation maps and observations by Romme and Jacobs on June 2-4, 2015). Fire regime information comes from Grissino-Mayer (1995), Grissino-Mayer and Swetnam (1997), and Allen et al. (2002). Note that this classification is based on ecological processes and dynamics of the vegetation more than on floristic composition and physiognomy. Table (including photos) from Romme and Jacobs (2015).

Ponderosa Pine-Piñon-Juniper Woodland-Savanna	
 	**Canopy:** The canopy is composed of *Pinus ponderosa*, *Pinus edulis*, and *Juniperus monosperma*; in places, *Juniperus scopulorum* and *Juniperus depeanna* are also present. *Pinus edulis* and *Juniperus monosperma* are more abundant on drier sites; *Pinus ponderosa* is more abundant on wetter sites; and *Juniperus scopulorum* and *Juniperus depeanna* are found only at the higher elevations. Many of the trees of all species are centuries old. Younger trees (<100 yr old) also are numerous, resulting in an all-aged stand structure.
	Understory: The understory is dominated by grasses, commonly *Bouteloua gracilis*, but a few shrubs may be present as well (e.g., *Ribes cereum*, *Rhus trilobata*).
	Site Conditions: Found most commonly on older lava flows having relatively well developed soil.
	Fire Regime: The historical fire regime was characterized mainly by spreading fires at intervals of years or decades that burned through the grasses and killed small trees and shrubs but spared most of the larger pine. More severe, stand-replacing fires also occurred in patches up to several acres.
	Plant associations from Muldavin et al. (2013) likely to be found: At least eight representative plant associations, such as *Pinus* ponderosa / *Quercus gambelii* Woodland*; Pinus ponderosa / Festuca arizonica* Woodland*; Pinus ponderosa / Bouteloua gracilis* Woodland.
Ponderosa Pine-Piñon-Juniper Rocky Woodland	
 	**Canopy:** The canopy is composed mainly of *Pinus ponderosa, Pinus edulis*, and *Juniperus monosperma*. Many of the trees of all species are centuries old. Younger trees (<100 yr old) also are numerous, resulting in an all-aged stand structure.
	Understory: The understory is composed of shrubs (e.g., *Quercus undulata*, *Rhus trilobata*, *Forestiera pubescens*), scattered grasses, and small trees, with much bare rock exposed.
	Site Conditions: Found on rugged terrain with much bare rock exposed, commonly young lava or sandstone bedrock. Little soil development except in cracks in the lava or bedrock. Woody plants are prevalent, probably because their roots can penetrate cracks to deep water sources.
	Fire Regime: Not well understood. Lightning-ignited fires occur yearly, but most apparently burn only a single tree or small group of trees and shrubs, and fail to spread over any larger area, except perhaps under extremely dry, windy conditions.
	Plant associations from Muldavin et al. (2013) likely to be found: At least seven representative plant associations, such as *Pinus* ponderosa / *Fallugia paradoxa* Woodland*; Pinus ponderosa / Fallugia paradoxa-Ribes cereum* Woodland*; Juniperus monosperma / Fallugia paradoxa; Pinus edulis - Juniperus spp. / Fallugia paradoxa* Woodland.

The several centuries prior to around 1880 was not a time without any human impacts, nor a time without any ecological change. However, the rate and magnitude of human impacts and ecological changes increased dramatically beginning in the late 19th century, with the onset of very heavy livestock grazing, industrial scale logging, and a market economy supported in part by an expanding network of railroads and capital from outside the region. Relative to what would come later, the pre-1880 period can be viewed as a time of comparatively natural ecological characteristics and ecological processes.

> Puebloan people (notably Acoma, Zuni, and Laguna) have continuously occupied the area around El Malpais and El Morro National Monuments since at least the 1100s A.D., and Spanish explorers, missionaries, and settlers began to frequent the area in the early 1600s (Weber 2009). Although Puebloan people began raising European livestock as early as the 1600s, the lands within present-day El Malpais NM probably were not heavily influenced by this early grazing, because they were somewhat remote from settlements and lacked water (Grissino-Mayer 1995). It seems likely that early livestock grazing would have had greater impacts on the vegetation within present-day El Morro NM, because that area was closer to Zuni Pueblo, provided a reliable water source, and was situated along a well-used trading route. However, the magnitude of pre-1880 grazing impacts at El Morro NM is not well understood. Puebloan people also harvested trees for construction and fuel, but those impacts probably were localized and left little lasting impact.

Note that upon park review of the above text from the Romme and Jacobs (2015) report, it was pointed out that some relevant historical information was missing, and so we present it here: Also around the early 1600s, Ramah Navajo began grazing sheep and cattle in the area. They continued to graze sheep in the El Morro area and in El Morro's Box Canyon until the late 1940s/early 1950s (Steve Baumann, Resources Management Chief, El Morro and El Malpais NMs, pers. comm.; Ferguson 2012, Bradford 2013).

> *Changes after 1880*
> After the Atlantic and Pacific Railroad arrived at what would become Grants, New Mexico, in 1881, the intensity of livestock grazing in and around the malpais increased dramatically. The town of San Rafael, at the edge of the lava flows, became a center for tens of thousands of sheep that grazed on lands within the future monument (Grissino-Mayer 1995). Large cattle companies also were established in the area, and horses were pastured on some of the kipukas within the malpais. Grazing intensity was greatest during the 1880s, then decreased in the 1890s and through the 20th century, but continues in the areas surrounding the two monuments (Grissino-Mayer 1995).

Importance of Climatic Variation

It is important to recognize that regional climate was not static during the pre-1880 reference period, nor has it been unchanging since that time. A 2,129-year local climate reconstruction, based on tree-rings collected from ancient trees in El Malpais NM (Grissino-Mayer 1995), reveals alternating wet and dry periods throughout the last two millennia. The driest period and the wettest period in the 2,129-year chronology occurred in the late 1500s and in the late 1900s, respectively (Table 4.9.3-2). Indeed, very few portions of that long climate chronology would be described as "normal" or "average." Wet periods generally favored vegetative growth, and severe droughts periodically stressed the vegetation as well as the people eking out a living in western New Mexico. Subsequently, the 20th century has been one of the wettest and warmest centuries in the last millennium. The long-term climate trends documented in the national monument also are seen across much of the Southwest (Swetnam and Betancourt 1998, Gray et al. 2003).

Although the 20th century was a generally wet period overall, its climate also fluctuated, and included some noteworthy drought periods. Grissino-Mayer's (1995) tree-ring based chronology extends only up to 1992. However, instrumental climate records are available for El Morro NM as far back as March of 1938

Table 4.9.3-2. Synopsis of climate variability since the late 15th century at El Malpais NM, based on a tree-ring chronology developed by Henri Grissino-Mayer. Adapted from Table 3.15 (pages 108-110) in Grissino-Mayer (1995), and taken from Romme and Jacobs (2015, Table 1a).

Period	Climate Conditions
1483-1540 A.D.	Generally favorable moisture conditions, but numerous drought years interspersed among wet years
1541-1567 A.D.	Great year-to-year variation, with more wet years than dry years
1568-1607 A.D.	The "Great Drought," seen throughout the West, worst short-term drought in the 2,129-year record at El Malpais NM
1608-1656 A.D.	Generally favorable moisture conditions, with a few severe drought years
1657-1723 A.D.	Variable moisture conditions, but few extremely wet or extremely dry years
1724-1790 A.D.	Generally unfavorable moisture conditions, with some wet years but many severe drought years
1791-1829 A.D.	Great year-to-year variation, with numerous very wet years
1830-1889 A.D.	Generally favorable moisture conditions, with many very wet years but also with occasional drought years
1890-1904 A.D.	Generally unfavorable moisture conditions, with many more drought years than wet years; a brief but severe drought from 1891-1893
1905-1943 A.D.	Very wet period, with variation from year to year but no extreme climate years
1944-1963 A.D.	Severe drought period, most years with below-average moisture but no extreme climate years
1964-1992 A.D.	Very favorable moisture conditions overall, but highly variable with some extremely wet and extremely dry years; 1978-1992 saw the greatest precipitation in the 2,129-year record at El Malpais NM

(http://www.ncdc.noaa.gov/cdo-web/). We calculated average annual precipitation for the entire period of record (1939-2014), and also for individual decades from the 1950s through 2014.....The 1950s and 1960s were dry decades, consistent with the pattern in the tree-ring record. Indeed, many piñon and ponderosa pine trees died during that drought (Breshears et al. 2005).

The 1970s had close to average annual precipitation, and then the 1980s and 1990s were very wet—although a few individual dry years occurred during those two decades of overall moist conditions. The first decade of the 21st century turned relatively dry again, with most years having below-average precipitation even though the decade's total precipitation was only a little below the long-term average as a result of one exceptionally wet year (2006 with 18.26 inches total). The climate since 2010 also has been dry, and the most recent three years (2012-2014) was the driest three-year period at El Morro NM since the 1950s...Global climate models predict a trend of increasing temperatures and perhaps decreasing precipitation throughout the 21st century (IPCC 2013).

4.9.4. Condition and Trend

The complete field assessment report of Romme and Jacobs (2015) is included on the park's final DVD. Their report also addresses condition of ponderosa pine in El Morro NM and contains more detailed information on some points than we present here.

Ponderosa pine-piñon-juniper woodland/savanna is found primarily in areas with gentle topography and where soils are fine-textured and relatively deep. In these areas, the substrate is conducive to the growth of grasses and other herbaceous vegetation. At El Malpais NM, this ponderosa pine type appears most prevalent in the northwest area of the park on older lava flows (Romme and

Jacobs 2015). Due to variability in local soils and microclimate, as well as fire disturbance, stand structure also varies. Ponderosa pine dominates the canopy, and piñon pine (*Pinus edulis*), one-seed juniper (*Juniperus monosperma*), Rocky Mountain juniper (*Juniperus scopulorum*), and alligator juniper (*Juniperus deppeana*) may occur in varying amounts. The understory contains sapling ponderosa pine and saplings of the other species mentioned. At the highest elevations and on north-facing slopes, Douglas-fir (*Pseudotsuga menziesii*) may also be present. The ground cover in these areas is diverse and nearly continuous. During the June field assessment, this ponderosa pine type was observed on the lower eastern and northern slopes of El Calderon, and along Highway 42 in the vicinity of Cerro Bandera.

The next few paragraphs come directly from Romme and Jacobs (2015) and summarize the history of fire in this vegetation type in the national monument area. The information aids in interpretation of the subsequent indicator/measure discussion:

> Prior to 1880, low-severity fires recurred frequently. Those fires killed many of the small trees and shrubs and consumed some of the dead organic matter on the ground, but killed few of the large canopy pines. The herbaceous ground layer also was generally uninjured; aboveground parts of the plants might be burned off, but roots and rhizomes survived the fire and re-sprouted vigorously. Henri Grissino-Mayer sampled and cross-dated numerous fire-scarred trees and stumps in this vegetation type in the northwestern portion of El Malpais NM in the early 1990s (Grissino-Mayer 1995, Grissino-Mayer and Swetnam 1997). Within a ca. 10 ha (25 acre) area, a fire was recorded approximately every 5-8 yrs during the period from the mid-1600s until 1880. Each fire did not necessarily burn the entire 10-ha area, but the fires in some years must have been extensive... More severe, stand-replacing fire also probably occurred in patches of perhaps several acres; however, this component of the historical fire regime has not been investigated in El Malpais NM...
>
> The fire regime in ponderosa pine-piñon-juniper woodland/savanna changed abruptly after 1880. Few extensive fires have occurred since that time; indeed, the 20th century witnessed the longest fire-free intervals in the past 600 years. NPS fire managers have been reintroducing fire to this vegetation type during the last couple of decades, but many sites still have gone for many decades without burning. As a consequence, some dense thickets of tree saplings have developed in places, and many stands probably have greater tree density today than they did before the 20th century. The story is further complicated by the intensive logging that took place throughout the region during the mid-20th century. Almost all merchantable ponderosa pine trees were cut across most of the accessible terrain in what is now the national monument. The canopy trees that we see today are mostly younger trees, left by the loggers because they were small at the time. Beneath the newly developing pine canopy, one can still trace the remnants of the pre-1900 forest in the form of moldering stumps. Some of these stumps contain multiple fire scars that document the pre-1880 fire regime (Figure 4.9.4-1 [Figure 3 in original report]).

An important discussion on the occurrence of piñons and junipers in this vegetation type was also provided in Romme and Jacobs (2015), and we present it here:

> Piñon, junipers, and ponderosa pine apparently increased in density during the last century in much of the Ponderosa Pine-Piñon-Juniper Woodland-Savanna. In similar areas throughout the Southwest, it is sometimes suggested that piñon

and juniper are "invading" the ponderosa pine forest, as a result of past fire exclusion. However, we think that this is a misinterpretation of the environmental gradients and ecological dynamics that characterize this vegetation type. The environment across much of El Malpais and El Morro National Monuments appears to straddle the lower portion of the ponderosa pine zone and the upper portion of the piñon-juniper zone. Consequently, all of these tree species find suitable habitats within the boundaries of the two monuments. Mature ponderosa pine trees are quite tolerant of low-severity fires, whereas piñon, the various juniper species, and small ponderosa pine seedlings or saplings are more easily killed by fire. Therefore, piñon and junipers are less abundant during periods of frequent fire, but become more abundant during long periods without fire— such as the 20th century. Although piñon and junipers probably have increased in this vegetation type since 1880, the climate and biogeographic location of the national monuments tell us that these species almost certainly were present before that time in at least small numbers throughout the ponderosa pine forests. Rather than "invading" the ponderosa pine forests, the piñon and junipers simply have increased their density in response to the lack of fire-caused mortality and the climate of the 20th century which has been generally favorable for tree establishment and survival in the region. The same mechanism has driven an increase in ponderosa pine density as well. Therefore, we include piñon and juniper in the name and characterization of this vegetation type, rather than identifying a "pure" ponderosa pine type that is being "invaded."

The second type of ponderosa pine-dominated vegetation, ponderosa pine-piñon-juniper rocky woodland, is found in areas at El Malpais NM having rugged topography, especially young lava flows with bare rock and little soil development (Romme and Jacobs 2015). The stand structure and composition in these areas varies greatly, largely due to variation in substrate characteristics and topography, with ponderosa pine, piñon pine, and one-seed juniper the dominant canopy species; Rocky Mountain juniper, Douglas-fir, and aspen (*Populus tremuloides*) may occur in some areas at higher elevations. Shrubs dominate the understory. During the June field assessment, these rocky woodlands were observed below the Sandstone Bluffs overlook area and along the west side of Encerrito Kipuka (which is near the western portion of the Zuni-Acoma Trail).

Stand structure and dynamics are also influenced by fire, but fire occurs less frequently in this type than in the woodland/savanna type just described. Romme and Jacobs (2015) summarized information from Grissino-Mayer (1995) and Grissino-Mayer and Swetnam (1997) on the history of fire in ponderosa pine forests on the El Malpais NM landscape. The latter researchers found that a fire was recorded about every 11 yrs within a 30-acre (12.5-ha) area at Hoya de Cibola from the mid-1600s until 1880. Romme and Jacobs (2015) pointed out that even though fires do occur in these rocky woodlands, many of the trees go unburned for centuries.



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Figure 4.9.4-1. Ponderosa pine stump on the east side of Cerro Bandera with fire scars from before 1900. Source: Romme and Jacobs (2015).

Grissino-Mayer (1995) determined some living trees in the area to be >600 years old, with the oldest being a >1,200-year-old Douglas-fir.

Are the Species Present, and their Distributions Consistent with Supply and Demand of Light, Water, Nutrients, and Growing Space, and within their Natural Range of Variability?

Ponderosa Pine-Piñon-Juniper Woodland/ Savanna

In general, the species present and their corresponding distributions appear to be within their natural range of variability, and therefore, are in good condition. Native species were predominant in the areas observed, although pockets of exotic plant species may exist. For example, an exotic species was observed in at least one location. Near the base of the El Calderon cinder cone, a small amount of cheatgrass (*Bromus tectorum*) was observed under ponderosa pine trees and near persistent piñon-juniper woodland (W. Romme, pers. comm., July 28, 2015). Concern exists over this plant because it is capable of expanding substantially, especially after fire and/or soil disturbance. Overall, however, exotic plants did not appear to be very abundant or widespread in this woodland type. Note that while exotic plants are addressed here to some extent, they are covered more thoroughly in the exotic plants section of the condition assessment (Section 4.13).



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Figure 4.9.4-2. Patch of dense ponderosa pine saplings and small trees on the northeast side of Cerro Bandera. Source: Romme and Jacobs (2015).

Ponderosa Pine-Piñon-Juniper Rocky Woodland

In ponderosa pine-piñon-juniper rocky woodland, the species present and their distributions generally appear to be within their natural range of variability and in good condition. Native species predominate. Although pockets of exotic plant species may exist, no exotic species were observed during the field assessment (Romme and Jacobs 2015).

Are Stand Densities Within Their Range of Natural Variability For Their Growing Conditions?

Ponderosa Pine-Piñon-Juniper Woodland/ Savanna

The condition for this indicator/measure deviates somewhat from the reference condition for ponderosa pine-piñon-juniper woodland/savannas. Tree densities are probably greater than before 1900 in some stands due to fewer fires and favorable climate conditions for trees over the last century. The higher stand densities, however, do not appear to threaten the ecological integrity of the vegetation type. In general, understory vegetation does not appear to be suppressed, except possibly in some patches of relatively dense pine saplings (Figure 4.9.4-2). Although some patches of dense pine saplings were observed, these stands were not comparable (in density) to those in other parts of the Southwest (e.g., in the forests near Flagstaff) where restoration programs have been undertaken (Friederici 2003, as described in Romme and Jacobs 2015). These increased densities in the national monument, however, may make this vegetation type more susceptible to somewhat larger and more severe wildfires than occurred historically (this is addressed in more detail below under the fifth indicator/measure).

In summary, the density of trees has increased in some patches of vegetation, but

other areas are very open. Although there is spatial heterogeneity in the density of trees, we consider condition to be of moderate concern. Romme and Jacobs (2015) suggest that if stand structures more typical of the reference period are desired in the national monument, prescribed fire alone may be adequate to achieve this.

Ponderosa Pine-Piñon-Juniper Rocky Woodland

Stand densities probably are somewhat greater in some areas today than before 1900 due to changes in fire frequency and, especially, favorable climatic conditions for trees throughout the past century. At El Malpais NM, in areas where this type grows on young lava flows, tree density is probably limited mostly by harsh environmental conditions. Where relatively higher stand densities do occur, they do not appear to pose any serious threat to ecological integrity. Condition under this indicator/measure is good.

Are The Age Class Distributions Of Trees Consistent With The Expected Range Of Variability For This Site/Ecosystem Type?

Ponderosa Pine-Piñon-Juniper Woodland/ Savanna

Although we have limited data for this indicator/measure, the age classes appear to be within their natural range of variability in many areas (Romme and Jacobs 2015). The exception, however, is that in some areas the largest/oldest trees were removed during logging activities in the early/mid 20th century. The oldest trees observed today appear to be generally younger than 150 yrs old. Although this represents a departure from historical conditions, it does not appear to be an overall threat to ecological integrity. As the existing, oldest trees in the woodland/savanna type continue to grow and age, they will eventually take the place of those harvested in the 1930s. This has represented somewhat of a loss, however, to native species that use mature, living and dead trees for habitat. Overall, we considered condition good for this indicator.

Ponderosa Pine-Piñon-Juniper Rocky Woodland

Based on limited information, the age classes generally appear to be within their natural range of variability. In some areas, however, 20th century logging activities removed many of the old trees. The removal of these old trees does not appear to seriously threaten ecological integrity of this vegetation type. Also, much of the ponderosa pine-piñon-juniper rocky woodland is inaccessible and still has all-aged tree population structures, including trees that are centuries old. Overall, we consider condition to be good for this indicator/measure.

Do the Trees and Understory Plants Appear Vigorous and Healthy for this Site/ Ecosystem Type?

Ponderosa Pine-Piñon-Juniper Woodland/ Savanna

For this ponderosa pine type, most individual trees and understory plants appeared healthy. Dead ponderosa pine trees, however, were observed in many areas. The trees appeared to have died within the last 5-10 years, probably due to recent drought conditions. Small-scale events such as this are natural, however, and the situation does not appear to threaten the ecological integrity of this woodland type (Romme and Jacobs 2015). Additionally, the availability of some dead ponderosa pines is beneficial to wildlife that nest or roost in such areas (e.g., some species of bats [Chung-MacCoubrey 1996]). Therefore, we consider condition under this indicator/measure to be good.

Ponderosa Pine-Piñon-Juniper Rocky Woodland

As with the woodland/savanna type, most trees and understory plants appeared healthy in the rocky woodland type, except for the occurrence of dead ponderosa pine trees in some areas. Again, they appeared to have died within the last 5-10 years, probably due to recent drought conditions. The dead trees do not appear to threaten the ecological integrity of this ponderosa pine vegetation type, and such small-scale events are natural. Also, as mentioned above, some large, dead trees are important habitat for some wildlife species. Therefore, condition was considered good for this indicator/measure.

Are Ecological Processes (e.g., Fire) Operating within a Natural Range of Variability?

Ponderosa Pine-Piñon-Juniper Woodland/ Savanna

Romme and Jacobs (2015) summarized changes in fire frequency in ponderosa pine habitat in the El Malpais NM area over the past several centuries:

> Intervals between successive fires were longer during the 20th century than in any previous century going back at least to the mid-1600s (Grissino-Mayer 1995, Grissino-Mayer and Swetnam 1997). Lightning ignitions continued throughout the 20th century, but spreading fires were essentially eliminated after ca. 1880 as a result of the very heavy livestock grazing that removed the fine herbaceous fuels that formerly carried low-intensity fires through the woodlands. Active fire suppression began to be pursued vigorously around the mid-1930s—about the time that grazing began to be better regulated. Fires were reduced even further after 1945 as suppression became increasingly effective due to the availability of new fire-fighting technologies, e.g., aerial tankers and smoke jumpers.

These longer fire intervals generally exceed the historical range of variability for this ponderosa pine vegetation type. This is at least partially the reason for the greater tree densities observed in at least some stands at the national monument (described previously). The increased tree densities may make this vegetation type more susceptible to somewhat larger and more severe wildfires than typically occurred historically; however, this risk appears much less than in some other areas of Southwest ponderosa pine forests, such as around Flagstaff and on the Mogollon Plateau (see Romme and Jacobs 2015). We consider condition for this indicator/ measure to be of moderate concern. We note, however, that the fire management program at the national monument is reintroducing fire to the ponderosa pine-piñon-juniper woodland/savannas using prescribed fire and by allowing wildfires to burn where/when possible.

Ponderosa Pine-Piñon-Juniper Rocky Woodland

Due to fire exclusion in the 20th century, fire intervals have lengthened considerably, even in areas of rugged topography and discontinuous fine fuels. This is also the case for this ponderosa pine vegetation type. However, even though the historical range of variability has been exceeded, the potential consequence of this is different than for the ponderosa pine-piñon-juniper woodland/ savannas. In the case of the rocky woodlands, fire probably did not play a critical role in maintaining the characteristic stand structure (Romme and Jacobs 2015). Additionally, the fire management program at the national monument is returning fire to this vegetation type using prescribed fire and allowing wildfires to burn where/when possible. For these reasons, and because overall ecological integrity does not appear to have been compromised by the lack of fire in the last century, we consider condition under this indicator/measure to be good.

Are the Current Levels of Insects and/or Disease within the Normal Range for this Ecosystem Type?

Ponderosa Pine-Piñon-Juniper Woodland/ Savanna

We found no evidence that the level of insects and/or disease are outside the normal range for this vegetation type. During the vegetation field assessment, trees were examined, but there was no evidence of tree mortality or morbidity due to insects or disease (Romme and Jacobs 2015; Figure 4.9.4-3). Trees that died due to the recent drought contained evidence of engraver beetles, which do not kill trees but colonize the inner bark of trees that have recently died from other causes. Notably, no evidence of tree-killing mountain pine beetles was seen, namely, no pitch tubes on the bark nor any of the distinctive gallery markings created by this beetle (W. Romme, pers. comm., August 13, 2015). Insects and disease appear to pose no serious threat at this time, and condition for this indicator/ measure is considered to be good.

Ponderosa Pine-Piñon-Juniper Rocky Woodland

As with the woodland/savanna type, during the field assessment we found no evidence that the level of insects and/or disease were outside the normal range for this ponderosa pine type (Romme and Jacobs 2015). As for the other ponderosa pine type, we found no evidence that insects or disease were the cause of trees that had died, and although bark beetle activity may have been observed, they were the type that typically colonize dead trees. Condition for this indicator/measure is considered to be good.



Overall Condition

For assessing the condition of ponderosa pine vegetation, we used a variety of indicators/measures that were adapted from Edmonds et al. (2011). Two vegetation experts, as well as additional ecologists with SCPN, and park staff participated in the field assessment. All of the indicators/measures for this resource were intended to capture different aspects of the ponderosa pine communities located within the national monument. A summary of the indicators/measures and how they contributed to the overall condition is summarized in Table 4.9.4-3.

As shown in the table, based on our assessment, the overall condition of ponderosa pine vegetation at El Malpais NM is good. There are, however, some areas of concern. Of the six indicators/measures for the two vegetation types (12 indicators/measures total), ten are considered to be in good condition. Two (for the woodland/savanna type) are considered to be of moderate concern. Overall, the main areas of concern for ponderosa pine-piñon-juniper woodland/savanna are the considerable increase in fire intervals (indicator/measure #5), which generally exceed the historical range of variability for this vegetation type, and the higher stand densities occurring today compared to pre-1900 (indicator/measure #2). It should be noted, however, that the fire management program is working to reintroduce fire to the system. The other area of concern, although condition was ultimately judged to be good for the related indicator/measure, is the loss of some of the oldest ponderosa pine trees due to mid-20th century logging (indicator/measure #3).

The main area of concern for the ponderosa pine-piñon-juniper rocky woodland, although condition was judged to be good for the indicator/measure, is the increase in fire intervals. Although it exceeds the historical range of variability, it appears less of an issue than for the other ponderosa pine type. As with the other type, fire managers at the national monument are reintroducing fire to this vegetation type as possible.

Based on our analysis and the information available, the condition of ponderosa pine vegetation at the national monument appears to have been generally stable over the last half century. Conditions for vegetation have been, on the whole, largely conducive for tree establishment and survival, although as described, there has been some mortality of trees over the last approximately 5-10 years. At this time, we consider the overall trend in condition as unchanging. However, see the last point below regarding uncertainty and climate.

Level of Confidence/Key Uncertainties

Overall, our confidence in this assessment is high. However, as is generally the case,



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Figure 4.9.4-3. Checking for signs of insects and/or disease on one of the dead ponderosa pine trees observed at the national monument.

Table 4.9.4-3. Indicators/measures of ponderosa pine condition for ponderosa pine-piñon-juniper woodland/savanna and ponderosa pine-piñon-juniper rocky woodlands. Table based on Tables 6c and 6d in Romme and Jacobs (2015).

Community Type	Indicator/Measure	Condition	Condition Rationale
Ponderosa Pine-Piñon-Juniper Woodland-Savanna	Is Species Presence & Distribution Within Natural Range of Variability?	Good	In general, the species present and their distribution appear to be in good condition. Some exotic species are present in local areas, but native species predominate in most places.
	Are Stand Densities Within Their Range of Natural Variability For Their Growing Conditions?	Moderate	Stand densities probably are greater in some areas today than before 1900 due to few fires and favorable climatic conditions for trees during the past century. These higher stand densities do not appear to pose any serious threat to ecological integrity, but they may make some areas more susceptible to somewhat larger and more severe wildfires than occurred historically. Overall, condition is of moderate concern.
	Are age class distributions of trees consistent with expected range of variability?	Good	With limited data, the age classes appear to be within their natural range of variability in many areas. However, where heavy logging was conducted in the 20th century, many of the oldest trees were removed, and the oldest trees today are generally <150 yrs old. This departure from historical conditions, however, does not appear to pose any serious threat to ecological integrity, and overall, we considered condition good.
	Do the trees and understory plants appear vigorous and healthy?	Good	Most individual trees and understory plants appeared healthy. However, dead ponderosa pine trees were observed in many areas and probably died in the last 5-10 yrs due to drought conditions. Such small-scale mortality events are natural and do not appear to threaten overall ecological integrity. Therefore, we considered condition good.
	Are ecological processes operating within natural range of variation?	Moderate	Fire intervals have lengthened considerably due to 20th century fire exclusion, and generally exceed the historical range of variation for this vegetation type. Condition, therefore, is of moderate concern. However, the fire management program at the national monument is reintroducing fire to this vegetation type via manager-ignited prescribed fire and allowing wildfires to burn when/where possible.
	Are the current levels of insects/disease within the normal range?	Good	Condition is good. We looked for, but saw, little evidence of tree mortality or morbidity due to insects or disease. Insects/disease appear to pose no serious threat at this time.
Ponderosa Pine-Piñon-Juniper Woodland-Savanna Summary	Overall condition based on all six indicators/measures	Good	Overall condition is good, with four of the indicators/measures good and two of moderate concern. Longer fire intervals are of relatively greatest concern, followed by patches of increased tree densities.

Table 4.9.4-3. Indicators/measures of ponderosa pine condition for ponderosa pine-piñon-juniper woodland/savanna and ponderosa pine-piñon-juniper rocky woodlands. Table based on Tables 6c and 6d in Romme and Jacobs (2015) (continued).

Community Type	Indicator/Measure	Condition	Condition Rationale
Ponderosa Pine-Piñon-Juniper Rocky Woodland	Is Species Presence & Distribution Within Natural Range of Variability	Good	In general, the species present and their distribution appear to be in good condition. Although they may exist, no exotic species were observed during the site visit. Therefore, native species predominate in most places.
	Are Stand Densities Within Their Range of Natural Variability For Their Growing Conditions?	Good	Stand densities probably are somewhat greater in some areas today than before 1900 due to few fires and favorable climatic conditions for trees during the past century. However, on the most unfavorable substrates (e.g., young lava flows), tree density probably is limited by harsh environmental conditions. Where they occur, higher stand densities than were typical of historical conditions do not appear to pose any serious threat to ecological integrity. Condition is considered good.
	Are age class distributions of trees consistent with expected range of variability?	Good	Condition is good. With limited data, the age classes appear to be within their natural range of variability in many areas. Although logging in the 20th century removed many of the old trees in some places, much of this habitat is inaccessible and still retains all-aged tree population structures including centuries-old trees. Past logging in these areas does not appear to pose any serious threat to ecological integrity.
	Do the trees and understory plants appear vigorous and healthy?	Good	Most individual trees and understory exhibit healthy appearances. However, dead ponderosa pine trees are seen in many areas. These dead trees appear to have died within the past 5-10 yrs, probably as a result of recent drought conditions. Small-scale mortality events of this kind are natural, and ecological integrity of this vegetation type is not threatened. Overall, condition is good for this indicator/measure.
	Are ecological processes operating within natural range of variability?	Good	Fire intervals have lengthened due to 20th century fire exclusion, even in areas of rugged topography and discontinuous fine fuels, and now generally exceed the historical range of variability for this vegetation type. However, a paucity of 20th century fire does not appear to have compromised overall ecological integrity, and fire is probably less important to stand structure than in the woodland/savanna type. Also, the fire management program at the park is reintroducing fire to this vegetation type (via prescribed fire and allowing wildfires to burn where/when possible). Condition was judged to be good.
	Are the current levels of insects/ disease within the normal range?	Good	Condition is good. We looked for, but saw, little evidence of tree mortality or morbidity due to insects or disease. Insects/disease appear to pose no serious threat at this time.
Ponderosa Pine-Piñon-Juniper Rocky Woodland Summary	Overall condition based on all six indicators/measures	Good	Overall condition is good, with all six of the indicators/measures good. The are some minor concerns over increased fire intervals, as well as increased tree density in some places and the potential occurrence of exotic plants.

there are some uncertainties. For example, some uncertainty exists with the assessment overall, because it is based on a field visit to only some areas of the park. Due to the size and inaccessibility of much of the national monument, it was not possible to visit all areas dominated by the subject vegetation. So, for example, some areas not observed might have had a higher incidence of exotic plants. On the other hand, the areas chosen were considered to be representative of areas within the park.

Another area of uncertainty is the level of significance of the increased tree density in places within the woodland/savanna type (Romme and Jacobs 2015). Increased tree densities lead to an increased potential for spreading crown fires, but the high-density stands were patchily distributed rather than continuous.

There is at least one uncertainty regarding trend. Although we considered the trend in condition to be unchanging based on current information, there are predictions for future climate that could lead to a decline in condition. If El Malpais NM experienced a major drought or extended drought conditions in the future, tree mortality could become more widespread, and the overall condition could decline. Romme and Jacobs (2015) wrote the following in the context of potentially managing the increase in tree densities in the ponderosa pine vegetation types (and piñon-juniper types) at the national monument (which is an important point), but it also applies to this discussion of uncertainty in future conditions.

> ...this increase [in tree densities] is in large part a manifestation of the climate of the 20th century, which was especially favorable for tree establishment and survival. But we are now moving rapidly out of the climate that characterized the 20th century. Higher temperatures, more frequent and severe droughts, and more frequent and difficult to control wildfires are in our future. Worldwide, trees are dying at an accelerated rate, especially old trees (Allen et al. 2010, Anderegg et al. 2013). We see this at El Malpais NM where the venerable 650+ year-old *Pseudotsuga menziesii* named Yoda recently succumbed to the drought of the last several years. Thus, we may find that a new 21st century management priority will be retaining trees in the face of deteriorating climate, rather than the imperative to reduce tree densities that probably made sense back in the climatically benign days of the late 20th century.

Even with these uncertainties, we have high confidence overall in this assessment. The field assessment consisted of two full days at El Malpais NM with two vegetation experts, two ecologists with SCPN, a biologist/writer, and three personnel from El Malpais NM with a substantial knowledge of the park.

Furthermore, we should note that the El Malpias NM landscape contains a unique and significant resource (Grissino-Mayer 1995, Grissino-Mayer and Swetnam 1997, Allen et al. 2002, and Romme and Jacobs 2015) that bolstered our confidence in this assessment. Old living trees, stumps, logs, and snags containing fire scars and tree-ring records were used by researchers to analyze wildfire patterns back to 1333 (Grissino-Mayer and Swetnam 1997), and to reconstruct climate conditions back to 136 BC (Grissino-Mayer 1995; p. 79, as cited in Romme and Jacobs 2015).

4.9.5. Sources of Expertise

During the course of this assessment, we consulted with the following individuals who provided subject matter expertise and participated in a two-day field assessment at El Malpais:

William H. Romme is Professor emeritus of fire ecology and senior research scientist in the Natural Resource Ecology Laboratory at Colorado State University, Fort Collins, CO. In addition to participating in the field assessment and co-authoring the report upon which this section is based, Dr. Romme reviewed a draft of this section. Brian J. Jacobs is a vegetation ecologist who recently retired

from the NPS at Bandelier NM. Both of these subject matter experts have conducted research on the ecology of ponderosa pine ecosystems and are well-published in this topic.

Two individuals with the SCPN also participated in the field assessment at the park, Lisa Thomas, Program Manager for the SCPN, and Jim DeCoster, Plant Ecologist for the SCPN.

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4.10. Vegetation - Grasslands and Shrublands

Indicators/Measures

- Soil/Site Stability (2 measures)
- Biotic Integrity (5 measures)

Condition – Trend - Confidence



Good – Unknown - Medium

4.10.1. Background and Importance

Grasslands at El Malpais National Monument occur on the older, more eroded flows. Old basalt plains (700,000 years old) and older cinder cones, as well as hills of sedimentary limestone and sandstone are prevalent around the perimeter of, or as islands (kipukas) within, the flows. These flows that have accumulated substantial sediments transported by wind and water over time support grasslands and other communities that are representative of typical non-volcanic landscapes of the southern Colorado Plateau (Muldavin et al. 2013).

Shrublands, dominated by Apache plume, skunkbush sumac, and wax currant, occur at the lowest elevations of the monument on the more recent flows and cinder cones. On these sparsely vegetated young flows, fire is infrequent and limited in extent, creating an environment where trees and shrubs can live to extended ages and sites develop unique assemblages of species (Muldavin et al. 2013).

Shortgrass prairie is the most prevalent grassland type at the monument and occurs most commonly next to lava flows on alluvial and eolian deposited sediment or on old basalt plains on which more recent flows lie (Muldavin et al. 2013) (Figure 4.10.1-1).

According to the New Mexico Department of Game and Fish (NMDGF 2006) regarding the Western Great Plains Shortgrass Prairie community type, the description of which is primarily based on the Southwest Regional Gap Analysis Project (SWReGAP) and The Nature Conservancy (TNC) New Mexico ecoregions:

> "This habitat forms a matrix system with blue grama dominating.



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Figure 4.10.1-1. The largest area of grassland at El Malpais NM is the Fringed Sage/Blue Grama Lava Plains Grassland shown in the photo.

Associated graminoids may include purple threeawn (*Aristida purpurea*), sideoats grama, hairy grama, buffalograss, needle and thread, prairie Junegrass (*Koeleria macrantha*), western wheatgrass, James' galleta, alkali sacaton and sand dropseed. Although mid-height grass species may be present especially on more mesic land positions and soils, they are secondary in importance to the sod-forming short grasses. Sandy soils have higher cover of needle and thread, spike dropseed (*Sporobolus cryptandrus*), and soaptree yucca. Scattered shrub and dwarf-dwarf species such as sand sagebrush, prairie sagewort *(Artemisia frigida*), big sagebrush (*Artemisia tridentata*), fourwing saltbush (*Atriplex canescens*), spreading buckwheat (*Eriogonum effusum*), broom snakeweed (*Gutierrezia sarothrae*), wolfberry (*Lycium palida*), may also be present. High variation in amount and timing of annual precipitation impacts the relative cover of cool and warm season herbaceous species. Large-scale processes such as climate, fire, and grazing influence this habitat. Fire is less important than other prairie habitats because the often dry and xeric climate conditions can decrease the fuel load and thus the relative fire frequency. The short grasses that dominate this habitat type are extremely drought and grazing-tolerant. These species evolved with drought and large herbivores and, because of their stature, are relatively resistant to overgrazing" (NatureServe 2004 as cited in NMDGF 2006).

Vegetation Inventories

Muldavin et al. (2013) provided a nice summary of previous botanical and vegetation studies conducted at El Malpais NM, which is included below.

"The earliest description of the vegetation of the El Malpais area was provided by Lindsey (1951). He described and broadly mapped three vegetation belts on the lava flows, dominated respectively by (1) *Pseudotsuga menziesii*, (2) *Pinus ponderosa*, and (3) *Fallugia paradoxa* (Apache plume), with *Pinus edulis* (piñon pine) and *Juniperus monosperma* (oneseed juniper) trees as part of the Apache plume belt. In addition, Lindsey described the vegetation associated with specific geologic substrates, which included lava cones, cinder cones, cinder benches, granite hills, yellow sandstones, high Tertiary plains, and the ice caves.

Bleakly (1994, 1997) mapped four broad vegetation zones: (1) Mixed Conifer, which was inclusive of Lindsey's Douglas-fir and ponderosa pine belts; (2) Bare to Sparse Grass/Shrub, more or less equivalent to Lindsey's Apache plume belt; (3) a Grass or Grass/Shrub zone that corresponds to Lindsey's high Tertiary plains associated with the early Pleistocene volcanic surfaces; and (4) a Shrub/Conifer zone associated with sedimentary rock substrates and alluvial plains that supported pinyon and juniper woodlands and grasslands. He also provided a comprehensive vascular plant species list for the monument.

Carroll (1989) produced a Biophysical Land Units (BLU) map at approximately 1:50,000 scale, which covered the monument and the adjacent BLM lands of El Malpais National Conservation Area (NCA) (also part of the general management plan for the NCA by BLM [1990]). This map was developed using 30-meter LANDSAT Thematic Mapper (TM) imagery from 1984 and has 11 BLU map units. BLUs use a combination of terrain, soil, and vegetation classes in the mapping process. Carroll (1989) identified eight vegetative classes which are similar in thematic content to Lindsey (1951) and Bleakly (1994): (1) Lava/lichen/pygmy scrub; (2) Sparse/bare; (3) Grass/shrub; (4) Shrub/ conifer; (5) Mixed conifer; (6) Pinyon-juniper woodland; (7) Deciduous; and (8) Ponderosa parklands" (descriptions excerpted from Muldavin et al. 2013).

Lightfoot et al. (1994) produced an inventory the same year Bleakly (co-author on this report) published maps of vegetation zones

at the monument. The Lightfoot et al. report was both a vegetation and a wildlife inventory. Their primary objectives were to document plant and animal species occurrences, as well as identify corresponding plant and animal habitats and communities. An emphasis was made to identify habitats and species that are rare or distinctive to the monument.

In 2005, a collaborative project involving the U.S. Geological Survey (USGS), NPS, Natural Heritage New Mexico (NHNM), and NatureServe was initiated with reconnaissance field surveys of the vegetation communities of the monument, followed by intensive field sampling from 2006 through 2009. The vegetation survey data were entered into a database and used to develop a park-wide vegetation classification following the National Vegetation Classification System (USNVC) (Federal Geographic Data Committee [FGDC] 2008) guidelines. Map units were designed to support ecologically based natural resources management with an emphasis on uses for fire, wildlife, and recreation management (Muldavin et al. 2013).

For this mapping project, Muldavin et al. (2013) mapped 16% of the monument as six shrubland units and 5% as five grassland map units (Table 4.10.1-1, Figure 4.10.1-2). The most common shrubland type was Apache Plume-Skunkbush Sumac Lava Scrub, followed by the largest area of grassland, which was the Fringed Sage/Blue Grama Lava Plains Grassland. Species most abundant in shrublands include (*Bouteloua gracilis*), Apache plume (*Fallugia paradoxa*), fourwing saltbush, prairie sagewort, and pigweed (*Portulaca oleracea*, an exotic species). In the grasslands, blue grama is also the most abundant species, distantly followed by western wheatgrass (*Pascopyrum smithii*), rubber rabbitbrush (*Ericameria nauseosa*), alkali sacaton (*Sporobolus airoides*), and spike dropseed.

Climate

The monument's climate is characterized by cool-to-cold, relatively dry winters, and warm, wet (monsoonal) summers (Figure 4.10.1-3). At the Grants airport (elevation 1987 m), about 20 km north of the park, daily temperature ranges between -36.1 °C and 28.9 °C (-32.9 °F and 84.0 °F) in winter, and -2.2 °C and 41.1 °C (28.0 °F and 106.0 °F) in summer (Muldavin et al. 2013). Winter and summer temperatures average 2.9 °C and 20 °C (37 °F and 70 °F), respectively. Values are averaged based on data obtained from the Western Regional Climate Center (http://www.wrcc.dri.edu/climsum.html). The large differentials between the average monthly minimum and maximum temperatures over the course of a year reflect an essentially continental climate.

The average annual precipitation is 218 mm (Figure 4.10.1-3), of which approximately a third falls in winter (October through March)

Table 4.10.1-1. The 11 shrubland and grassland National Vegetation Classification (NVC) map units identified by Muldavin et al. (2013) at El Malpais NM and their corresponding areas occupied.

Vegetation Map Unit Name	Primary Class	Area (hectares / acres)	
Apache Plume Cinder Scrub	Shrubland	12.6	31.1
Apache Plume-Skunkbush Sumac Lava Scrub	Shrubland	6,289.8	15,542.5
Skunkbush Sumac-Gooseberry-Apache Plume-Lava Scrub	Shrubland	572.5	1,414.6
Fourwing Saltbush Shrub-Steppe	Shrubland	234.6	579.8
Sand Sagebrush Sandy Plains Shrubland	Shrubland	65.8	162.7
Rubber Rabbitbrush/Blue Grama Shrub-Steppe	Shrubland	369.7	913.6
Blue Grama-Mountain Muhly Lava Plains-Foothill Grassland	Grassland	528	1,304.6
Fringed Sage/Blue Grama Lava Plains Grassland	Grassland	863.9	2,134.8
Blue Grama/Mesa Dropseed Sandy Plains Grassland	Grassland	223.8	553.1
Blue Grama Ruderal Grassland	Grassland	77.7	192
Blue Grama-Western Wheatgrass Lowland Grassland	Grassland	501	1,237.9

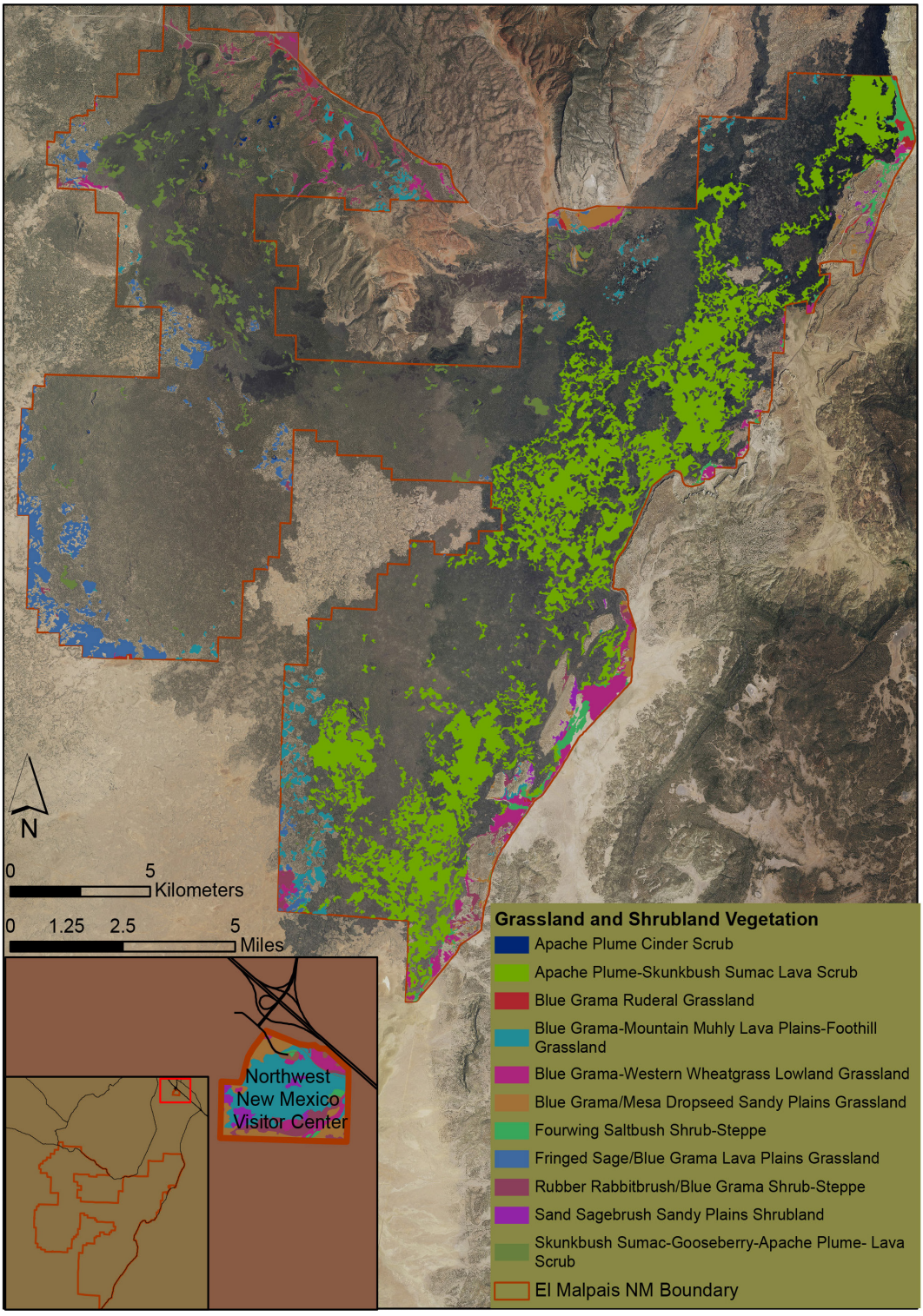


Figure 4.10.1-2. Muldavin et al. (2013) mapped 16% of the monument as six shrubland units and 5% as five grassland map units.

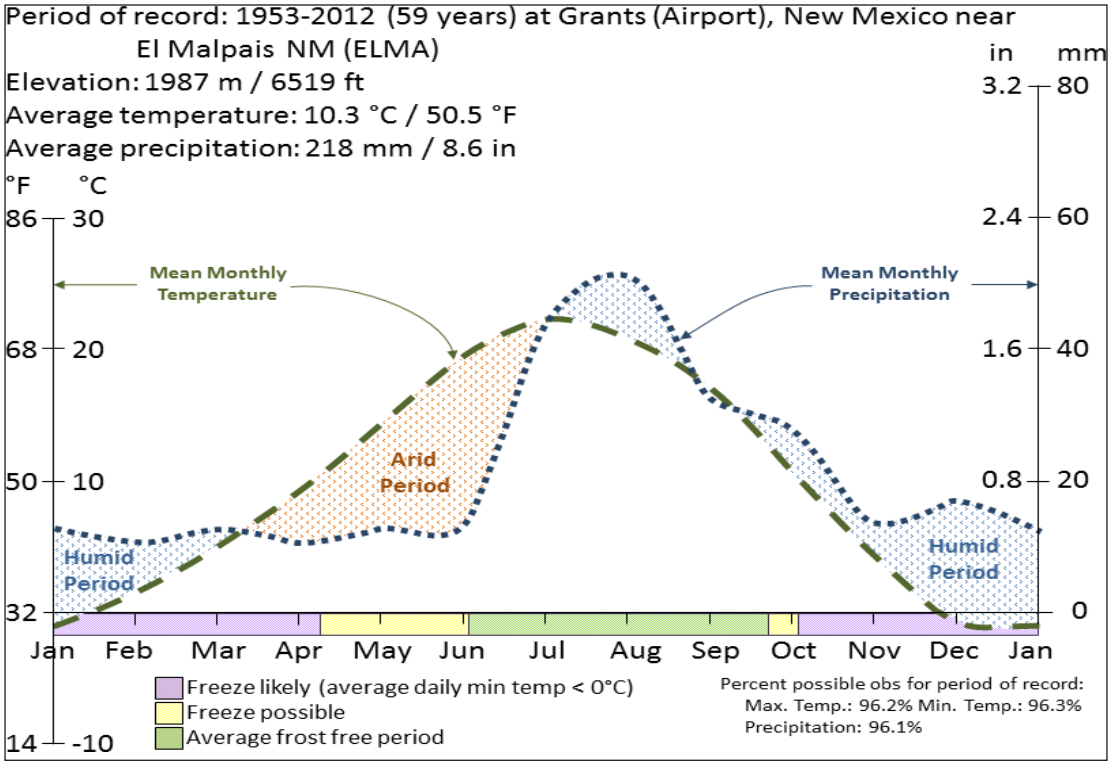


Figure 4.10.1-3. Climate conditions at El Malpais NM (http://science.nature.nps.gov/im/units/scpn/climate/climate.cfm).

and is delivered principally by low-pressure systems that sweep from west to east across the Southwest, and coalesce with moisture from the Pacific Ocean or the Gulf of Mexico (Muldavin et al. 2013).

Winter precipitation is generally followed by a seasonal dry period from April through June. This dry period is defined as much by the increased potential evapotranspiration that accompanies increased day length, solar radiation, and temperatures, as by decreased precipitation. The spring dry period is usually relieved by the onset of the Mexican/ Arizona monsoon, which lasts from July through September, and is associated mostly with short-duration, high-intensity thunderstorms. The thunderstorms can be localized, leading to high year-to-year variability of precipitation over small areas across the park (Muldavin et al. 2013).

Historical Context

There is a long history of use of the monument and adjacent lands for hunting, farming, and ranching by Native American groups that was extended by European settlers. According to Muldavin et al. (2013), the ruggedness of much of the young lava flows on the monument, in combination with little running or ponding water, likely limited grazing in the 20th century, and therefore, these flows may still reflect much of their natural, pre-settlement character (although 19th century sheep grazing may still have been a factor). After 150 years of livestock grazing, grazing was formally terminated in 1998 as outlined in Public Law 100-225, which established the monument in 1987.

4.10.2. Data and Methods

This assessment is primarily based upon data collected at 150 plots in 2005-2006 for the vegetation mapping project (Muldavin et al. 2013) and supplemented with fire effects monitoring data from 30 plots sampled more recently (2006-2013) (Figure 4.10.2-1). These two projects implemented different sample designs and data collection methods to estimate vegetation and surface cover and any comparisons made in this document are qualitative and ad hoc. It is not our intent to imply any formal trend.

We considered soil/site stability and biological integrity as two categories of indicators for the assessment of grassland and shrubland condition at El Malpais NM using a modified approach based on methods presented by Pellant et al. (2005).

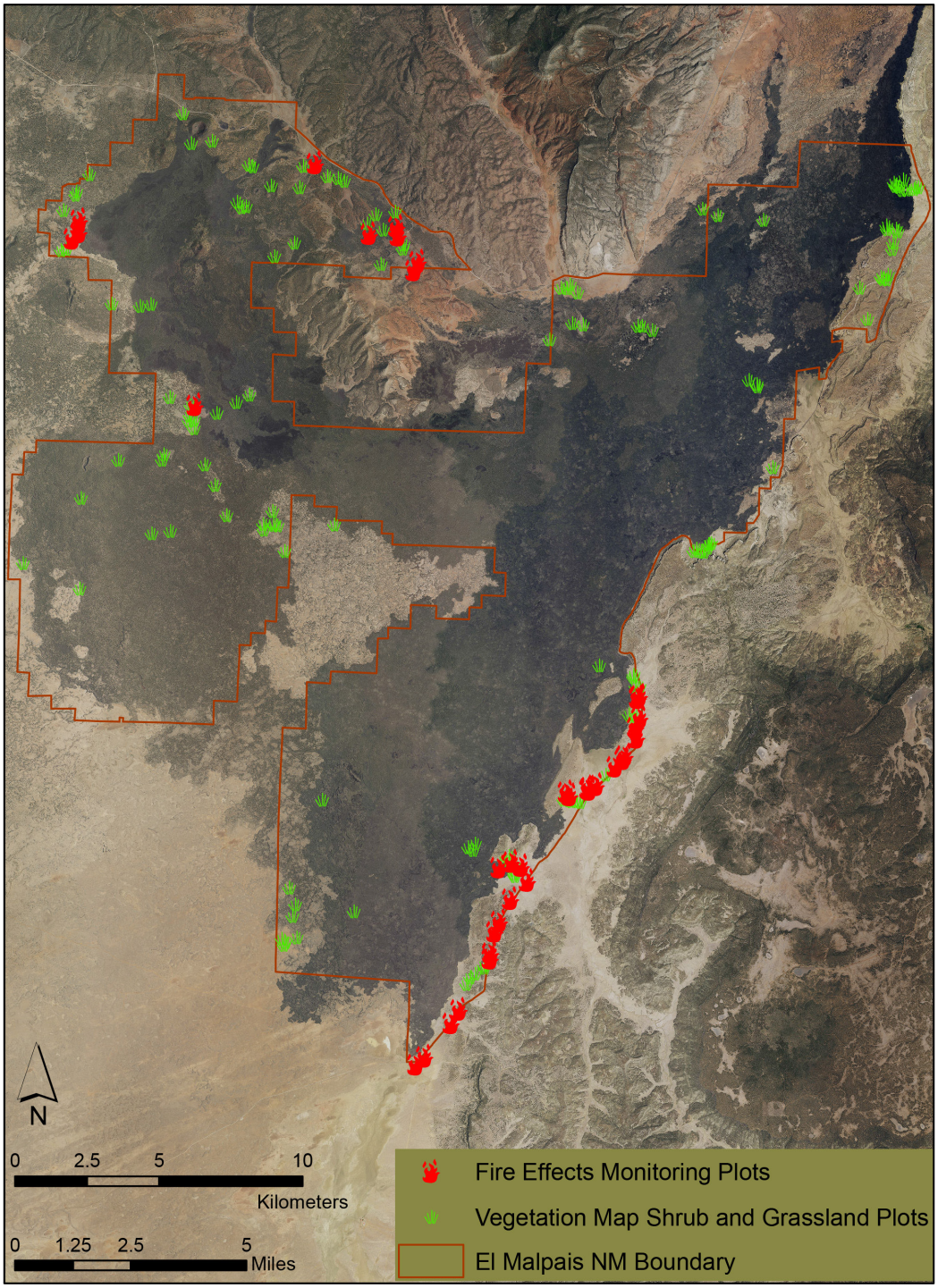


Figure 4.10.2-1. There are 150 plots that were established in 2005-2006 for the vegetation mapping project (Muldavin et al. 2013) and 30 plots for fire effects monitoring data sampled more recently (2006-2013) at El Malpais NM.

Indicator/Measures

Soil/Site Stability (2 measures)

The methodology for the soil assessment used an approach based on those described in the qualitative assessment protocol "Interpreting Indicators of Rangeland Health (Pellant et al. 2005), in which Soil/Site Stability qualitative measures (Table 4.10.2-1) were used to assess the ability of an area to limit redistribution and loss of soil resources by wind and water.

Assessment methods were modified from those outlined by Pellant et al. (2005) as

Table 4.10.2-1. Indicators and measures used to assess grasslands and shrublands at El Malpais National Monument.

Indicator	Measure	Definition
Soil/Site Stability	Soil Cover	Soil cover is the most important dynamic factor affecting water erosion. Most soil loss occurs in areas with uncovered, bare soils; soil cover slows water flow and provides resistance to erosion and greater stability.
	Biological Soil Crust	Biological soil crusts provide key ecosystem functions, such as increasing water and wind erosion resistance, contributing organic matter, and fixing atmospheric nitrogen.
Biotic Integrity	Landscape-scale Diversity	The extent to which landscape-scale diversity reflects spatial pattern of soils and disturbance.
	Local Species Composition	The extent to which species composition within a site (e.g., ecological site) deviates substantially from the expected native species compliment either from exotics or native species.
	General Life Cycles Relative to Disturbance	The proportion of annual, biennial, and perennial species relative to the time since disturbance.
	Relative proportion of functional groups (e.g., graminoid, forbs, shrubs, etc.)	The relative proportions of functional groups relative to what would be expected based on site characteristics (e.g., lack of forbs, excessive shrub density, etc.)
	Relative proportion of C3 and C4 species.	The relative proportions of C3 and C4 plants relative to what would be expected based on site characteristics

reference sheets that describe a standard for comparison were not available as they have not been finalized for the national monument. Use of these reference sheets is required to conduct assessments of soil / site stability per the Pellant et al. protocol. In lieu of the Natural Resource Conservation Service (NRCS) reference sheets, our assessment is based upon the comparison of surface cover data collected for both the vegetation map and fire effects monitoring against expected cover as provided in the community type descriptions outlined in the vegetation map report (Muldavin et al. 2013).

Soil Cover

The amount of total cover (soil cover and vegetation cover) is the single most important dynamic factor affecting water erosion (Herrick et al. 2005). Most soil loss occurs in "unprotected" areas with uncovered bare soils (Davenport et al. 1998), whereas rock, gravel, vegetation, biological soil crusts, and even plant debris (litter and duff) can "armor" the soil, slowing the flow of water and permitting increased infiltration of water into the soil profile (Belnap et al. 2007).

Biological Soil Crust

Biological soil crusts (or "biocrusts") are composed of a community of cyanobacteria, algae, lichens, and bryophytes. Lichens are a composite, symbiotic organism composed of a fungus and either a cyanobacteria or a green algae. Bryophytes are small, non-vascular plants, including mosses and liverworts. Biocrusts provide key ecosystem functions, such as increasing water and wind erosion resistance, contributing organic matter, and fixing atmospheric nitrogen. They contribute fixed carbon to soil through decaying and leaching processes (Lange 2003). Some cyanobacteria and cyanolichens have the ability to fix atmospheric nitrogen. This process reduces atmospheric nitrogen (N_2) to ammonia (NH_4^+), which is usable by vascular plants (Belnap 2003). Biocrusts can be the dominant source of nitrogen for desert ecosystems. The distribution and species composition of biological soil crusts is influenced by climate, soil chemistry, and disturbance (Belnap et al. 2001).

Indicator/Measures
Biotic Integrity (5 measures)

Pellant et al. (2005) defines biotic integrity as the capacity of the biotic community to support ecological processes within the normal range of variability expected for the site, to resist a loss in the capacity to support these processes, and to recover this capacity when losses do occur. The five categories described below and in Table 4.10.2-1 are indicators as to the extent in which the biotic integrity of El Malpais NM grasslands and scrub/shrublands is intact.

Landscape-scale Diversity

Daubenmire (1974 as cited in Muldavin et al. 2013) suggested that plant communities integrate all impinging environmental conditions, and hence, the classification and description of plant associations provides a framework for understanding the ecological composition and structure of a given landscape (Muldavin et al. 2013). The local species composition generally reflects local conditions of soils, moisture, disturbance, and other factors. As such, we would expect the diversity across a broader region to generally reflect the variation in these site characteristics; however, it is not reasonable to expect a one-to-one correspondence between local communities and their corresponding sites, because a multitude of factors can influence the local expression of vegetation communities at a given site. Rather, with this measure we are trying to determine if some reasonable level of landscape diversity exists and that it generally corresponds to changes in ecological conditions. To assess diversity of communities on the monument landscape, we looked to the soils (NRCS 2013) and geology (Muldavin et al. 2013) maps of the national monument to see how they aligned with the range of variability in the vegetation communities observed during the vegetation mapping effort (Muldavin et al. 2013).

Local Species Composition

The intent behind this measure is to see if the species composition is generally consistent with what might be expected for the site, given the local conditions (soils, disturbance, moisture, etc). We considered this from two perspectives. First, we examined the degree to which the local communities consisted of native vs exotic species. Details about which exotic species are present and their effect on the site are presented in greater detail in Chapter 4.12. Here we simply provide an initial indication of the extent of invasion of exotic species by looking at the proportion of native and exotic species. Second, we looked at the species composition of the native species relative to what might be expected for that site. This was based on USNVC association descriptions (Muldavin et al. 2013) as well as plant composition described by NRCS (2013) in the soil surveys for Cibola County. Species noted in earlier surveys (Lindsey 1951, Bleakly 1994, Lightfoot et al. 1994) as being characteristic or dominant in shrublands or grasslands were also considered. Many grassland and scrub vegetation types at the national monument fall under a standard NVC description. Several others were provisional, meaning that they are under review before being made a standard; until that time the occurrences at the park are the best known examples of the individual community types and are the reference standard. For this assessment, comparisons were made between plot data (composition, lifeform, functional group, photosynthetic pathway) and the NVC descriptions. Significant departures, namely omissions or additions to species noted in the older studies, were also noted.

General Life Cycles Relative to Disturbance

It is generally expected that the number of annual species at a given site would be higher immediately following a disturbance and would shift toward an increasing number of perennials as time passes since a disturbance. The persistence of annuals after a disturbance could indicate some basis for concern. For example roadside areas that are frequently and unnaturally disturbed might be expected to have a greater persistence of annual species compared to interior sites.

Relative Proportion of Functional Groups

The composition of functional groups can have a dramatic effect on grassland ecosystems and their associated processes (Tilman et al. 1997, Pellant et al. 2005). Tilman et al.

(1997) found that functional composition and functional diversity were principal factors explaining plant productivity, plant percent nitrogen, plant total nitrogen, and light penetration. They further concluded that habitat modifications and management practices that change functional diversity and functional composition would likely have a dramatic effect on ecosystem processes.

Relative Proportion of C3 and C4 Species
Higher temperatures and wetter conditions favor the growth of C4 plants. The Colorado Plateau, where the monument is situated, is an arid region with irregular rainfall, periods of drought, warm to hot growing seasons, and long winters with freezing temperatures (Davey et al. 2006). In this setting, the grasslands and shrublands support a solid mix of perennial C4 (warm season) and C3 (cool season) grasses (Paruelo and Lauenroth 1996). C4 photosynthesis is somewhat favored at El Malpais NM due to considerable precipitation falling during the warmer weather, which promotes vigorous growth during the summer months.

The proportion of C3 and C4 grasses can also dramatically influence how these grassland communities respond to climate change and levels of CO_2, although the nature of such response has been much debated (Wand et al. 1999).

4.10.3. Reference Conditions

Soil Cover/Site Stability
Pellant et al. (2005) described general reference conditions they considered to be an optimal functional state (their "none to slight" category) under natural disturbance regimes. They then described general descriptions for departures from that optimal state into four other categories of condition. These categories ranged from their optimal state to an extreme or total state of degradation.

We considered the condition of grasslands and shrublands as "good" if the current condition fell either within Pellant et al.'s (2005) "none to slight", or "slight to moderate" categories (Table 4.10.3 1). The "moderate" ranking was assigned if the departure from optimal fell within the "moderate" class. And finally, we considered the condition of grasslands and shrublands to be of "significant concern" if the departure from optimal fell within Pellant et al.'s "moderate to extreme" or "extreme to total" classes.

It should be noted that in a shortgrass ecosystem, it is common for as much as 30%-70% of the ground surface to be unvegetated, either as bare ground or areas covered in litter. In fact, at 15 grazed locations at the Shortgrass Steppe Long-Term Ecological Research (LTER) site in Colorado, bare ground accounted for at least 63% of surface cover (Lauenroth 2008). The shortgrass steppe is an ecosystem that, without even considering a lava substrate, is often sparsely vegetated, and our assessment categories reflect conditions normal for this specific system, that might cause similar conditions in more productive systems to score poorly.

Biotic Integrity
Determining definitive quantitative reference conditions for grassland and shrubland communities at El Malpais NM is somewhat problematic given the dynamic nature of these resources. Part of our consideration in choosing the measures we have used for biotic integrity is that they are moderately robust to the potentially substantial seasonal and annual variation that plant communities often exhibit. We began with a conceptual framework for assigning condition based on what might be expected for the site conditions at the national monument (Table 4.10.3-1). We recognize, however, that seasonal and annual variation in such things as rainfall and disturbance can results in dramatic shifts in specific measurement that are still within an acceptable range of natural variation.

Our measure of landscape-scale diversity focuses on whether or not the diversity of plant communities reflects, to a reasonable extent, the diversity in site characteristics. As such, we used the spatial pattern of soil types (NRCS 2013) and geologic units (mapped by Maxwell 1986 in Muldavin et al. 2013) as a general reference for the extent and pattern of landscape diversity that might be expected.

Table 4.10.3-1. Reference conditions used to assess the current condition for measures of grassland and shrubland soil/site stability and biotic integrity.

Indicator	Measure	Significant Concern	Moderate	Good
Soil/Site Stability	Soil Cover	Significantly to extremely reduced throughout the site. Stabilization agents (biological soil crust, vegetation, or rock) are largely absent.	Significantly reduced in at least half the sites examined..	Matches that expected for the site (or a minority of sites have slight reduction). Soil surface is stabilized by organic matter decomposition, rock, vegetation, or biological soil crust. Note that it is common for as much as 30%-70% of the ground surface to be unvegetated, either as bare ground or areas covered in litter.
	Biological Soil Crust	Greatly reduced occurrence of biological soil crust, or extensive signs of disturbance or degradation of soil crusts.	Biological soil crusts show signs of disturbance or reduction compared to what is expected in natural ecosystems.	Biological soil crust is present in the form and extent expected in natural ecosystems.
Biotic Integrity	Species Composition and Landscape-scale Diversity	Significant lack of spatial landscape heterogeneity that does not reflect the expected diversity for the soil types and sites.	Moderate lack of spatial landscape heterogeneity that does not fully reflect the spatial pattern of soils and disturbance.	Landscape-scale diversity reflects spatial pattern of soils and disturbance.
	Local-scale Species Composition	Species composition deviates substantially from the native species compliment that would typically occur at such sites. Such a deviation could also be either from exotics or native species.	Species composition moderately deviates from the expected native species compliment either from exotics or native species in such a way that does reflect typical types of natural disturbance (e.g., fire).	Species composition reflects expected native species compliment consistent with the site characteristics (e.g., from ESDs). Species composition need not reflect expected climax communities if their current state reflects typical types of natural disturbance (e.g., fire).
	Response of Annual Species to Disturbance	Substantially higher proportion of annual species than expected in sites not recently disturbed.	Proportion of perennial species is moderately lower than what might be expected given the site and time since disturbance.	Proportion of perennial species is approximately what would be expected given the site and time since disturbance.
	Relative Proportion of Functional Groups	Proportions of functional groups differ substantially from what might be expected based on site characteristics (e.g., lack of forbs, excessive shrub density, etc.).	Proportions of functional groups exhibit moderate departure from what might be expected given the site and disturbance history.	Proportions of functional groups (e.g., grasses, forbs, and shrubs) are consistent with what might be expected given the site characteristics.
	Relative Proportion of C3 and C4 Species	Sites dominated by C4 species traditionally dominated by C3 species.	Higher than expected proportion of C4 species given the ecological site and disturbance history.	A mix and natural variability of C3 (cool season) and C4 (warm season) species for the site (to maximize resilience).

For the remaining measures, we used a combination of the USNVC descriptions (usnvc.org and in Muldavin et al. 2013), plant composition descriptions as described for each NRCS (2013) soil type, and expert opinion as a general reference for plant community characteristics that might be expected given the soil types that occur at El Malpais NM. It is important to note however, the global descriptions typically represent what are considered as the historic climax plant communities (HCPCs). Consequently we do not strictly adhere to the HCPCs as a reference condition in the sense that departures from that reference necessarily represent a degraded quality, especially in a system that is prescriptively burned— rather as a general guide to be used in conjunction with expert

opinion to determine resource condition. Proposed community classifications based solely on what was observed at the national monument will naturally align well with species composition in our assessment, but as these descriptions will likely be setting the standard for these community types moving forward, we thought it appropriate to include these site specific classifications in establishing reference condition.

4.10.4. Condition and Trend

Soil Cover/Soil Stability

Plot data from both the vegetation mapping (VM) effort and fire effects monitoring (FEM) show that the percent of bare soil is high at grassland and shrubland sites sampled at El Malpais NM (Figures 4.10.4-1, -2, -3). Based on the NVC descriptions, the extent of bare soil patches in these community types is to be expected in the geographic setting at the park, based on substrate and climate variables. FEM bare soil cover values ranged from 10% to 60%, with a mean value of 38%; other ground surface (e.g., litter, rock, lichen) cover values ranged from 7%-36% with a mean of 18%. VM bare soil values ranged from 0% to 96% with the highest values found in the sparse vegetation / alluvial flat community. Other surface type cover values collected ranged from 0% to 79%. While sites with lower bare soil cover would be better protected from soil erosion, cover values at most sites fell within a range to be expected at the park. Assuming that the distribution and sample size of the sites sampled represent overall condition of El Malpais grasslands and shrublands, we consider the soil cover to be in good condition.

Biological crust data were not specifically identified in the surface cover data in the VM effort, but at the 30 FEM sites used for this evaluation, they documented moss and lichen at six sites with cover never exceeding 4%. VM data did include "Other" surface cover. Even if biological crusts fell under this category, values did not exceed 3.5%. Expected values are low based on the NVC descriptions, but at nearby El Morro NM, "continuous establishment of cryptobiotc crust" was common, perhaps due to the absence of grazing (Valentine-Darby et al. in prep). Additionally, there has been at least

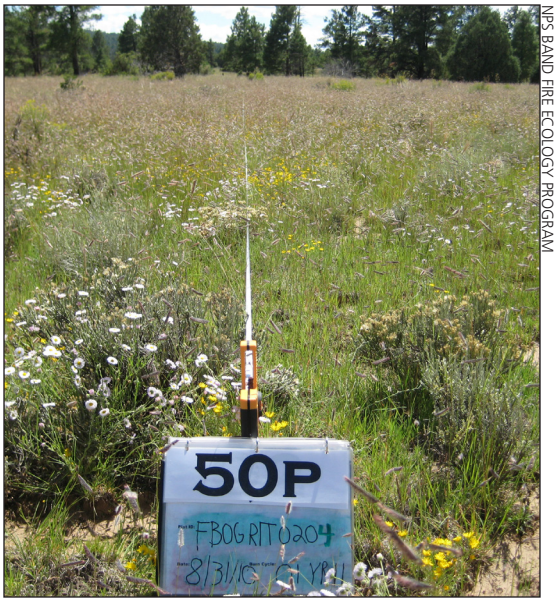


Figure 4.10.4-1. Fire effects monitoring plot sampled in 2010 in southwest Cerro Bandera, eleven years post-burn; predominant vegetation is blue grama.

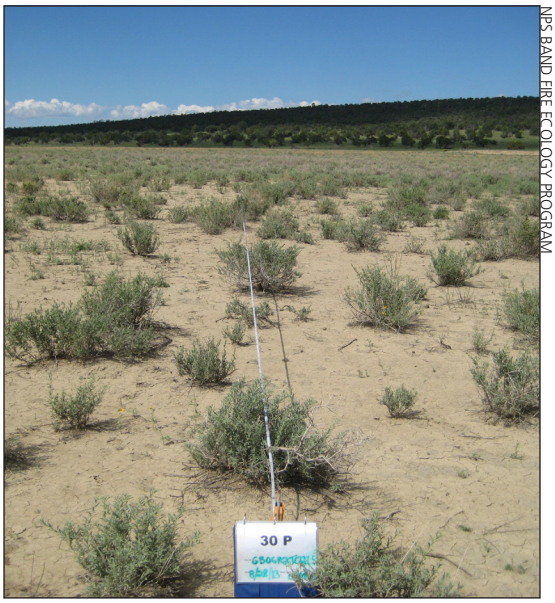


Figure 4.10.4-2. Fourwing saltbush fire effects monitoring plot sampled in 2013.



Figure 4.10.4-3. Blue grama/Mesa Dropseed Sandy Plains grassland fire effects monitoring plot sampled in 2013.

one report of "plenty of biocrusts" on the El Malpais NM kipukas in areas that had been historically less disturbed (Bowker 2014). We do know that biological soil crusts are sensitive to mechanical disturbance such as from trampling (Belnap and Eldridge 2003) and may take considerable time to recover: 200 years or more for moss and lichen crusts (Callison et al. 1985, Johansen 2001 as cited in Hilty et al. 2004). So it may very well be that grazing in accessible grasslands and shrublands has had impact on biological soil crust cover at El Malpais NM. However, additional data collected more systematically would be required before an assessment of condition could be confidently made.

Biotic Integrity

Landscape-scale Diversity

The spatial patterns of plant community distribution generally coincide with that of the soils (Figure 4.10.4-4) and geology (Figure 4.10.4-5). Thus, landscape-scale diversity was considered in good condition with no evidence for any degrading trend.

Local Species Composition

The Colorado Natural Heritage Program (CNHP 2005) description of Western Great Plains shortgrass prairie in good condition largely holds for data summarized for this assessment. Native grasses and shrubs are dominant. Species richness is often high and includes many native grasses as well as a diverse forb component. Cool season grasses maintain a healthy presence (CNHP 2005). At El Malpais NM, common cool season (C3) grasses are western wheatgrass, squirreltail (*Elymus elymoides*), and muttongrass (*Poa fendleriana*). Non-native species may be common on a very minor part of the land area (CNHP 2005).

More specifically, VM local species composition fell within a normal range of variability expected for Great Basin & Intermountain Dry Shrublands & Grasslands, Great Plains Shortgrass Prairie & Shrublands, and Southern Rocky Mountain Montane Shrublands, which are the most common vegetation grassland and shrubland types at the national monument. Canopy cover and species present at sampled sites for the vegetation map and for fire effects monitoring generally paralleled respective community type descriptions. Both of these efforts showed that scattered sites supporting the western wheatgrass-blue grama association were in a degraded state in that they demonstrated higher cover of annuals, woody species, and exotic species. Rubber rabbitbrush (*Ericameria nauseosa*) sites also tended to be a bit weedier and woodier.

While Lindsey (1951) did not quantify species cover in his Apache plume belt, he did record common species and fourteen of these are still present in the Apache plume shrublands today. Four species within the same genus described by Lindsey also remain. Only two forbs, western germander (T*eucrium canadense v. occidentale*) and Fremont's goosefoot (*Chenopodium fremontii*) were not recorded in the Apache plume shrubland plots by Muldavin et al. (2013) and in the FEM plots.

El Malpais NM is engaged in an active prescribed fire regimen, and livestock, with occasional exceptions by trespass cattle, has largely been removed from the monument. With measures in place to maintain and restore natural and historical conditions, we considered the overall condition of this measure to be good.

Exotic vs. Native Species

One of the major threats to grasslands and other plant communities is invasive species. Invasive species have been directly linked to the replacement of dominant native species (Tilman 1999), the loss of rare species (King 1985), changes in ecosystem structure, alteration of nutrient cycles and soil chemistry (Ehrenfeld 2003), shifts in community productivity (Vitousek 1990), and changes in water availability (D'Antonio and Mahall 1991).

Based on vegetation map sampling and fire effects monitoring of national monument grasslands and shrublands, 219 of 235 (93%) of the total species observed were native. All five exotic species recorded in the fire effects monitoring were forbs, with lambsquarters (*Chenopodium album*) and burningbush

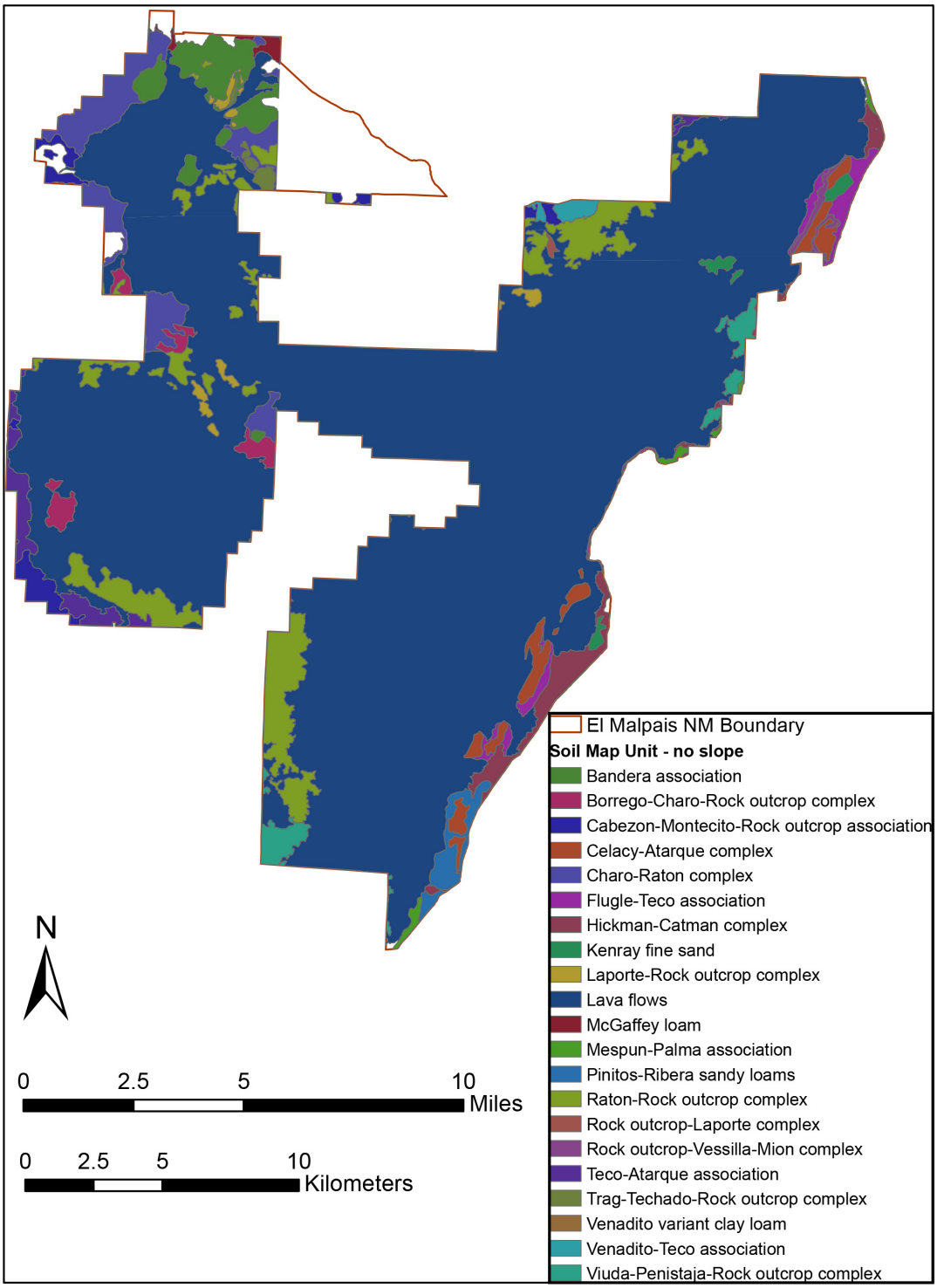
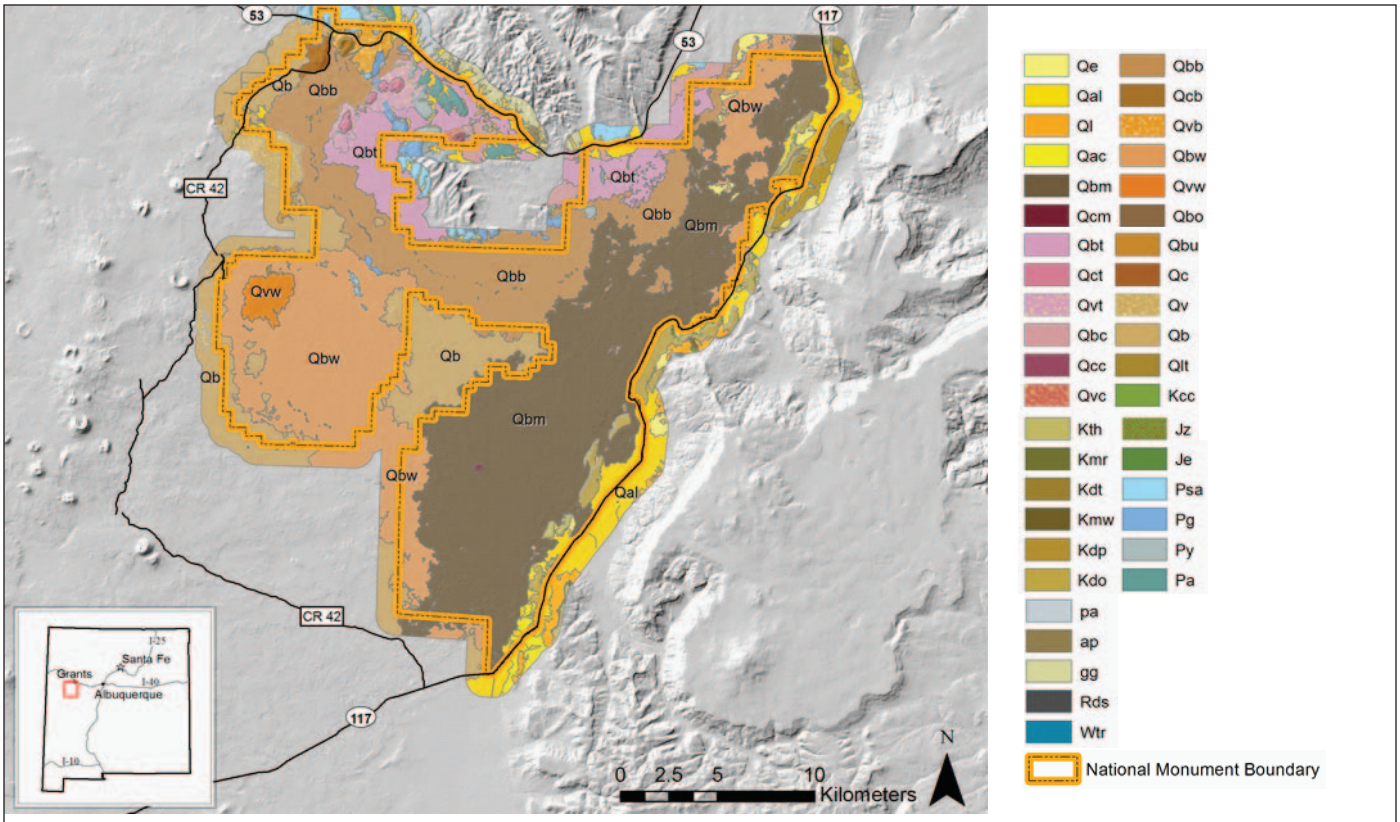


Figure 4.10.4-4. The distribution of soil types based on NRCS (2013).



Qe	Eolian Deposits (Holocene)	Qvt	Mixed Pyroclastics and Flows (Holocene and Pleistocene Volcanics)	Kdp	Paguate Tongue of Dakota Sandstone (Cretaceous)
Qal	Alluvium (Pleistocene)	Qbc	El Calderon Flows (Holocene and Pleistocene Volcanics)	Kdo	Clay Mesa Tongue of Mancos Shale and Lower Part of Dakota Sandstone (Cretaceous)
Ql	Landslide Deposits (Pleistocene)	Qcc	El Calderon Crater (Holocene and Pleistocene Volcanics)	Jz	Zuni Sandstone and Wanakah Formation (Jurassic)
Qac	Alluvium, Colluvium, and Soil (Holocene and Pleistocene)	Qvc	El Caleron Cinder Field (Holocene and Pleistocene Volcanics)	Je	Entrada Sandstone (Jurassic)
Qbm	McCartys Flows (Holocene and Pleistocene Volcanics)	Qbu	Basalt Flows (Holocene and Pleistocene Volcanics)	Psa	San Andres Limestone (Permian)
Qcm	McCartys Crater (Holocene and Pleistocene Volcanics)	Qc	Cinder Cones (Holocene and Pleistocene Volcanics)	Pg	Glorieta Sandstone (Permian)
Qbb	Bandera Flows (Holocene and Pleistocene Volcanics)	Qv	Volcanic Debris (Holocene and Pleistocene Volcanics)	Py	Yeso Formation (Permian)
Qcb	Bandera Crater (Holocene and Pleistocene Volcanics)	Qb	Old Basalt Flows (Holocene and Pleistocene Volcanics)	Pa	Abo Formation (Permian)
Qvb	Bandera Cinder Field (Holocene and Pleistocene Volcanics)	Qlt	Lava Tube (Quaternary Lava Tube)	pa	Porphyritic Aplite (Permian)
Qbw	Hoya de Cibola Flows (Holocene and Pleistocene Volcanics)	Kcc	Crevasse Canyon Formation (Cretaceous)	ap	Gneissic Aplite (Precambrian)
Qvw	Hoya de Cibola Shield Volcano (Holocene and Pleistocene Volcanics)	Kth	Tres Hermanos Sandstone (Cretaceous)	gg	Gneissic Granite (Precambrian)
Qbo	Oso Ridge Flows (Holocene and Pleistocene Volcanics)	Kmr	Rio Salado Tongue (Cretaceous)	Rds	Roads
Qbt	Twin Craters Flows (Holocene and Pleistocene Volcanics)	Kdt	Twowells Tongue of Dakota Sandstone (Cretaceous)	Wtr	Water
Qct	Twin Craters Cinder Cones (Holocene and Pleistocene Volcanics)	Kmw	Whitewater Arroyo Tongue (Cretaceous)		

Figure 4.10.4-5. The geology of El Malpais NM (Muldavin et al. 2013).

(*Kochia scoparia*) decidedly higher in cover (Table 4.10.4-1). However, hogweed (*Portulaca oleracea*) was considerably more prevalent across the landscape (seven out of 12 sites with exotics). There were 14 exotic species recorded at 84 VM sites (Table 4.10.4-1). Only two of these were grasses, cheatgrass (*Bromus tectorum*) and stinkgrass (*Eragrostis cilianensis*), these found at five sites. The exotics most abundant in cover were hogweed, burningbush, and Russian thistle (*Salsola tragus*), similar to what was found in fire effects monitoring plots. These three species are also most widespread, occurring in the highest number of sites. It should also be noted that hogweed was also documented by Lindsey in 1951. The NPSpecies plant list (NPSpecies 2016), a current list maintained by the NPS of potential and observed plant species at the monument, reports 33 species, or 6%, of all species documented as present in the monument as being exotic. Based on the low number of exotic species documented and the fact that the 53% of sites with exotics typically had one exotic species recorded there at <10% cover, we considered the current threat of exotics to El Malpais NM grasslands and shrublands to be fairly low. Note that the exotics plants assessment (section 4.13) considered the prevalence of exotic plants at a park-wide level, whereas the grasslands/shrublands assessment is focused on those communities where the majority of plots are located, providing more information for assigning a condition rating.

General Life Cycles Relative to Disturbance

The proportion of annual, biennial and perennial species provides an indication of the stability of the site, and it is generally expected that the proportion of annual species at a given site would be higher immediately following a disturbance, but would shift toward an increased proportion of perennials as time passes since a disturbance. The FEM and VM data revealed a similar abundance of annuals, with 15% and 13% cover, respectively. Graminoids were most often perennial. Forbs were considerably more variable among sites, accounting for approximately 97% of the annual species. We were unable to determine if VM plots experienced similar fire return intervals or intensity as nearby FEM plots as none of the VM plots fell within 150 meters of the FEM plots. But, the presence of annuals was quite low at the six FEM sites that have burned in the last 17 years. With few exceptions, sites with considerable number and/or cover of annual species, most of these species were

Table 4.10.4-1. List of exotic plant species at El Malpais NM as recorded in the 2006-2009 vegetation map (VM) project (Muldavin et al. 2013) and at the fire effects monitoring (FEM) plots sampled between 2006 and 2013.

Scientific Name	Common Name	Project Effort
Amaranthus retroflexus	redroot amaranth	FEM
Chenopodium album	lambsquarters	FEM
Bromus tectorum	cheatgrass	VM
Convolvulus arvensis	field bindweed	VM
Eragrostis cilianensis	stinkgrass	VM
Erodium cicutarium	redstem stork's bill	VM
Kochia scoparia	burningbush	FEM, VM
Melilotus officinalis	yellow sweetclover	VM
Portulaca oleracea	little hogweed	FEM, VM
Salsola collina	slender Russian thistle	VM
Salsola tragus	prickly Russian thistle	FEM, VM
Tamarix chinensis	five-stamen tamarisk	VM
Tragopogon dubius	yellow salsify	VM
Tragopogon pratensis	Jack-go-to-bed-at-noon	VM
Verbascum thapsus	common mullein	VM

also exotic species indicating some kind of disturbance if not fire. Manyflower false threadleaf (*Schkuhria multiflora*), a native, annual forb, was the primary exception, occurring in great abundance (12 and 25%) at two of FEM sites in the southeast section of the monument referred to as the Homestead project by the Bandelier NM Fire Program.

As previously discussed, we did not have any expectation for the proportion of annuals, biennials, and perennials, to coincide exactly with historic climax plant communities, in part because of local site variability and not all sites are at a climax stage. At El Malpais NM, sites that exhibited relatively low proportion of perennials might have experienced more recent disturbance. Thus, it would not be surprising that we observe a higher proportion of annual species on these sites. The time frames over which we might expect a shift toward increasing perennial species likely depends on the intensity and duration of the disturbance. That said, 30% of the 235 species recorded were annual (15% of the annual species were exotic), which is fairly high. As represented by canopy cover, abundance of exotic annuals shoot up to 68% cover for both projects. It might be worthwhile to explore potential explanations a bit further.

Given that most species recorded were perennial and native, and exotics are addressed elsewhere, we assigned a good condition overall with respect to this measure.

Relative Proportion of Functional Groups
Like our other measures, the proportion of functional groups was similar between the FEM and VM data. This proportion typically matched expectations of site potential with graminoids most highly represented, followed by a diversity of forbs and shrubs. VM plots showed higher shrub and lower graminoid values when compared with FEM data. These differences may be due, in part, to the fact that a higher percentage of VM plots were situated in shrublands while FEM plots placed a stronger emphasis on grasslands. A few sites exhibited a higher woody component than might be expected, but cover was still in the 5-15% range. A far more extensive discussion regarding woody encroachment into grasslands may be found in the piñon-juniper assessment. Given the diversity of functional groups and low tree cover, we considered condition of this measure to be good.

Relative Proportion of C3 and C4 Species
Results from summarizing the FEM monitoring data and the VM plot data revealed C4 graminoids to be far more prevalent, in both number and cover, than C3 grasses in most grassland and shrubland vegetation types (Table 4.10.4-2). The exceptions to this pattern were in the Apache Plume Rockland Shrubland, Fourwing Saltbush/ Alkali Sacaton and the Western Wheatgrass (a C3 grass)/ Curly Gumweed associations.

The balance of warm and cool season graminoids could fluctuate and tip either way in grasslands of this region (Paruelo et al. 1996, Epstein et al. 1997). High variation in amount and timing of annual precipitation impacts the relative cover of cool and warm season herbaceous species (NatureServe 2004). El Malpais NM experiences warm mean annual temperatures (hot summers and cool to cold winters) and precipitation that, while drier than what falls to the east, falls primarily during the growing season.

Predicted, generalized climate change impacts for this region are drier, hotter, and more severe storms (and more frequent, severe fires). Should these predictions be correct, it may alter C4 and C3 species composition.

Table 4.10.4-2. The relative cover and number of C3 and C4 graminoid species found in the vegetation mapping project (VM) and during fire effects monitoring (FEM).

Relative cover of C3 and C4 Graminoid Species		
	VM	FEM
C3	7%	10%
C4	93%	90%
Number of C3 and C4 Graminoid Species		
	VM	FEM
C3	11	6
C4	32	6

The Role of Fire and Grazing in Grassland Shrubland Condition at El Malpais NM

Grazing

Large-scale processes such as climate, fire, and grazing influence this habitat. The short grasses that dominate this habitat type are extremely drought and grazing-tolerant. These species evolved with drought and large herbivores, and because of their stature, are relatively resistant to overgrazing (NatureServe 2004 as cited in NMDGF 2006).

As noted in the introduction, Muldavin et al. (2013) are of the opinion that historical livestock grazing has not played a significant role at El Malpais NM due to restricted access to some areas. Others have taken a different view, indicating that grazing has had more of an impact on modern condition of national monument grasslands and shrublands. In Lightfoot et al. (1994), Henri Grissino-Mayer (pers. comm.) purported that "grazing has probably been the greatest human-caused influence on the ecology in the El Malpais NM area. Although the grasslands surrounding the lava flows were the most heavily used, it is possible that interior lava flows were visited by sheep. The introduction of domestic sheep and the decline of the grasslands appear to correlate with the decrease in numbers of pronghorn and extirpation of bighorn sheep."

Possible evidence for livestock grazing on the monument's interior on older lava flows - Hoya de Cibola and Bandera- comes from the cultural resources survey of lava flow trails extending from the Sandstone Bluffs. The majority of trails on the monument's lava flows are pre-contact\prehistoric, but cultural resource crews have documented segments of prehistoric trails that were modified/ enhanced possibly to accommodate pack animals as well as historic era camps on old lava near the monument's north boundary, northeast of Sandstone Bluffs. The open grassland on the old flows in this area seem favorable for grazing (S. Baumann, Chief of Resources, pers. comm.).

In NMDGF (2006), authors state that "despite the shortgrass prairie's apparent evolutionary adaptation to grazing, livestock use has been an agent of change. Much of this effect occurred in the late 1880s when livestock numbers peaked and shortgrass prairies were grazed beyond their sustainable use. Barbour (1988) stated, "When the shortgrass prairie was first grazed by domestic livestock, the original grasses persisted probably because of their low stature and natural resistance to grazing pressure. As abuse occurred (due to improper grazing use) and the grasses declined, weedy perennial species of cacti (*Opuntia spp.*), snakeweed (*Gutierrezia sarothrae*) and yucca (*Yucca*) increased. Invader annuals have come from the brome (*Bromus spp.*), Russian thistle (*Salsola tragus*), barley (*Hordeum spp.*), and fescues (*Festuca spp.*) genera." (in NMDGF 2006). While all of these species referenced above have been documented at the national monument, they do not appear to be broadly distributed and have only gained footholds in a few community types.

It appears that experts might not agree on the extent to which national monument grasslands and shrublands might be degraded and the underlying cause. Strictly based on FEM and VM data, we certainly observed the presence of exotics, in some areas more commonly than others, but the high-value, iconic species still appear to be amply represented. With livestock grazing now a much rarer occurrence, conditions should only improve.

Fire

Historical records of fire frequencies for prairies of the southern Great Plains before settlement are generally nonexistent or unreliable because there are no trees to carry fire scars from which to estimate fire frequency (Ford and McPherson 1996). Although fire is generally reported to play a prominent role in health and functioning of grasslands (e.g., Joern and Keeler 1995), this role likely varies substantially among grassland types. In particular, the role of fire as a primary determinant of grassland structure likely decreases strongly from tallgrass prairie to shortgrass steppe as a result of the gradient in productivity and fuel (Kucera 1981, Oesterheld et al. 1999, Scheintaub et al. 2009). In fact, grassland experts Drs. Alan Knapp and William Lauenroth (pers comm.) suggest that fire probably plays a much lesser role in

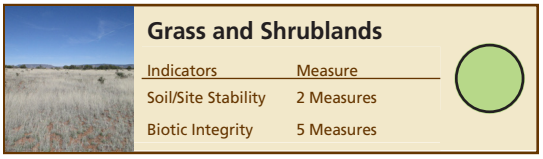
maintaining a healthy prairie in the shortgrass steppe than other drivers such as herbivory and climate variation.

One of the perceived benefits of fire in grassland systems is the reduction of litter. In tallgrass prairie, litter removal increases soil temperature and light leading to increased productivity (Hulbert 1988; Knapp and Seastedt 1986). However, shortgrass steppe has minimal litter accumulation (Burke et al. 1998), and Scheintaub et al. (2009) reported a positive relationship between litter and productivity, suggesting that litter may facilitate, or at least not inhibit productivity as it does in tallgrass prairie. However, Scheintaub et al. (2009) also suggest that further research is needed on the relationship between litter and productivity in short grass steppe.

According to Muldavin et al. (2013), savanna woodlands on the older flows and cinder cones at El Malpais NM tend to have the highest grass cover and hence the highest historical surface fire frequency - every three years (Grissino-Mayer et al. 1997). Fire frequency dropped off dramatically beginning in the late 19th century as a result of heavy livestock grazing. Grissino-Mayer (1995) reports that there was a major change in fire regimes in the malpais region ca. 1940, which is thought to reflect intensive and successful fire suppression efforts by land agencies. Before this time, fires in the often rugged and inaccessible sites received less attention, and therefore, suppression was less effective. Early grazing practices may have affected fire-carrying grasses, resulting in minimal spread (NPS 2005).

The current (NPS 2005) fire management plan purports that most of the early fire-adapted vegetative communities at the national monument have become altered from combinations of human use, early fire suppression, and climate change. The more open grasslands that occurred before the 1900s have changed to grass-shrub communities and piñon-juniper woodland with understories of non-native exotics. In some areas, ponderosa pine has been known to invade adjacent grasslands where fires have been suppressed (Allen 1984, 1989). Hence, some stands of the various savanna associations may be considered invasive depending on edaphic conditions and disturbance history (Muldavin et al. 2013).

In 1994, a limited controlled burn program was being initiated (K. Mabery, pers. comm. as cited in Bleakly 1994). By 2001, there was a fire management plan (NPS) in place that identified restoring fire as a keystone natural process that encourages native grassland ecosystems and reducing established noxious and non-native plant cover as prime objectives in grassland management. The national monument currently has an active prescribed fire program.



Overall Condition

For assessing the condition of grasslands, we used a variety of indicators/measures that were not mutually exclusive but were intended to be different ways of capturing the essence of what we thought represented the condition of the El Malpais NM's grasslands and shrublands. Vegetation community condition can be assessed from many different angles, but we chose two main categories for this resource. A summary of how they contributed to the overall grassland and shrubland condition is summarized in Table 4.10.4-3.

Based on the indicators, data, and expert opinion, we consider the overall condition of the grasslands at El Malpais NM to be in good condition. While this condition appears to be stable with the cessation of livestock grazing almost 20 years ago and an active fire management program with objectives to manage for optimal ecological condition and to reinstate a more natural fire regime, the following has been suggested for this region of New Mexico in the light of changing climate:

> "As for the current state of the shortgrass prairie, Dick-Peddie (1993)

Table 4.10.4-3. Summary of the indicators and measures and their contributions to the overall assessment of grassland and shrubland condition.

Indicator	Measure	Condition	Condition Rationale
Soil/Site Stability	Soil Cover	Good	Bare soil predominates as would be expected in this location, given substrate and sparse vegetation cover. These conditions, while not ideal for slowing erosion and slowing water flow are normal in this setting. Gravel, rocks, biological soil crusts (moss and lichen), bedrock, and some litter contribute to ground cover (30%) and help protect the soil surface.
	Biological Soil Crust	Unknown	Some biological soil crusts (moss and lichen) were found, but data were scant. Condition of this measure could not be assigned.
Biotic Integrity	Landscape-scale Diversity	Good	Species composition is consistent with expected species based on spatial patterns of soils and geology; vegetation communities reflect the natural range of variation.
	Local Species Composition	Good	Species composition is consistent with expected species; few exotics were commonly found, and many sites exhibited high diversity.
	General Life Cycles Relative to Disturbance	Good	The proportion of annual, biennial and perennial species relative to the time since disturbance was not obviously consistent. There are sites with ruderal species for which the disturbance mechanism is unknown to the authors.
	Relative Proportion of Functional Groups (e.g., graminoid, forbs, shrubs, etc.)	Good	The relative proportions of functional groups are consistent with what would be expected; there was a good diversity of grasses, forbs, subshrubs, and shrubs. Only slight and occasional woody encroachment was evident.
	Relative Proportion of C3 and C4 Species	Good	The relative proportions of C3 and C4 plants are consistent with what would be expected based on site characteristics and local climate variables.

> wrote, "The succession from plains-mesa grassland to juniper savanna will probably continue in many areas of the state. At the lower (drier) boundaries of plains-mesa grassland, many acres of grama grassland will become desert grassland, and much of the present desert grassland will become Chihuahuan or Great Basin desert shrubland. On many sites, these successional trends, which range users consider deterioration of grassland, were set in motion early in this century; subsequent range management efforts are unlikely to halt, let alone reverse the trend." (NMDGF 2006).

Level of Confidence/Key Uncertainties

Overall, our confidence in this assessment is moderate, given a number of uncertainties and limitations. Some of the key uncertainties for the grassland and shrubland assessment include annual variability, the effect of drought conditions and changing climate, the effect of recovery from disturbance, and the potential success of ongoing management actions.

Additionally, the assessment was based largely on data that are now somewhat dated, and in the case of the FEM data, were not collected in all representative areas of the monument as fire management has a stronger focus in the wooded regions. For example, NPS and academic ecologists conducted a field assessment of piñon pine-juniper and ponderosa pine communities for both the El Malpais NM and El Morro NM NRCAs in June 2015. They observed patches of dead and dying blue grama grass in portions of the grassland savanna at nearby El Morro NM. They attributed the cause to recent drought conditions since this keystone species is dependent upon summer rains

and in August 2013 and 2014 precipitation levels were considerably lower than normal. This condition or trend in condition would not have been captured in this grassland/shrubland assessment given the timing of data collection. 2015 precipitation levels were higher than average, both in annual and summer precipitation, so it will be interesting to see if this iconic grass is able to make a recovery if favorable conditions continue. For detailed information on the field assessment and their observations, see Sections 4.8 and 4.9 and Appendix F.

4.10.5. Sources of Expertise

During the course of this assessment, Laura Trader, Bandelier NM fire ecologist, provided the fire effects monitoring data and plot photos. Donna Shorrock, NPS IMR NRCA Coordinator, authored this assessment.

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4.11. Vegetation - Distinct Communities

Indicators/Measures

- Ecological Integrity (no measures)

Condition – Trend - Confidence



Unknown – Unknown - Unknown

4.11.1. Background and Importance

The landscape of El Malpais National Monument consists of young basaltic lava flows with little soil development, cinder cones and cinder fields, and small areas of sedimentary rock substrate, including isolated areas such as in kipukas where older rocks (including volcanic ones) were surrounded by younger lava flows. As a result, strong alliances between geologic substrate and vegetation exist, a key aspect of the lava flow-influenced ecosystem of El Malpais NM.

The earliest ecological studies of the El Malpais region noted the strong influence of the young volcanic features on the region's vegetation (Lindsey 1951), as evidenced by stands of stunted or deformed *Pseudotsuga menziesii*, (Douglas-fir) and *Pinus ponderosa* (ponderosa pine) growing on the Bandera and McCartys flows. Lindsey reported that the bedrock geology has a profound impact on the area's vegetation, with many herbaceous plant species present only on a single geologic substrate type, and cinder cones having the most distinctive floras.

Important biogeographic aspects and characteristics of the monument's vegetation include ancient trees growing on the young lava flows, the endemic plant species *Phacelia serrete* (cinders phacelia), endemic and vulnerable plant associations, including ones that have only been found at El Malpais, and the vegetation communities found on kipukas.

4.11.2. Data and Methods

This assessment is based primarily on information available in the Vegetation Classification and Map: El Malpais National Monument (Muldavin et al. 2013), supplemented by additional, although limited, information.



NPS

Figure 4.11.1-1. Phacelia serrate (*cinders phacelia*) is an endemic species that grows only on volcanic cinders and is a USFWS Species of Concern.

Indicator
Ecological Integrity (no measures)

We used one indicator, ecological integrity, with no measures, for assessing current condition of the park's distinct vegetation communities: ancient trees, *Phacelia serrate*, endemic and vulnerable plant associations, and the vegetation communities growing on kipukas.

Ancient Trees

El Malpais contains some of the oldest living trees in the southwest (Grissino-Mayer et al. 1997). These trees, along with dead wood found on the young lava flows, were essential in the establishment of a tree ring chronology extending from 136 BC to AD 1992 (Grissino-Mayer 1996). The ancient trees used in the chronology were from two areas of the Bandera lava flows: the Cerro Rendija East (Lindsey) site, northeast of Cerro Rendija, and the Bandera Ice Caves site, along the perimeter of the lava tube southwest of Bandera Crater (Grissino-Mayer et al. 1997).

Very old living Douglas-fir (Figure 4.11.2-1) and ponderosa pine trees grow on the rough surfaces of the Bandera and McCartys lava flows in a uniquely mesic environment (Grissino-Mayer et al. 1997). Old pinyon pines and Rocky Mountain junipers are also present from the McCartys flow (Lindsey 1951 and Wayman 2015), with the oldest trees being more than 400 years old (Wayman 2015).

The ancient trees of El Malpais, while scientifically important, are not being monitored (David Hays, personal communication, 2015). For the most part, precise (GPS) locations of these trees are not known. However, two locations of ancient trees have been recorded (Figure 4.11.2-2) (Grant Harley, personal communication, 2015).

A 600-year old Douglas-fir, "Yoda," died in 2014 and at least one other 600-800-year old Douglas-fir had experienced "strip-barking," which is a partial cambial dieback



Figure 4.11.2-1. An ancient Douglas-fir growing on the Bandera lava flows in August 2014. This tree has experienced a partial cambial dieback, causing part of its crown to die. If it lives, it will have a smaller crown (Grant Harley, personal communication, 2015).

(Figure 4.11.2-1) (Grant Harley, personal communication, 2015).

Phacelia serrate

Phacelia serrate is an endemic species that grows on volcanic cinders in only two areas: the San Fransisco Peaks in Arizona, including Sunset Crater Volcano National Monument, and in El Malpais NM (NatureServe.org 2015a).

In 2011, NPS staff from El Malpais NM conducted a survey of cinders phacelia locations at El Calderon, Lost Woman Crater, Twin Craters, Bandera Crater, Cerro Bandera, and cinder cone hill (an area of NPS land on the north side of New Mexico 53) (NPS 2011). Cinders phacelia was found growing in all locations except for Cerro Bandera, which was a site not previously surveyed. Older

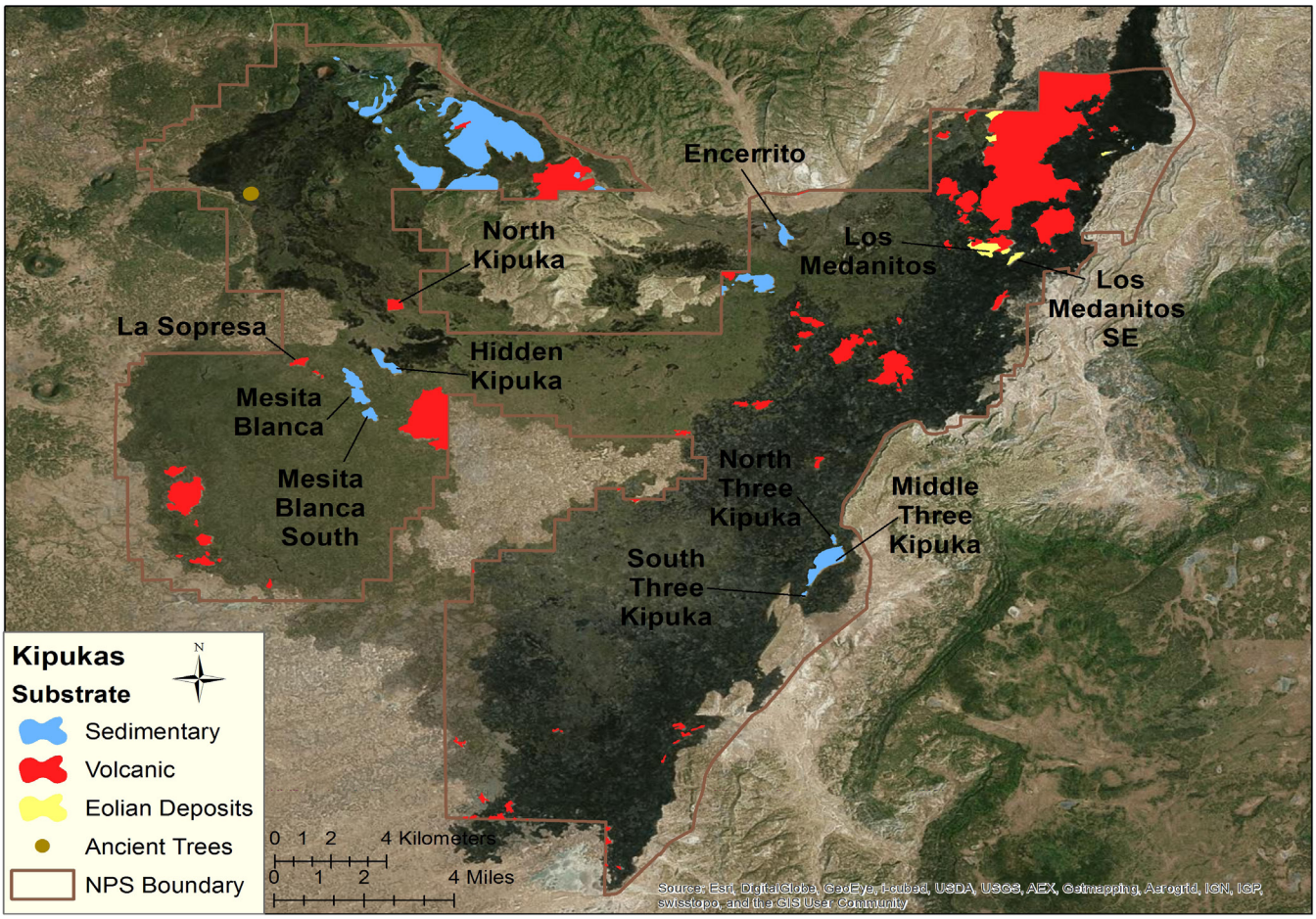


Figure 4.11.2-2. Map showing locations of kipukas by major substrate type: volcanic, sedimentary, and eolian. Areas of Quaternary alluvium (Qal) were grouped into substrate type based on the overall bedrock geology of the kipuka. Geologic mapping by Maxwell (1986) and KellerLynn (2012). Kipuka names are from Bleakly (1996) and Lewis (2003). The large kipukas that are mostly outside of the monument boundaries (Hole-in-the-Wall and Cerritos de Jaspe) are not shown except where inside the monument. Locations of the ancient Douglas-fir trees are from Grant Harley (personal communication, 2015).

cinder cones such as Cerro Bandera have comparatively stable, well-developed soils (Muldavin et al. 2013), perhaps accounting for the absence of cinders phacelia there. These 2011 monitoring reports provided limited data that confirmed the presence and location of the species, but did not use methodologies that allow for repeatable data collection.

Endemic and Vulnerable Plant Associations

Information on the endemic and vulnerable plant associations were compiled from the park's Vegetation Classification and Map report (Muldavin et al. 2013) and are summarized in Table 4.11.2-1.

Five plant associations are only known from El Malpais, and an additional six associations are regionally endemic; e.g., found in a restricted area of New Mexico and Colorado. Fourteen associations were designed "Park Specials" needing further documentation before being included in the National Vegetation Classification. Seven plant associations were classified as vulnerable, including *Pinus edulis* / *Achnatherum scribneri* Woodland, which is also regionally endemic (Muldavin et al. 2013).

Vegetation Communities Growing on Kipukas

We identified all kipukas (areas of older rock surrounded by younger lava flows) within the boundary of El Malpais NM using geologic maps (KellerLynn 2012 and Maxwell 1986) (Figure 4.11.2-2). The rock type, or substrate for vegetation, of these kipukas was either volcanic, sedimentary or eolian. Information

Table 4.11.2-1. Endemic and Vulnerable Plant Associations present in El Malpais NM.

Plant Association	Map Unit Component[1]			Geologic Substrate[2]	Global Conservation Assessment Ranking[3]
	Primary	Secondary	Related Inclusion		
Only Known from El Malpais NM					
Bouteloua gracilis - Sporobolus cryptandrus Herbaceous Vegetation	9D			Old basalt flows	GNRQ
Fallugia paradoxa - Rhus trilobata Shrubland	6C	6b, 6C		McCartys, Bandera, Hoya de Cibola and El Calderon flows	GNR
Pinus edulis - Juniperus spp. / Fallugia paradoxa Woodland	4D	4A, 4E	2C	McCartys, Bandera and Twin Crater flows	GNR
Pinus ponderosa / Fallugia paradoxa - Ribes cereum Woodland	2D, 2E	2B	2G	Bandera, Twin Craters, Hoya de Cibola and El Calderon flows	GNR
Populus tremuloides / Mixed Shrubs / Cinder Woodland			1A, 3A	Bandera, Twin Craters and Old basalt flows	GNR
Regionally Endemic					
Artemisia frigida / Bouteloua gracilis Dwarf-shrubland	9C			Old basalt flows	GNR
Juniperus monosperma / Muhlenbergia pauciflora Woodland			4H	Sedimentary	GNR
Juniperus monosperma / Quercus × pauciloba Woodland		4C, 5B, 5G		McCartys and Bandera flows, and sedimentary	GNR
Pinus edulis - Juniperus monosperma / Quercus × pauciloba Woodland	4C	4H		McCartys and Bandera flows, and sedimentary	G5
Pinus edulis - Juniperus scopulorum / Holodiscus dumosus Woodland	4E	1B	1A, 1B, 2B, 2D	Bandera, Twin Craters and El Calderon flows	GNR
Pinus edulis / Achnatherum Scribneri Woodland[4]		4H		Sedimentary	G3
Park Specials					
Atriplex canescens / Panicum obtusum Shrubland		7A		Old basalt flows	GNR
Bouteloua gracilis - Muhlenbergia montana Herbaceous Vegetation	9B			Hoya de Cibola, El Calderon and Old basalt flows, and sedimentary	GNR
Bouteloua gracilis Ruderal Herbaceous Vegetation	9E			Old basalt flows	GNA
Juniperus monosperma / Bouteloua gracilis - Sporobolus cryptandrus Woodland		4G, 5F		El Calderon and Old basalt flows, and sedimentary	GNR
Juniperus monosperma / Fraxinus cuspidata Woodland	5B, 5C			Bandera and Twin Crater flows	GNR
Pascopyrum smithii - Bouteloua gracilis Herbaceous Swale Vegetation	9F			Old basalt flows	G5
Pascopyrum smithii / Grindelia squarrosa Herbaceous Vegetation		9F		Old basalt flows	GNR
Pinus edulis - (Juniperus spp.) / Cinder Woodland	4A	4B		Twin Craters, El Calderon and Old basalt flows	GNR
Pinus edulis - Juniperus deppeana - Quercus grisea Woodland			4H	Sedimentary	GNR
Pinus ponderosa / Artemisia filifolia Woodland		3D		Old basalt flows	GNR
Populus tremuloides / Ribes cereum Woodland			1B, 2D, 2G, 4E, 6C	Bandera, Twin Craters, Hoya de Cibola and El Calderon flows	GNR
Pseudotsuga menziesii / Holodiscus dumosus Lavaflow Woodland	1B			Bandera flows	GNR

Table 4.11.2-1. Endemic and Vulnerable Plant Associations present in El Malpais NM continued.

Plant Association	Map Unit Component[1]			Geologic Substrate[2]	Global Conservation Assessment Ranking[3]
	Primary	Secondary	Related Inclusion		
Pseudotsuga menziesii / Ribes (leptanthum, cereum) Woodland	1A			Bandera and Twin Craters flows	GNR
Vulnerable					
Bouteloua gracilis - Pleuraphis jamesii Herbaceous Vegetation		9B	9B	El Calderon flows and sedimentary	G2G4
Bouteloua gracilis Herbaceous Vegetation	9F	9A, 9B, 9C	9A	Bandera, Twin Craters, Hoya de Cibola, El Calderon and Old basalt flows, and sedimentary	G4Q
Pinus ponderosa / Bouteloua gracilis Woodland	3B, 3C	2G, 3B, 3C	2E, 3A	Bandera, Twin Craters, Hoya de Cibola and Old basalt flows, and sedimentary	G4
Pinus ponderosa / Carex inops ssp. heliophila Woodland	2F	2A, 2G	2E	Bandera, Twin Craters and Hoya de Cibola flows	G3G4
Pinus ponderosa / Schizachyrium scoparium Woodland			2E, 2G, 3B	Bandera, Twin Craters and Hoya de Cibola flows	G3G4
Sarcobatus vermiculatus / Sporobolus airoides Shrubland			9F	Old basalt flows	G3?

Data are from Muldavin et al. (2013).

[1] Plant associations identified as part of Level 2 map units for El Malpais NM used in the Vegetation Classification and Map (Muldavin et al. 2013). Primary Components make up greater than 50% of areal extent of the map unit, Secondary Components are present in less than 50% of the map unit, and related inclusions occupy less than 10% of the area of the map unit. Map units are as designated in the vegetation map (Appendix F).

[2] Geologic substrate that the vegetation map units occupy as identified in Table 8 in Muldavin et al. (2013). The geologic map for El Malpais NM is available in KellerLynn (2012) and Maxwell (1986). Identified substrates may include both lava flows and associated cinder cones.

[3] Global Rank definitions (Natureserve.org 2015b and Sneddon 2010):

G2: Imperiled: (At high risk of extinction or elimination due to very restricted range, very few populations, steep declines, or other factors.)

G3: Vulnerable (At moderate risk of extinction or elimination due to restricted range, relatively few populations, recent and widespread declines, or other factors.)

G4: Apparently Secure (Uncommon but not rare; some cause for long-term concern due to declines or other factors.)

G5: Secure (Common; widespread and abundant.)

GNR: Unranked (Global rank not yet assigned).

GNA: Not applicable (A conservation status rank is not applicable because the species is not a suitable target for conservation activities.)

G#G#: Range Rank (A numeric range rank (e.g., G2G3) is used to indicate the range of uncertainty in the status of a community.)

G#Q: Questionable taxonomy (Taxonomic distinctiveness of this entity at the current level is questionable.)

G#?: Inexact numeric rank (Denotes inexact numeric rank.)

[4] This regionally endemic association is also vulnerable (G3).

about the distribution of vegetation in El Malpais and its geologic substrate is available in Muldavin et al. (2013).

Two plant associations, *Pseudotsuga menziesii / Quercus gambelii* Forest and *Pinus edulis / Achnatherum scribneri* Woodland, were described as only growing on kipukas with sedimentary substrates, and one vegetation map unit, Douglas-fir/Gambel Oak Foothill Forest (1C) was restricted to a single kipuka within the monument boundary (Muldavin et al. 2013). However, this kipuka is Cerritos de Jaspe, a large kipuka that is mostly outside of the monument.

Of the 42 vegetation Level 2 map units, all but five were found growing on kipukas (Muldavin et al. 2013), indicating that kipukas usually support the same vegetation types as found in the rest of the monument. The five map units not found on kipukas are Douglas-fir/Gooseberry Cinder Forest (1A), Ponderosa Pine/Mountain Muhly Lava Woodland Savanna (3A), Pinyon-Juniper/ Blue Grama Cinder Woodland Savanna (4B), Oneseed Juniper/Wavyleaf Oak/Blue

Table 4.11.2-2. Known anthropogenic disturbances on kipukas in El Malpais NM.

Kipuka[1]	Substrate	Logged	Grazed	Reference
Mesita Blanca	Sedimentary	No	Yes	Lewis 2003; Bleakly 1996
Mesita Blaca South	Sedimentary	No	Yes	Lewis 2003; Bleakly 1996
Hidden Kipuka	Sedimentary	No	No	Lewis 2003; Bleakly 1996
La Sopresa	Volcanic	Yes	Uncertain	Lewis 2003
North Kipuka	Volcanic	Yes	No Information	Lewis 2003
Encerrito	Sedimentary	No information	Uncertain[2]	Bleakly 1996
Los Medanitos	Eolian & Volcanic	N/A	Yes	Bleakly 1996
Los Medanitos SE	Eolian	N/A	Yes	Bleakly 1996
North Three Kipuka	Sedimentary	No information	No	Bleakly 1996
Middle Three Kipuka	Sedimentary	No information	No	Bleakly 1996
South Three Kipuka	Sedimentary	No information	No	Bleakly 1996

[1]Figure 4.11.2-1 shows the location and the substrate type of these kipukas.

[2]Bleakly (1996) did not provide information on the anthropogenic impacts to this kipuka. The author visited this site in February 2015 and noted that it did not have any geographic barriers that would prevent livestock access, and it is near Highway 53 with easy access to the general area.

Grama Foothill Woodland Savanna (5G), and Fourwing Saltbush Shrub-Steppe (7A). Map units 1A, 3A, and 4B are only found on cinder cones, and map units 5G and 7A are restricted to areas outside of the young lava flows.

Two studies (Bleakly 1996 and Lewis 2003) looked at a subset of kipukas (mostly with sedimentary substrates) and provided information on their anthropogenic disturbances (grazing and logging) along with those on a select area of the surrounding lava flows (Table 4.11.2-2). Of the five kipukas studied by Lewis (2003), two (La Sopresa and North Kipuka) had been heavily logged and two other kipukas had been grazed (Mesita Blanca and Mesita Blanca South). Hidden kipuka did not have evidence of past logging or grazing. Of the nine kipukas studied by Bleakly (1996), four had been grazed, including two that were also in the Lewis study. Bleakly (1996) did not provide information on logging. Lewis (2013) also identified an area on the Hoya de Cibola lava flow between Hidden kipuka and Mesita Blanca that had no evidence of either logging or grazing.

4.11.3. Reference Conditions

A logical reference condition for ecological integrity of the distinct vegetation communities is whether they are sustaining themselves, but without ongoing monitoring, this information is lacking. No reference conditions were developed for this assessment.

4.11.4. Condition and Trend

The condition of the ecological integrity indicator for the identified distinct plant communities in El Malpais NM is unknown (Table 4.11.4-1.)

Ancient Trees

Information on the current condition of the ancient trees used in the Malpais Long Chronology is extremely limited. In August 2014, Grant Harley discovered that one of the ancient Douglas-fir trees ("Yoda") had died since his previous visit in March 2014 (Grant Harley, personal communication, 2015). Recent drought conditions with high temperatures may have contributed to this mortality (Fleck 2014). In August 2014, another tree on the Bandera flows nearby showed similar signs of stress that Yoda had before its death (Figure 4.11.2-1). It is unknown how, and if, stress from climate change, such as the recent extreme warm conditions for five climate variables (Monahan and Fisichelli 2014), and/or drought may be impacting these old trees.

Phacelia serrate

Based on photographs and population estimates in the 2011 cinders phacelia monitoring reports (NPS 2011), sizable

Table 4.11.4-1. Indicators, measures, and their contributions to the overall distinct vegetation condition rationale.

Indicator of Condition	Measure	Condition	Rationale for Condition.
Ecological Integrity	n/a	Unknown	The ancient trees, cinders phacelia, endemic and vulnerable plant associations, and vegetation communities growing on kipukas are not being monitored. Therefore, their current condition is unknown.

populations of this endemic plant were present at several cinder cones. Current condition or any population trends for this species in the park is unknown. Staff from El Malpais NM plan to re-initiate monitoring in 2016 (Eric Weaver, personal communication, 2015). The overall population trend for this species is stable, although the plant will become scare to rare even in prime habitat in drought years as it is dependent upon precipitation (NatureServe.org 2015a).

The species has the Global Conservation Assessment Ranking of G3, Vulnerable (at moderate risk of extinction or elimination due to restricted range, relatively few populations, recent and widespread declines, or other factors) (NatureServe.org 2015a). It has a Natural Heritage New Mexico ranking of S2 Imperiled (imperiled in NM because of rarity or because of some factor(s) making it very vulnerable to extirpation from New Mexico) (New Mexico Rare Plant Technical Council 2005). It is also a US Fish and Wildlife Service species of concern (New Mexico Rare Plant Technical Council 2005).

Endemic and Vulnerable Plant Associations

El Malpais has a large number of endemic plant associations, with five plant associations only known from the monument, 14 Park Special associations and an additional six associations that are regionally endemic. This high degree of endemism likely is a result of not only the unique habitat available on the lava flows and cinder cones, but also the fact that El Malpais is situated along the southern edges of the Colorado Plateau and Rocky Mountains, and has the Basin and Range and Mogollon Rim to the south and east, each providing their own floristic components.

The five plant associations that have been found only in El Malpais NM have not been assigned a Global Conservation Assessment Ranking (Muldavin et al. 2013). They are only known to grow on volcanic substrates. Four of these associations make up primary components (>50%) of vegetation map units, but *Populus tremuloides* / Mixed Shrubs / Cinder Woodland is only found as related inclusions (<10%) of two map units (1A, Douglas-fir/Gooseberry Cinder Forest and 3A, Ponderosa Pine Cinder Forest Savanna) where it occurs only on steep sideslopes of and the bottom of Bandera Crater (Muldavin et al. 2013).

One of the six regionally endemic plant associations, *Pinus edulis* / *Achnatherum Scribneri* Woodland, has a vulnerable (G3) Global Conservation Assessment Ranking (Muldavin et al. 2013). Four regionally endemic associations are unranked (GNR). These regionally endemic plant associations make up primary and/or secondary components of map units, except for *Juniperus monosperma* / *Muhlenbergia pauciflora* Woodland, which only occurs as related inclusion on sedimentary substrates (Muldavin et al. 2013).

The Park Special plant associations have mostly GNR Global Conservation Assessment Rankings. Ten of these associations grow only on volcanic substrates, including four that are restricted to young volcanic units. One Park Special, *Pinus edulis - Juniperus deppeana - Quercus grisea* Woodland, only occurs as a related inclusion on sedimentary substrates.

Seven plant associations are vulnerable, with either G2G4, G3, G3? G3G4, G4, or G4Q Global Conservation Assessment Rankings. Two of these associations, *Pinus ponderosa* / *Schizachyrium scoparium* Woodland and *Sarcobatus vermiculatus* / *Sporobolus airoides*

Shrubland, only occur as related inclusions (Muldavin et al. 2013).

Vegetation Communities Growing on Kipukas

Most of the plant associations and vegetation map units found in El Malpais NM also occur on kipukas. Only two plant associations and one map unit were restricted to kipukas. Therefore, with these exceptions, the vegetation on kipukas is similar the vegetation in the rest of the national monument and is likely in similar condition.

The small subset of kipukas (mostly with sedimentary substrates) that were studied (Bleakly 1996 and Lewis 2003) included kipukas both without the anthropogenic impacts of logging and/or grazing and those that had been logged and/or grazed. Additionally, relatively inaccessible areas of the lava flows, such as between Mesita Blanca (grazed) and Hidden kipuka (ungrazed), were identified as being undisturbed (Lewis 2003). Therefore, a correlation between kipukas and lack of anthropogenic disturbance(s) may not exist, as has previously been postulated (Grissino-Mayer 1995, Lewis 2003, and NPS 2014).

Plant associations and vegetation map units that only are found on sedimentary rocks, including kipukas, are rare in the monument because sedimentary rocks are rare. However, there are other plant associations that are restricted to other types of substrates, including ones only found on cinder cones or on the young lava flows of the El Malpais phase of volcanism. For example, *Pinus edulis* - (*Juniperus spp.*) / Cinder Woodland, and *Pseudotsuga menziesii* / *Ribes (leptanthum, cereum)* Woodland are Park Specials that are only present on cinder cones (Muldavin et al. 2013). Other associations, such as the Park Special *Juniperus monosperma* / *Fraxinus cuspidata* Woodland, only grow on lava flow surfaces. Vegetation growing on kipukas, with different plant associations on ones with volcanic, sedimentary and eolian substrates, is but one part of the monument's distinctive biogeography, which includes endemic plant associations (including Park Specials), cinders phacelia, the ancient trees in stunted forests on the McCartys and Bandera flows, and plant associations that only grow on cinder cones or the young lava flows.

The biogeography on the monument's vegetation is not island biogeography, (e.g., resulting from isolation). Vastly different geologic substrates with differing levels of soil development are in close proximity to one another, precluding geographic isolation. Further, the McCartys lava flow, which is El Malpais' youngest, is approximately 3,900 years old, which is too old for its eruption to have impacted the modern vegetation of the monument.



Overall Condition

The overall condition of the distinct vegetation communities in El Malpais NM is unknown. However, the condition of aspects of the monument's distinct vegetation that are part of the broad ecological categories (i.e., pinyon-juniper and ponderosa pine assessed in Sections 4.8 and 4.9, respectively), are likely to be the same as that for the broader ecosystem (e.g., good).

4.11.5. Sources of Expertise

Allyson Mathis, a science writer for Utah State University, authored this section. Grant Harley, Assistant Professor in the Department of Geography and Geology at the University of Southern Mississippi, provided information about and photographs of the ancient trees. Dr. Henri Grissino-Mayer, Professor and Associate Department Head at The University of Tennessee, Knoxville reviewed the assessment and provided two additional literature sources concerning the malpais (Rother 2010 and Pilote 2012), which are included in the final DVD sent to the park.

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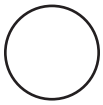
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4.12. Exotic Plants

Indicators/Measures

- Potential to Alter Native Plant Communities (1 measure)
- Prevalence of Exotic Plants (1 measure)

Condition – Trend - Confidence



Unknown – Unknown - Medium

4.12.1. Background and Importance

Globalization of commerce, transportation, human migration, and recreation in recent history has introduced invasive exotic species to new areas at an unprecedented rate. Biogeographical barriers that once restricted the location and expansion of species have been circumvented, culminating in the homogenization of Earth's biota. Approximately 4-19% of species introduced into the United States may become invasive (USFWS 2012).

Invasive species have been directly linked to displacing several native species of plants (Pimentel et al. 1999). Approximately 42% of threatened and endangered species are at risk primarily because of alien-invasive species (Pimentel et al. 2005). Exotic plants cause changes in ecosystem structure, alteration of nutrient cycles and soil chemistry, alteration of normal successional trajectory of a system (Ehrenfeld 2003, Emery 2012), negative impacts to agriculture (Pimentel 2009), and limitations on water availability (USFWS 2012) (Figure 4.12.1-1).

The spread of invasive species is one of the most environmentally serious global changes, causing economic and environmental damage in the United States and worldwide (UCSUSA 2008). Consequently, the dynamic relationships among plants, animals, soil, and water established over many thousands of years are at risk of being destroyed in a relatively brief period. For the National Park Service (NPS), the consequences of these invasions present a significant challenge to the management of the agency's natural resources "unimpaired for the enjoyment of future generations." National parks, like land managed by other organizations, are deluged by new exotic species arriving through



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Figure 4.12.1-1. *Verbascum thapsus* (common mullein) is a species of special concern at El Malpais NM because it grows well on young basaltic lava flows and cinder deposits.

predictable (e.g., road, trail, and riparian corridors), sudden (e.g., long-distance dispersal through cargo containers and air freight), and unexpected anthropogenic pathways (e.g., weed seeds in restoration planting mixes). Nonnative plants claim an estimated 4,600 acres per day on federal lands alone in the western United States, quadrupling their range from 1985-1995, claiming approximately 17 million acres (BLM 2011) and significantly altering local flora. For example, in Great Smoky Mountains National Park, over ¼ of the plants (27%) are non-native species. On the big island of Hawaii 35% of the plants are non-native (Pimentel et al. 2005). Invasive plants are dominant on approximately 5% of the lands managed by the NPS (NPS 2009).

4.12.2. Data and Methods

In assessing current condition and trend for exotic plants at El Malpais National Monument, we used two indicators. The first indicator, which has one measure, evaluates the overall impact an exotic plant has on the native plant communities throughout the monument. This indicator utilizes known natural history characteristics of exotic plant species in order to characterize their impact on natural ecosystems.

The second indicator, also with one measure, assesses the prevalence of the exotic plant species in the monument.

Information on exotic plant species that have been documented at El Malpais includes species lists in Excel spreadsheets or PDF documents, El Malpais NM (ELMA) (2009), Southern Colorado Plateau Network (SCPN) (2014), and NPSpecies (NPS) (2015), and published reports, Lightfoot et al. (1994), Bleakly (1997) and Muldavin et al. (2013).

Table 4.12.2-1 lists the 38 species of exotic plants that have been documented in El Malpais NM. Three species (*Eschscholzia californica ssp. mexicana*, *Lepidium densiflorum* and *Oxalis corniculata*) that have been reported in El Malpais NM as exotic species are excluded from this table as their nativity is unclear (USDA-NRCS 2015a).

Indicator/Measure

Potential to Alter Native Plant Communities (Significance of Exotic Plant Impact)

The first indicator and measure, potential to alter native plant communities (significance of exotic plant impact), was derived from the Handbook for Ranking Exotic Plants for Management and Control (Hiebert and Stubbendieck 1993). The handbook's analytical approach provides NPS managers with scientific information that encompasses the full array of significant factors that measure the ecological impact of an exotic species.

For the purposes of this assessment, Hiebert and Stubbendieck's significance of exotic plant impact was modified to capture only its innate ability to become a pest. The innate ability for a species to become a pest section quantifies the characteristics, such as ability to reproduce vegetatively, the number of seeds per plant, germination requirements, and the plant's competitive ability, that preadapt it to become a problem.

The numerical ranking for this measure ranged between 0 - 50 possible points, with 50 representing the highest possibility of impacting and altering the native plant communities and zero being the lowest. We assigned the numerical rankings to the following categories:

- 40 - 50 = Highest Concern
- 35 - 39 = High Concern
- 30 - 34 = Medium Concern
- 0 - 29 = Low Concern

The significance of exotic plant impact rankings for each exotic species documented in El Malpais is reported in Table 4.12.2-2. Six species were ranked as having the highest concern, with five additional species having high concern. Six species, *Acroptilon repens (*Russian knapweed), *Carduus nutans (*nodding musk thistle), *Cirsium vulgare* (bull thistle), *Convolvulus arvensis* (field bindweed), *Tamarix chinensis* (Chinese tamarisk) and *Ulmus pumila* (Siberian elm)

Table 4.12.2-1. Exotic plant species documented in El Malpais NM.

Species	Common Name	Lightfoot et al. 1994	Bleakly 1997	ELMA 2009	SCPN 2014	NPSpecies 2015
Acroptilon repens	Russian knapweed	X	X	X	X	X
Amaranthus albus	pigweed	X	X		X	X
Amaranthus blitoides	prostrate pigweed	X	X	X	X	X
Amaranthus retroflexus[1]	redroot pigweed	X	X	X		False Report
Bromus tectorum	cheatgrass	X	X	X	X	X
Carduus nutans	nodding musk thistle			X	X	X
Cichorium intybus	chicory				X	X
Cirsium vulgare	bull thistle	X	X	X	X	X
Convolvulus arvensis[5]	field bindweed	X	X	X	X	X
Eragrostis cilianensis	stinkgrass				X	X
Eragrostis curvula	weeping lovegrass	X	X	X	X	X
Eragrostis lehmanniana	Lehmann lovegrass	X	X	X		False Report
Erodium cicutarium	redstem filaree	X	X	X	X	X
Kochia scoparia	kochia		X	X	X	X
Lactuca serriola	prickly lettuce	X	X	X	X	X
Marrubium vulgare	horehound	X	X	X	X	X
Medicago lupulina	black medic clover	X	X	X	X	X
Melilotus spp.	yellow sweetclover	X	X	X	X	X
Mollugo cerviana	carpetweed				X	
Panicum miliaceum	Broomcorn millet			X		
Poa compressa	Canada bluegrass				X	
Poa pratensis	Kentucky bluegrass				X	X
Polygonum aviculare	common knotgrass				X	
Portulaca oleracea	common purslane		X			X
Rumex crispus	curly dock	X	X	X	X	X
Salsola spp.	prickly Russian thistle	X	X	X	X	X
Setaria viridis	green foxtail	X	X	X	X	X
Sisymbrium altissimum	tumbleweed mustard	X	X	X	X	X
Solanum elaeagnifolium	silverleaf nightshade				X	
Sonchus asper	spiny sowthistle	X	X	X	X	X
Tamarix chinensis	Chinese tamarisk		X	X	X	X
Taraxacum officinale	dandelion		X	X	X	X
Tragopogon dubius	common salsify	X	X	X	X	X
Tragopogon pratensis	meadow salsify	X	X	X	X	X
Tragus berteronianus	burr grass				X	
Tribulus terrestris	puncturevine	X		X	X	
Ulmus pumila	Siberian elm	X	X	X	X	X
Verbascum thapsus	common mullein	X	X	X	X	X

Eschscholzia californica ssp. mexicana, Lepidium densiflorum and *Oxalis corniculata* have been reported at El Malpais, but are excluded from this list as their nativity is unclear.

Table 4.12.2-2. Significance of exotic plant impact ranking for species recorded at El Malpais (Lightfoot et al. 1994, Bleakly 1997, ELMA 2009, SCPN 2014, and NPS 2015) using a subset of Hiebert and Stubbendieck's (1993) Handbook for Ranking Exotic Plants for Management and Control.

Species	Common Name	Noxious	Ranking
Acroptilon repens[1]	Russian knapweed	X	Highest
Bromus tectorum[1]	cheatgrass		Highest
Convolvulus arvensis[1]	field bindweed	X	Highest
Eragrostis curvula[1]	weeping lovegrass		Highest
Poa pratensis[1]	Kentucky bluegrass		Highest
Tamarix chinensis[1]	Chinese tamarisk	X	Highest
Carduus nutans[2]	nodding musk thistle	X	High
Eragrostis lehmanniana[2]	Lehmann lovegrass		High
Portulaca oleracea[2]	common purslane		High
Solanum elaeagnifolium[2]	silverleaf nightshade		High
Sonchus asper[2]	spiny sowthistle		High
Cirsium vulgare	bull thistle	X	Medium
Erodium cicutarium	redstem filaree		Medium
Kochia scoparia	kochia		Medium
Lactuca serriola	prickly lettuce		Medium
Marrubium vulgare	horehound		Medium
Medicago lupulina	black medic clover		Medium
Panicum miliaceum	Broomcorn millet		Medium
Rumex crispus	curly dock		Medium
Salsola spp.	prickly Russian thistle		Medium
Setaria viridis	green foxtail		Medium
Sisymbrium altissimum	tumbleweed mustard		Medium
Taraxacum officinale	dandelion		Medium
Tribulus terrestris	puncturevine		Medium
Amaranthus albus	pigweed		Low
Amaranthus blitoides	prostrate pigweed		Low
Amaranthus retroflexus	redroot pigweed		Low
Cichorium intybus	chicory		Low
Eragrostis cilianensis	stinkgrass		Low
Melilotus officinalis (spp.)	yellow sweetclover		Low
Mollugo cerviana	carpetweed		Low
Poa compressa	Canada bluegrass		Low
Polygonum aviculare	common knotgrass		Low
Tragopogon dubius	common salsify		Low
Tragopogon pratensis	meadow salsify		Low
Tragus berteronianus	burr grass		Low
Ulmus pumila	Siberian elm	X	Low
Verbascum thapsus[3]	common mullein		Low

[1] Species considered to be of highest concern using the significance of exotic plant impact, innate ability to become a pest measure (Hiebert and Stubbendieck 1993) are highlighted in the darker tone.

[2] Species considered to be of high concern using the significance of exotic plant impact, innate ability to become a pest measure (Hiebert and Stubbendieck 1993) are highlighted in the darker tone.

[3] Species of special concern is highlighted in the brown tone.

Eschscholzia californica ssp. mexicana, Lepidium densiflorum and *Oxalis corniculata* have been reported at El Malpais, but are excluded from this list as their nativity is unclear.

are New Mexico state noxious plants (USDA-NRCS 2015b).

Indicators/Measures

Prevalence of Exotic Plants (Number of Observations in Vegetation Mapping Plots)

The prevalence of exotic plants has one measure: the number of observations recorded in vegetation mapping plots (Muldavin et al. 2013) (Table 4.12.2-3).

Muldavin et al. (2013) reported the cumulative number of all observations for vascular plants encountered in vegetation mapping and classification plots in the report's Appendix B. Mapping plots each were visited once between 2006 and 2009. Plots were usually 400 m^2 (4305 ft^2), although size and shape were modified as needed to fit the structure of a community. In standard plots, a list of all vascular plant species, stratified by life form and height, and with a cover estimate was recorded. In quick plots, only the cover of dominant species in each strata was recorded. Muldavin et al. (2013) recorded a total of 476 plots, including 253 standard plots.

Because of the rough terrain of El Malpais, especially the surface of the young lava flows, the location of plots were generally constrained to the outer portions of flows, along trails, and/or within two miles from a road (Muldavin et al. 2013) (Figure 4.12.2-1).

Table 4.12.2-3. Prevalence of exotic plant species detected in vegetation mapping 2006-2009 (Muldavin et al. 2013).

Species	No. of Observations in Mapping Plots
Portulaca oleracea[2]	127
Salsola spp.	126
Kochia scoparia	58
Verbascum thapsus[3]	56
Bromus tectorum[1]	27
Amaranthus spp.[4]	22
Cirsium spp.[4]	5
Erodium cicutarium	4
Marrubium vulgare	4
Convolvulus arvensis[1]	3
Mollugo cerviana	3
Melilotus spp.	2
Taraxacum officinale	2
Eragrostis cilianensis	1
Lactuca serriola	1
Poa pratensis[1]	1
Rumex spp.[4]	1
Setaria viridis	1
Tamarix chinensis[1]	1
Tragopogon dubius	1
Tragopogon pratensis	1
Poa compressa	1
Tragus berteronianus	1
Solanum elaeagnifolium[2]	1

[1] Species considered to be of highest concern in (Table 4.12.2-2) are highlighted in the darker tone.

[2] Species of high concern (Table 4.12.2-1) is highlighted in the lighter tone.

[3] Species of special concern is highlighted in the brown tone.

[4] *Amaranthus, Cirsium, and Rumex* were only identified at the genus level in Muldavin et al. (2013) and their observations may have included exotic and native species.

4.12.3. Reference Conditions

Whenever an exotic plant is present that has the biological characteristics to alter native plant communities, there is cause for concern. However, early detection of these species provides managers with the necessary information to apply a rapid response management strategy before the exotic plant becomes established. If a rapid response is not implemented, the exotic plant may become established and potentially degrade the integrity of the native plant communities.

Our good, moderate, and significant concern reference conditions are based upon both an exotic plant's ability to alter native plant communities as well as its prevalence. A summary of the reference conditions is shown in Table 4.12.3-1.

A good reference condition is the capability for primary communities to be maintained. By this, we mean that ecological attributes (e.g., species composition, structure, etc.) and natural processes remain within the natural variation for the community type.

A moderate condition is assigned to exotic plant species that have been ranked as high or highest concern but prevalence remains low,

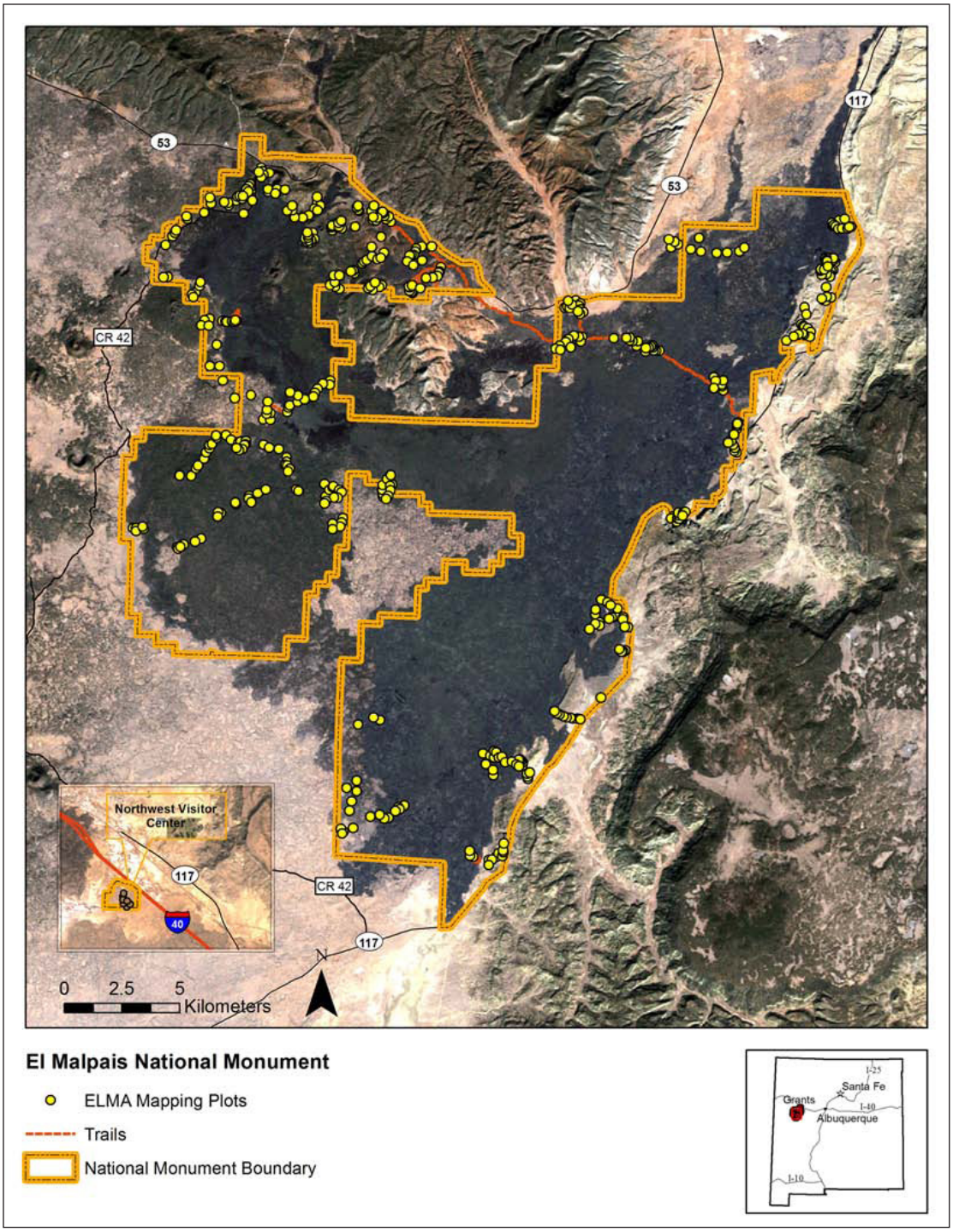


Figure 4.12.2-1. Location of vegetation mapping and classification plots used by Muldavin et al. (2013).

or when a plant has been assigned a medium impact ranking score and is found in medium prevalence.

A condition of significant concern is assigned when an exotic plant is ranked as high or highest for its ability to alter native plant communities and occurring at medium to high prevalence levels. A species with a moderate impact ranking and high prevalence is also of significant condition.

Further consideration of condition is warranted on a case by case basis, especially for species with low prevalence, or when a species' prevalence may be increasing. Given the early detection and rapid response model for the control of exotic plants, species with low prevalence may be considered to be

Table 4.12.3-1. Descriptions for determining condition based on exotic plant potential to alter native plant communities impact ranking and degree of prevalence.

Prevalence of Exotic Plant	Potential to Alter Native Plant Communities Impact Ranking			
	Low	Medium	High	Highest
Low	Good Condition*	Good Condition*	Moderate Condition	Moderate Condition
Medium	Variable*	Moderate Condition	Significant Concern	Significant Concern
High	Variable*	Significant Concern	Significant Concern	Significant Concern

* Species in these cells may warrant further consideration of condition on a case by case basis.

in moderate condition even though they may have low or medium impact rankings. Further, species that scored low in the Hiebert and Stubbendieck's (1993) innate ability to become a pest ranking system may considered to be of moderate condition depending on the individual characteristics of a species, and the unique attributes of the NPS site, regardless of prevalence.

4.12.4. Condition and Trend

Thirty-eight exotic plant species have been documented within El Malpais according to published species lists (Lightfoot et al. 1994 and Bleakly 1997), and in NPS-managed databases or spreadsheets (ELMA 2009, SCPN 2014, and NPS 2015). These species were assessed for their potential to alter native plant communities and their prevalence.

Exotic plants at El Malpais NM have significant potential to alter native plant communities. Six exotic species were ranked as having the highest exotic plant impact, and five species have a high exotic plant impact. Thirteen species have a medium ranking and 14 species were ranked low for exotic plant impact. One species is of special concern.

Information about the prevalence of exotic plants at El Malpais NM is extremely limited. Muldavin et al. (2013) reported observations of exotic plant species in vegetation mapping and classification plots. In field work that took place in 2006-2009, 24 exotic species were observed in plots at least once.

Potential to Alter Native Plant Communities

While the presence of any exotic plant species can alter primary ecological communities, plants with highest or high significance of exotic plant impact have inherent characteristics that preadapt them to become invasive (Hiebert and Stubbendieck 1993). Species of special concern have characteristics that make their impacts in the type of ecosystems found in El Malpais especially significant.

Six species recorded as occurring in El Malpais NM are considered to be the highest concern based upon their significance of exotic plant impact (Table 4.12.4-1). Five additional species are of high concern for exotic plant impact, and one additional species (*Verbascum thapsus*) is of special concern. Because twelve of the 38 exotic plant species that have been found in El Malpais NM are either of highest or high concern for exotic plant impact or are species of special concern, we find that this indicator is in the condition of significant concern.

Species of Highest Concern

Acroptilon repens is a New Mexico noxious plant. Ranked as highest for its exotic plant impact, Russian knapweed has the potential to form dense monocultures from widely spreading root systems (USDA Forest Service 2001). The plant also releases allelopathic compounds.

Exotic bromes such as *Bromus tectorum* (cheatgrass) are well known to dramatically

Table 4.12.4-1. Significance of exotic plant impact for species documented in El Malpais NM.

Scientific Name	Common Name	Rationale for Rating[1]
Highest Exotic Plant Impact		
Acroptilon repens	Russian knapweed	Russian knapweed reproduces vegetatively has the potential to form dense monocultures via its root system. The species is listed as a noxious species in New Mexico.
Bromus tectorum	cheatgrass	Cheatgrass is a highly invasive plant that can have a significant adverse impacts on natural ecosystems, especially grasslands. It is also extremely competitive during period of drought.
Convolvulus arvensis	field bindweed	*Convolvulus arvensis* reproduces predominantly vegetatively, and is very difficult to control once established. Field bindweed is listed as a noxious species in New Mexico.
Eragrostis curvula	weeping lovegrass	Weeping lovegrass is many seeded, and can outcompete native species and have significant impact on natural ecosystems.
Poa pratensis	Kentucky bluegrass	Kentucky bluegrass produces a great deal of seed, has a high potential to alter native plant communities, and is extremely difficult to control.
Tamarix chinensis	Chinese tamarisk	A riparian species that utilizes a great deal of water and outcompetes native plants and reduces biodiversity, Chinese tamarisk is listed as a noxious species in New Mexico.
High Exotic Plant Impact		
Carduus nutans	nodding musk thistle	Nodding musk thistle is listed as a noxious species in New Mexico. The species produces abundant seed and outcompetes native species.
Cirsium vulgare	bull thistle	*Cirsium vulgare* also is a many-seeded thistle that is listed as a noxious species in New Mexico.
Eragrostis lehmanniana	Lehmann lovegrass	Lehmann lovegrass produces abundant seed and can have a significant impact in natural ecosystems. It was identified in Lightfoot et al. (1994), Bleakly (1997) and ELMA (2009), but identified as a false report in NPSpecies (2015).
Portulaca oleracea	common purslane	Common purslane can produce a thick mat that is difficult to control.
Sonchus asper	spiny sowthistle	Spiny sow thistle may form dense monocultures. The species produces abundant seeds that may be dispersed great distances.
Species of Special Concern		
Verbascum thapsus	common mullein	Mullein grows well in disturbed areas and undisturbed areas such as on cinder cones and lava flows where other vegetation is sparse. This biennial species produces a great deal of seed that remains viable in the soil for an extremely long tine. Since mullein is known to be invasive in other areas with young basaltic lava flows and cinder deposits, it was considered a species of special concern at El Malpais NM.

change the character of an ecosystem, including such changes as major shifts in community composition and structure (Knapp 1996) as well as substantial alteration of fire regimes (Whisenant 1990). In many cases these changes have become, for all practical purposes, irreversible (Knapp 1996). From a standpoint of significance of impact to a park's native grassland community, *Bromus tectorum* is one of the highest exotic plant concerns (Folts-Zettner SOPN biologist, personal communication, 2014). It adds biomass to the ecosystem, outcompetes other cool season grasses and is especially competitive during times of drought.

While *Convolvulus arvensis* produces seed, it reproduces predominantly by its persistent root system. Once field bindweed gets established, it is very difficult to control and is highly competitive with native species (USDA Forest Service 2004).

Eragrostis curvula (weeping lovegrass) is native to southern Africa and was planted in the United States for erosion control and livestock forage. Weeping lovegrass is a tall bunch grass that produces abundant seed, can germinate in a variety of conditions, is highly competitive, and has significant impact to natural ecosystems (USDA Forest Service 2009).

Poa pratensis (Kentucky bluegrass) produces abundant seed and is generally highly competitive, but is intolerant to drought (USDA Forest Service 1993). The species is extremely difficult to control and has an extremely high potential to alter native plant communities.

Tamarix chinenses, which is on the New Mexico list of noxious plants, is highly competitive in riparian habitats, outcompetes native species and reduces natural biodiversity.

Species of High Concern
Carduus nutans (nodding musk thistle) has a high potential to alter native plant communities at El Malpais. This exotic thistle, which is also a New Mexico noxious species, produces abundant seed, can outcompete native species, and is difficult to control (USDA Forest Service 2002a).

Also listed as a New Mexico noxious species, *Cirsium vulgare* is a biennial thistle reproduces exclusively by seed, which it produces abundantly (USDA Forest Service 2002b). Bull thistle grows extremely well in disturbed sites.

Eragrostis lehmanniana (Lehmann lovegrass) was listed as a false report for El Malpais NM in NPSpecies (NPS 2015), although it was reported for the monument in Lightfoot et al. (1994), Bleakly (1997) and ELMA (2009). Lehmann lovegrass is a warm-season grass that produces abundant seed (USDA Forest Service 1992).

Portulaca oleracea (common purslane) reproduces entirely by seed and can form a thick monocultural mat that is difficult to control (University of California Agriculture and Natural Resources 2007).

Sonchus asper (spiny sow thistle) may form a dense monoculture and its seeds may be spread long distances by animals and by wind (Arizona Wildland Invasive Plant Working Group 2005). While it usually is found in disturbed sites, it has been found in areas such as dry washes that have had no human disturbances.

Species of Special Concern
Verbascum thapsus (common mullein) is designated as a species of special concern at El Malpais. While only ranked low for its exotic plant impact using the Hiebert and Stubbendieck (1993) system, the species has an innate ability to become a pest in open landscapes, especially those with substrates of young basaltic lava flows and cinder deposits. The species is at least locally common at other NPS sites in the continental United States with similar volcanic resources, including Capulin Volcano National Monument, Sunset Crater Volcano National Monument, Craters of the Moon National Monument, Lava Beds National Monument and Lassen Volcanic National Park. In Hawaii, mullein is on the state noxious weeds list, and is under active management at Hawaii Volcanoes National Park where there are extensive infestations (Benitez et al. 2012).

Mullein is a biennial plant that grows up to 2 m (7 ft) in height. Each plant can produce more than 100,000 seeds that remain viable for multiple years (USDA Forest Service 2008). Generally understood to only occupy disturbed lands, mullein also grows in undisturbed open areas such as meadows on the eastern side of the Sierra Nevada Mountains in California (California Invasive Plant Council 2015) and in Hawaii, especially on areas of weathered lava flows with sparse vegetation and pockets of soil (Benitez et al. 2012). Mullein appears to be highly competitive in these environments and is not replaced by successional species (California Invasive Plant Council 2015).

Verbascum thapsus is native in Eurasia where it is found mostly on dry stony hillsides and woodlands (Starr et al. 2003). Cinder deposits appear to provide similar habitat, and mullein is common on cinder cones in Hawaii (Pacific Island Ecosystem at Risk 2011), and at Capulin Volcano NM (Bennetts et al. 2012). At Capulin Volcano, active management of mullein has decreased population density (Folts-Zettner and Sosinski 2012).

Prevalence
Information on the prevalence of exotic species in El Malpais NM is very limited. Observations of exotic plants in vegetation mapping and classification plots were reported by Muldavin et al. (2013); however, this information is not current as field work for mapping was conducted in 2006-2009. Further, these study plots were designed for vegetation mapping and classification and not explicitly for the detection of exotic plant

species. While many of the plots were located near roads and trails because of the difficulty of access because of El Malpais' rough volcanic terrain, they were not inherently designed to monitor along a vector as in Folts-Zettner et al. (2013). Additionally, these plots also did not capture the condition of the interior of the monument, especially in the central parts of the young lava flows where the very rough terrain most likely has limited direct human disturbances.

Muldavin et al. (2013) observed 24 of the 38 species documented at El Malpais at least once in vegetation classification plots. *Portulaca oleracea* was the exotic species observed the most in mapping plots, followed by *Salsola spp.*, *Kochia scoparia* and *Verbascum thapsus*. Eleven exotic plant species were observed only one time. *Tamarix chinenses* was reported from the *Sporobolus airoides* Monotype Herbaceous Vegetation association, which is only known at the Northwest New Mexico Visitor Center, for monument lands (Muldavin et al. 2013).



Exotic Plants

Indicators	Measure
Potential to Alter Native Plant Communities	1 Measure
Prevalence of Exotic Plants	1 Measures



Overall Condition and Trend

In assessing the condition of exotic plants in the national monument, we used two indicators that were intended to be different ways of capturing the essence of what we thought represented an exotic plant's potential for concern.

Several factors contribute to an exotic plant's ability to threaten the integrity of a native ecosystem including its inherent ability to alter native plant communities and its prevalence. Thus, our measures for this resource were intended to capture different aspects of these contributing factors. A summary of how they contributed to the overall exotic plants condition assessment is in Table 4.12.4-2.

The potential for exotic species present in the NRA to alter native plant communities is of significant concern because eleven species, 29% of the exotic species documented in the monument, were ranked as highest or high for their significance of exotic plant impact based on their innate ability to become a pest.

Exotic plants have an unknown extent within the monument. The overall trend for the condition of exotic plants at El Malpais was also unknown.

After analyzing all the available information about exotic plant species at El Malpais NM, we consider the overall condition for exotic plants to be in an unknown condition with an unknown trend.

Level of Confidence/Key Uncertainties

Overall, we have a medium level of confidence in this assessment, although the prevalence and trend of exotic plants at El Malpais is not known due to lack of available data.

Application of the Hiebert and Stubbendieck (1993) Handbook for Ranking Exotic Plants for Management and Control to determine exotic plant impact provides high confidence for the significance of exotic plant impact measure. However, an uncertainty for this measure is the general variability in how a given exotic plant species will respond to localized conditions. What may be considered a non-threatening plant in one region may become a nuisance in a different region.

4.12.5. Sources of Expertise

Allyson Mathis, a science writer for Utah State University, authored this section. Exotic species rankings using the Handbook for Ranking Exotic Plants for Management and Control (Hiebert and Stubbendieck 1993) were done by Allyson Mathis, Kim Struthers, researcher/science writer, Utah State University, Tomye Folts-Zettner, biologist/botanist, Southern Plains Network and Lori Makarick, Vegetation Program Manager, Grand Canyon National Park.

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Table 4.12.4-2. Indicators, measures, and their contributions to the overall exotic plants condition rationale.

Indicator	Measure	Condition	Rationale for Condition.
Potential to Alter Native Plant Communities	Significance of Exotic Plant Impact	Significant Concern	This measure is based on the premise that species with the highest innate ability to become a pest generally cause the most severe problems in natural ecosystems. Six of the 38 species of exotic plants documented in El Malpais were ranked as having the highest innate ability to become a pest, and 5 species were ranked as high. There was one species of special concern. Therefore, we consider this measure to be of significant concern.
Prevalence of Exotic Plants	Number of observations in vegetation mapping plots	Unknown	The prevalence of exotic plants at El Malpais is unknown. The reporting of exotic plant observations in vegetation mapping and classification plots in 2006-2009 provides limited information on the occurrence of exotic plants. However, specific information about exotic plants in the interior of the monument and along vectors is unknown.

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4.13. Cave Ecology and Species

Indicator/Measure

- Cave-dependent Species (2 measures)

Condition – Trend – Confidence



Unknown- Unknown - Unknown

4.13.1. Background and Importance

Cave ecosystems and dependent species are important parts of the distinct biogeography at El Malpais NM. El Malpais is one of more than 125 NPS units that contain cave or karst resources. Caves in NPS units such as Carlsbad Caverns, Mammoth Cave, Great Basin, Lava Beds and Chickamauga and Chattanooga are known to have important cave ecosystems and species where all or some aspects of the cave's biota and ecology are being monitored (Baker et al. 2015).

A cave ecosystem is defined by the NPS Cave Ecology Inventory and Monitoring Framework "as the community of living organisms in conjunction with the nonliving components of their environment that include both organisms that live entirely in the cave (e.g., cave obligate invertebrates) as well as those that may only come in contact with the cave periodically (e.g., bats) or in a small way (e.g., tree roots)" (Baker et al. 2015). Caves provide habitat for many species that are wholly or partially dependent on them, and provide unique environments for some plants and animals at cave entrances (Baker et al. 2015). Caves, especially the shallow lava tubes at El Malpais that may have multiple entrances, have great connectivity with the surrounding landscape, with some species being cave-obligate (troglobites), and other species using caves for all of their life cycle (troglophiles), or using caves for shelters but foraging on the surface (trogloxenes) (Baker et al. 2015). Additionally, species that use cave entrances and twilight zones (eisodophiles and eisodoxenes) or hunt deep within caves or in cave entrances but live on the surface (xenosylles) are important parts of both cave and surface ecosystems. Species that are found in caves but cannot survive in the cave environment are known as accidentals.



NPS

4.13.1-1. Cave entrance flora includes moss gardens at cave entrances and under skylights. These areas contain distinct vegetation assemblages and also are extremely important for invertebrates (Wynne 2013).

The ecology of lava tube caves is substantially different than karst caves for a variety of reasons, including the shallow nature of most lava tubes with great nutrient input from the surface, more interaction between surface and subsurface species and the presence of root systems in some caves (Baker et al. 2015).

Species found in El Malpais caves, including at cave entrances and skylights, include microbes, invertebrates, vertebrates and plants (Northup and Welbourn 1997, and Wynne 2013).

Vertebrates

Bats are the most common species of vertebrates present in El Malpais caves and will be assessed in Section 4.15. Only extremely limited information about the occurrence of other vertebrate species is available. Northup and Welbourn (1997) documented only one accidental vertebrate species.

Wynne (2013) searched for the presence of vertebrates via direct observation, and the presence of signs such as scat, feathers and skeletal remains. Small carnivore scat, either ringtail (*Bassariscus astutus*), skunk (*Conepatus sp.*) or raccoon (*Procyon lotor*), was observed in two caves. Signs of recent packrat (*Neotoma spp.*) activity was present in two caves, and the carcass of a gopher snake (*Pituophis catenifer*) was found in the twilight zone of one cave. And a barn owl (*Tyto alba*) was observed roosting near a cave entrance.

Bones of other vertebrates have also been observed in El Malpais lava tubes, but it is unknown whether these bones are fossiliferous or modern given the preservation capabilities of caves (Eric Weaver, personal communication, 2015). A ringtail skeleton observed Wynne (2013) may be between 1,000 and 10,000 years old.

Microbes

Microbial mats, some of which are informally known as "lava wall slime," are present in some El Malpais caves (Northup and Welbourn 1997, Snider 1999, Northup et al. 2004, Moya et al. 2009, Northup et al. 2011, Northrup 2011, and Northup and Lavoie 2015). The white, tan to gold microbial mats have been documented in five El Malpais caves (012, 147, 148, 261 and 315), including two caves with visible microbial communities associated with root curtains (148 and 261) (Northup 2011). While the park doesn't have an exact count on the number of caves, they have documented the presence of microbial colonies in many more caves than what has been systematically inventoried (E. Weaver, personal communication, 2016).

The microbial mats include bacterial and algal mats (Northup et al. 2004). Bacterial mats in Cave 012 did not have associated invertebrates, but invertebrates were found on algal mats (Northup et al. 2004).

Root curtains provide carbon and nitrogen in the cave environment and root zones contained a higher level of diversity at the phlyum level for microbial species than other parts of the caves (Snider 1999).

Microbial mats that have different colors have different species composition (Moya et al. 2009 and Northup 2001), and each cave has a distinct community of microorganisms (Northup 2011). Additionally, microbial mats in El Malpais contain novel species and possible novel high taxonomic units (Northup et al. 2011).

A comparison of microbial mats in Cave 012, which was open to recreational caving until 2010 and four caves (147, 148, 261 and 315) that have never been open to recreational use suggested that human use does not impact the microbial mats (Northup 2011).

4.13.2. Data and Methods

Limited inventory information related to cave ecology and species is available. Currently, no systematic program to monitor cave ecology and species at El Malpais NM is in place, but NPS staff will be implementing a cave management program (Eric Weaver, personal communication, 2015).

A study of six lava tube caves between 1993 and 1995 provided baseline information on cave fauna (Table 4.13.2-1) (Northup and Welbourn 1997).

In 2007 and 2008, research teams visited 10 El Malpais caves to inventory arthropods and look for vertebrate signs (Table 4.13.2-1) (Wynne 2013).

Additional information about cave ecology and species, including cave entrance floras, is available in Lindsey (1951), Lightfoot et al. (1994), and Bleakly (1997).

Indicator
Cave-Dependent Species (2 Measures)

We used one indicator, cave-dependent species, with two measures (invertebrates and cave entrance floras), for assessing current condition of the park's cave ecology and species.

Measure
Invertebrates

Visual inspections, pitfall trapping and extraction from substrates were used to conduct baseline inventory invertebrates in six El Malpais caves (Northup and Welbourn 1997). Sixty-one invertebrate species were found, including 5 troglobites, 10 troglophiles, 2 trogloxenes, 2 guanophiles and 41 accidentals (Table 4.13.2-1) (Northup and Welbourn 1997).

Table 4.13.2-1. Arthropod morphospecies and other (non-bat) vertebrate observations by Wynne (2013).

Cave #	No. of arthropod species (Northup and Wellbourn 1997)	No. of arthropod morphospecies (Wynne 2013)	No. of other vertebrates (Wynne 2013)
008	35	15	—
012	33	16	—
029	24	—	—
054	13	2	1
061	26	1	2
062	8	13	1
110	n/a	4	—
262	n/a	11	1
303	n/a	15	—
315	n/a	22	—

Wynne (2003) used three techniques to inventory arthropods in 11 caves (including 10 in El Malpais NM and one on adjacent BLM land): opportunistic collecting, baited pitfall trapping, and timed searches. Fifty-nine arthropod morphospecies were identified (Table 4.13.2-1), including at least 13 orders and two classes (Wynne 2013). The classification of these morphospecies included one troglobite, two questionable troglobites, five troglophiles, 18 questionable troglophiles, 7 trogloxenes, one questionable

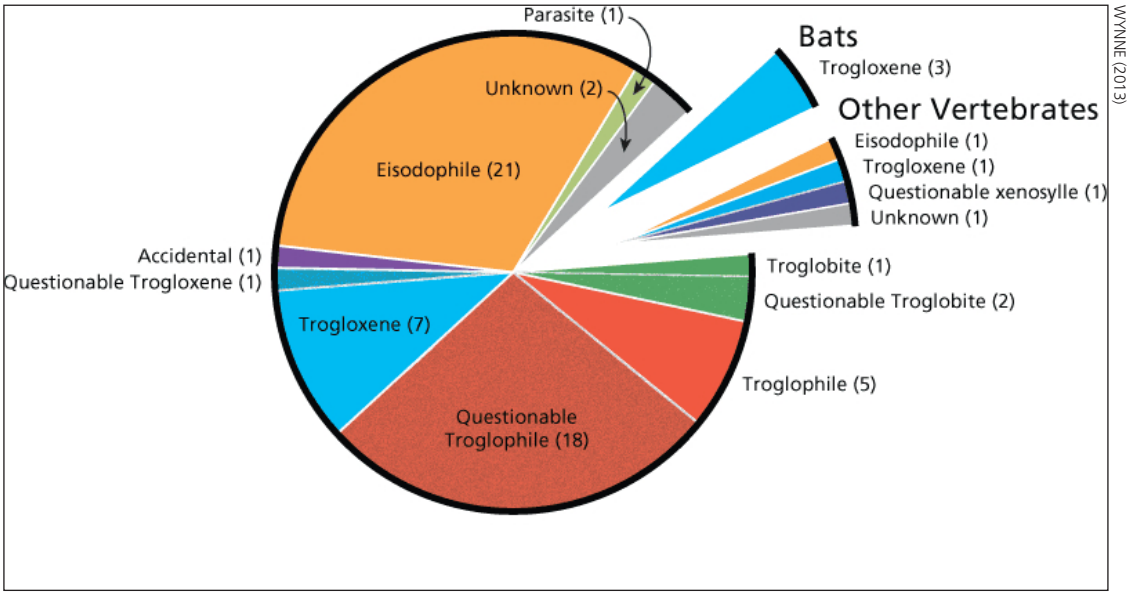


Figure 4.13.2-1. Functional groups for cave-dependent species found during inventory efforts in 10 El Malpais NM caves and one BLM cave in 2007-2008 (Wynne 2013).

Table 4.13.3-1. Reference conditions used to assess the current condition of cave ecology and species for each indicator.

Indicator	Measure	Good	Moderate Concern	Significant Concern
Cave-dependent Species	Invertebrates	Presence and persistence of native species	Some loss of species and threats to populations	Increasing loss of species and threats to populations
	Cave Entrance Floras	Presence and persistence of native species	Some loss of species and threats to populations	Increasing loss of species and threats to populations

trogloxene, 21 eisodophile, one parasite, one accidential and two unknown morphospecies (Figure 4.14.2-1) (Wynne 2013). Additionally, at least 7 new species were discovered, a new species documented by Northup and Welbourn (1997) was confirmed, and range expansions for two species of parasitic wasps were documented (Wynne 2013). Wynne (2013) was only able to resample one of the 5 troglobites documented by Northup and Welbourn (1997).

Two microhabitats were especially important to arthropods in El Malpais caves: root curtains exposed in the ceilings of some caves and cave entrance floras consisting of "moss gardens" (Northup and Welbourn 1997 and Wynne 2013). The microbial mats present on the floors and walls of some caves is another specialized habitat for cave arthropods (Northup and Welbourn 1997).

Measure
Cave Entrance Floras

Very limited information on cave entrance flora at El Malpais NM exists. These cool mesic environments have unique plant assemblages including ferns, mosses, lichens and mesic vascular plants (Muldavin et al. 2013). Cave entrance floras at El Malpais typically consist of "moss gardens" and cryptogams that occur in entrances and under skylights in a number of caves in the monument. Lindsey (1951) collected 28 species of moss from the El Malpais lava flows, mostly from the entrances of ice caves or from crevices in the lava flow surfaces, including an arctic-alpine moss *Homomallium incurvatum* that is not included in the species occurrences for North America in the Natural Resources Conservation Service Plants Database (USDA NRCS 2015). Lightfoot et al. (1994) documented 16 species of moss in the national monument. Lindsay (1951), Lightfoot et al. (1994) and Bleakly (1997) noted a distinct zonation in cryptogam species at ice cave entrances and identified them as one of the most unusual and important biological features of El Malpais.

Both Northup and Welbourn (1997) and (Wynne 2013) indicated that arthropod diversity is great in moss gardens at cave entrances and that cave entrance floras provide important and sensitive microhabitats for arthropods. Approximately 25% of the arthropods detected by Northup and Welbourn (1997) were from moss gardens.

The El Malpais Vegetation Classification and Map likely undersampled some microclimates such as those that occur at cave entrances (Muldavin et al. 2013).

As El Malpais staff map caves, they are documenting the presence/absence of moss gardens at cave entrances (Eric Weaver, personal communication, 2015). Caves with seasonal or perennial ice are more likely to have moss gardens at entrances and/or skylights. The moss gardens in Cave 012 have been roped off and monument staff are in the process of installing protective ropes around the moss gardens in Cave 008 (Eric Weaver, personal communication, 2015).

4.13.3. Reference Conditions

Reference conditions for cave-dependent species are in Table 4.13.3-1. The reference conditions for good condition for invertebrates and cave entrance flora are the presence and persistence of native species.

4.13.4. Condition and Trend

The condition of cave-dependent species in El Malpais is unknown. Inventories of arthropods have only occurred in 10 caves (Northup and Welbourn 1997 and Wynne

Table 4.13.4-1. Indicators, measures, and their contributions to the overall cave ecology and species condition rationale.

Indicator of Condition	Measure	Condition	Rationale for Condition.
Cave-dependent Species	Invertebrates	Unknown	The condition of invertebrates in El Malpais caves is unknown because limited inventory information for arthropods only exists for 10 El Malpais caves. Invertebrates in El Malpais caves are not being monitored.
	Cave Entrance Floras	Unknown	The condition of cave entrance flora in El Malpais caves is unknown. A full inventory of cave entrance flora has not been completed, and species composition of the flora is also unknown. Cave entrance flora in El Malpais caves are not being monitored.

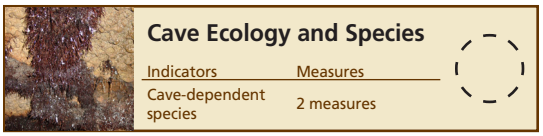
2013), a small proportion of the 441 caves documented in El Malpais NM. Further, many cave species are cryptic because they have small populations, restricted range and low rates of reproduction making them difficult to detect (Baker et al. 2015), and difficult to determine their presence and persistence. Multiple site visits are often required to compile a baseline overview of species composition (Wynne 2013). Further, caves may contain endemic species that occur in only a single cave such as the troglomorphic bristletail (order Diplura: family Campodeidae) found near the terminus of Cave 054 (Wynne 2013). Additional inventory work in El Malpais caves, especially in important microclimates such as deep zones, root curtains, microbial mats and in cave entrance floras, is needed (Wynne 2013). Pools of water and/or ice bodies in caves may also provide unique and important habitats for invertebrates (Northup and Welbourn 1997, Wynne 2013 and Eric Weaver, personal communication, 2015). The invertebrates in El Malpais caves are not being monitored.

Given the range of microclimates present in El Malpais caves with a great range of temperature and humidity conditions, there is a high potential for additional endemic invertebrate species to be found in monument caves (Eric Weaver, personal communication, 2015). Cave environments, especially those of lava tubes, are also highly fragmented and separated from one another, further giving the possibility for endemism (Baker et al. 2015).

The terminus of Cave 054 has been closed to recreational caving to protect the troglomorphic bristletail that lives there (Wynne 2013)

The plant species compositions of cave entrance floras are largely unknown. These areas may contain plants found nowhere else in the national monument, and given that the El Malpais ice caves are the southernmost ice caves in North America, the entrance floras of these caves may contain plants that require a cooler and more mesic environment than typically found in New Mexico. Moss gardens found underneath skylights and in cave entrances also are one of the riches habitats for cave invertebrates (Northup and Welbourn 1997 and Wynne 2013).

Cave entrance floras are fragile and are susceptible to impacts from trampling. Moss gardens in two caves (008 and 012) either are or will be roped to protect them (Eric Weaver, personal communication, 2015). The establishment of marked trails, such as the one in Xenolith Cave, may reduce visitor impacts to invertebrates and cave entrance flora. The condition of cave entrance flora in El Malpais caves is not being monitored.



Overall Condition

The overall condition of cave ecology and species in El Malpais NM is unknown. Only a small portion of the total number of species that live in or utilize El Malpais caves most likely have been documented, and the park recently submitted a proposal for 2018 funding to map of the moss gardens and inventory the invertebrates contained in them. They will begin the process of mapping

the moss gardens beforehand, which will be a significant focus in 2016 (E. Weaver, pers. comm. 2016).

Cave biodiversity is generally low compared to other environments because of fewer food resources, less habitat diversity and decreased ecotones (Baker et al. 2015). However, caves provide distinct ecological resources for species that are partially or wholly dependent on caves for their survival. El Malpais caves contain known endemic species and most likely contain others that have yet to be documented.

4.13.5. Sources of Expertise

Allyson Mathis, a science writer for Utah State University, authored this section. Eric Weaver is the Cave Management Specialist and acting Chief of Natural Resources at El Malpais NM and provided much information about the cave resource management program.

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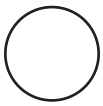
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4.14. Mammals

Indicators/Measures

- Species Occurrence (1 measure)

Condition – Trend – Confidence



Insufficient Data - Insufficient Data - Medium

4.14.1. Background and Importance

World-wide, the class of animals known as mammals is extremely diverse. Different mammal species are able to swim, fly, climb, burrow in the ground, live in trees, hop and run. Mammals also vary tremendously in size, from large members of the class, such as bear and elk, to small members, such as shrews and some bats. Approximately 151 mammal species live in the state of New Mexico (Frey and Yates 1996), and 78 mammal species (including subspecies) are known to live in Cibola County (extant species; New Mexico Department of Game and Fish [NMDGF] 2015a; Figure 4.14.1-1).

Only a few studies of mammals in or in the immediate vicinity of El Malpais NM have been conducted. Additional studies have been conducted specifically on bats, but bats and their study are the focus of Section 4.15 (although we present some of the results here, as appropriate). The most recently conducted survey of mammals in the national monument was that by the U.S. Geological Survey (USGS), "Mammal Inventories for Eight National Parks in the Southern Colorado Plateau Network," in 2003 and 2004 (Bogan et al. 2007).

Bogan et al. (2007) had a goal of documenting as many species as possible, and they focused on groups of mammals having the most species, such as rodents and carnivores. They also incorporated information from the mammal inventories that preceeded theirs. The two previous studies were Hooper (1941) and Lightfoot et al. (1994). Hooper (1941) looked at mammals on the lava fields and adjacent lands of the area (including lands outside of the present day national monument). No comprehensive mammal inventories or monitoring at the park have been conducted since the 2003-2004 Bogan



NPS/MURPHY

Figure 4.14.1-1. The American black bear is one of the large mammals known to occur in Cibola County and at El Malpais NM.

et al. (2007) work. Unfortunately, current condition and trends cannot be determined due to the lack of current data.

Note that this assessment focuses on mammals as a group, but only on species occurrence. Bats are included in this section so that we address all mammals in the park as a whole. However, the next major section of the assessment focuses on bats alone. This is because bats are of particular interest to the park, and recent information exists on them from research and monitoring related to White-nose syndrome.

4.14.2. Data and Methods

This limited assessment is based on the 2003-2004 USGS mammal inventory at the national monument (Bogan et al. 2007), as well as the supplemental sources described below. We also reviewed the NPSpecies list of mammals for the park (NPS 2014).

We used one indicator/measure of condition--species occurrence: presence/absence.

Indicators/Measures
Species Occurrence: Presence/Absence

Species Occurrence: Presence/Absence
Because there is no recent information to assess current condition of mammals at El Malpais NM, we used the 2003-2004 surveys to assess the occurrence of native and non-native mammal species at the park. We also used a report on bat sampling to supplement information on the occurrence of bat species, and we included the results of the work of Lightfoot et al. (1994) in the early 1990s. We also reviewed the NPSpecies list of mammals for the park (NPS 2014). As discussed above, see Section 4.15 of the condition assessment for a separate (and more detailed) assessment of bats, specifically, at the national monument.

The Occurrence of Species of Conservation Concern
We also used the surveys of Bogan et al. (2007) to generate a list of species of conservation concern (note that we use this term in a general sense). The list was complied by comparing the list of species observed during 2003-2004 surveys (and the other surveys) at the national monument to a federal/state list of endangered and threatened species (described below) and those of Greatest Conservation Need in New Mexico (described below). We also reviewed the NPSpecies list for the park (NPS 2014) to see whether any additional species should be included.

Primary Data Sources
Bogan et al. (2007)
In the eight parks that Bogan et al. (2007) surveyed, their main objective was to document the occurrence of at least 90% of the mammal species expected to occur at each park using their field inventory and a review of existing records. Additional objectives included providing baseline information for future monitoring, and describing the distribution and abundance of species of management interest (e.g., endangered species, exotic species). In order to observe as many species as possible, a variety of sampling methods were used: trapping, mist-netting, scat and track surveys, spotlighting, and opportunistic observations. Details of each method are contained in Bogan et al. (2007). The researchers spent 69 person-days on the work in 2003 and 2004 for a total of 3,010 trap-nights, 9 net-nights, 6 hours of spotlighting, and 67 miles (108 km) of walking to observe carnivores and diurnal mammals. As discussed below in section 4.14.4, they recorded more than 40 species of mammals at the park during surveys. Note that in reviewing records for each species observed by the various studies, Bogan et al. (2007) provided a few changes/clarifications, which we followed and presented in our table in section 4.14.4.

Secondary Data Sources
Lightfoot et al. (1994)
Lightfoot et al. (1994) conducted surveys for mammals at the national monument as part of a larger vegetation and wildlife inventory. Not many details are presented in the report regarding survey methods for mammals. However, this group of animals was recorded during study site visits (in general, multiple visits to 101 study sites), using Sherman live traps (for small mammals), using mist

nets for bats, and while driving at the park, particularly along state highways 117 and 53 and county road 42. Lightfoot et al. (1994) also included additional information on the earlier study by Hooper (1941). Of the 162 species of vertebrates observed, Lightfoot et al. (1994) reported 36 mammal species.

Valdez et al. (2002)
Valdez et al. (2002) conducted a study on bats in 1999 and 2000 in the national monument and adjacent lands. They surveyed bats using mist nets and echolocation detectors, and in addition to documenting the occurrence and distribution of bats at the monument, they collected information on relative abundance, reproduction, and seasonal activity. Their specific results are discussed in more detail in section 4.14.4 and in section 4.15 on bats, but they recorded at least 14 species during their work, with the dominant ones including Western small-footed myotis (*Myotis ciliolabrum*), long-eared myotis (*M. evotis*), long-legged myotis (*M. volans*), and big brown bat (*Eptesicus fuscus*).

NPSpecies List for the National Monument
The NPSpecies list for the park was used to see whether additional species have been documented in the park that were not recorded by Bogan et al. (2007), Lightfoot et al. (1994), or Valdez et al. (2002). We also used the list as supporting information for the lists shown in the subsequent tables.

Protected/Rare Species Lists
In New Mexico, wildlife species are designated as threatened and endangered under the New Mexico Wildlife Conservation Act (NMDGF 2015b). For each endangered or threatened species, the NMDGF develops a recovery plan. A database of all vertebrate species in New Mexico, including threatened and endangered species, is maintained and can be searched online (NMDGF 2015a). The database is called the Biota Information System of New Mexico (BISON-M). Under the Endangered Species Act, the U.S. Fish and Wildlife Service (USFWS) lists species as threatened, endangered, or candidates for listing. Lists of federal and state-listed species (i.e., USFWS 2015a and NMDGF 2015a) were obtained and compared to the list of mammal species recorded at the national monument.

Under the Comprehensive Wildlife Conservation Strategy (CWCS) for New Mexico, Species of Greatest Conservation Need (SGCN) have been designated in the state (NMDGF 2006). Of the 452 vertebrate, mollusc, and arthropod SGCN statewide, 42 are mammals. There are lists of SGCN for the entire state, as well as those for each of the individual ecoregions in New Mexico. The ecoregion in which El Malpais NM occurs is the Arizona-New Mexico Mountains. The BISON-M database maintains information on which species are SGCN, and it provides lists of species so designated for Cibola County (and other counties; NMDGF 2015a).

4.14.3. Reference Conditions
No reference conditions were developed for this resource topic. This is because no two similar studies or surveys to compare species occurrence exists (e.g., to examine changes in species occurrence over time). However, the information presented from the surveys/inventories that do exist provides a good baseline for future monitoring and assessment for mammal species occurrence at the national monument. In other words, if standardized surveys of mammals are conducted in the future, the new survey results could be compared to the survey/inventory results from the early 2000s. The survey results from the early 2000s could become the reference conditions for the future assessments.


NPS

Figure 4.14.4-1. Elk at El Malpais NM.

Table 4.14.4-1. Mammal species recorded in El Malpais NM during surveys by Bogan et al. (2007; in 2003-2004), as well as by Valdez et al. (2002; in 1999-2000) and Lightfoot et al. (1994; early 1990s). Notes/entries with a letter are explained in the Comments column, and notes with a number are found below the table.

Common Name	Scientific Name	Bogan et al. (2007)	Valdez et al. (2002) [1]	Lightfoot et al. (1994)	Comments
Abert's squirrel	*Sciurus aberti*	a		X	[a] On Bogan et al. (2007) list, but observed by NPS
American badger	*Taxidea taxus*				Probably present per Bogan et al.; Recorded on park trail cameras at least twice in 2014-2015 (E. Weaver, ELMA)
American black bear	*Ursus americanus*	X		X	
Banner-tailed kangaroo rat	*Dipodomys spectabilis*	X		X	
Big brown bat	*Eptesicus fuscus*	X	X	X	
Big free-tailed bat	*Nyctinomops macrotis*		X		
Black-tailed jackrabbit	*Lepus californicus*	X		X	
Bobcat	*Lynx rufus*	X			
Botta's pocket gopher	*Thomomys bottae*	X		X	
Brazilian free-tailed bat	*Tadarida brasiliensis*	X	X	X	
Brush mouse	*Peromyscus boylii*	X		X	
California myotis	*Myotis californicus*	X	X	X	
Canyon bat [3]	*Parastrellus hesperus* [3]		X		
Cave myotis	*Myotis velifer*			b	[b] NPS (2014) considers this a mistake (i.e., a "false report")
Cliff chipmunk	*Neotamias dorsalis*	X		X	
Collared peccary (javelina)	*Pecari tajacu*	c			[c] On Bogan et al. (2007) list; based on voucher from Albert et al. (2004); Recorded on park trail cameras in 2011 (E. Weaver, ELMA)
Colorado chipmunk	*Neotamias quadrivittatus*	X		X	
Coyote	*Canis latrans*	X		X	
Crawford's desert shrew	*Notiosorex crawfordi*				Probably present per Bogan et al.
Deer mouse	*Peromyscus maniculatus*	X		X	
Desert Cottontail	*Sylvilagus audubonii*	X		X	
Dwarf shrew	*Sorex nanus*			X	NPS (2014) considers this a mistake (i.e., a "false report")
Elk	*Cervus elaphus*	X			
Fringed myotis	*Myotis thysanodes*	X	X	X	
Gray fox	*Urocyon cinereoargenteus*	X		X	
Gunnison's prairie dog	*Cynomys gunnisoni*	X		X	
Hoary bat	*Lasiurus cinereus*	X	X		
Hog-nosed skunk (white-backed)	*Conepatus leuconotus*	d			[d] Species listed as present by Bogan et al., but not observed by them
House mouse	*Mus musculus*				Probably present per Bogan et al.
Kit fox	*Vulpes macrotis*	X			
Long-eared myotis	*Myotis evotis*	X	X	X	
Long-legged myotis	*Myotis volans*	X	X		
Long-tailed weasel	*Mustela frenata*	X			

Table 4.14.4-1. Mammal species recorded in El Malpais NM during surveys by Bogan et al. (2007; in 2003-2004), as well as by Valdez et al. (2002; in 1999-2000) and Lightfoot et al. (1994; early 1990s). Notes/entries with a letter are explained in the Comments column, and notes with a number are found below the table (continued).

Common Name	Scientific Name	Bogan et al. (2007)	Valdez et al. (2002) [1]	Lightfoot et al. (1994)	Comments
Mexican gray wolf [2]	*Canis lupus baileyi*				Documented by NPS and USFWS
Mexican woodrat	*Neotoma mexicana*	X		X	
Mogollon vole	*Microtus mogollonensis*	X			
Mountain lion	*Puma concolor*	X		X	
Mule deer	*Odocoileus hemionus*	X		X	
North American (common) porcupine	*Erethizon dorsatum*	X		X	
Northern grasshopper mouse	*Onychomys leucogaster*	X			
Northern raccoon	*Procyon lotor*				Probably present per Bogan et al.
Northern rock mouse	*Peromyscus nasutus*	X		e	[e] Lightfoot et al. recorded So. rock mouse, but it only occurs in Mexico
Ord's kangaroo rat	*Dipodomys ordii*	X [f]		X	[f] Bogan et al. reviewed voucher specimen, but also appears to have observed species per their Table 12
Pallid bat	*Antrozous pallidus*	X	X		
Pinyon mouse	*Peromyscus truei*	X		X	
Plains pocket mouse	*Perognathus flavescens*	X			
Pronghorn	*Antilocapra americana*	X		X	
Red fox	*Vulpes vulpes*	X [g]			[g] Bogan et al. (2007) observed tracks
Ringtail	*Bassariscus astutus*	X			
Rock squirrel	*Spermophilus variegatus*	X		X	
Silky pocket mouse	*Perognathus flavus*	X		X	
Silver-haired bat	*Lasionycteris noctivagans*	X	X	X	
Spotted bat	*Euderma maculatum*	X	X		
Spotted ground squirrel	*Spermophilus spilosoma*	X [h]			[h] observed just off park
Stephens's woodrat	*Neotoma stephensi*				Probably present per Bogan et al.
Striped skunk	*Mephitis mephitis*	i			[i] Bogan et al. listed as present, but not observed by them
Tawny-bellied cotton rat	*Sigmodon fulviventer*	X			
Townsend's big-eared bat	*Corynorhinus townsendii*	X	X	X	
Western harvest mouse	*Reithrodontomys megalotis*	X		X	
Western small-footed myotis	*Myotis ciliolabrum*	X	X	X [j]	[j] Lightfoot et al. recorded as *M. subulatus*
Western spotted skunk	*Spilogale gracilis*				Probably present per Bogan et al.
Western white-throated woodrat	*Neotoma albigula*	X		X	
White-footed mouse	*Peromyscus leucopus*			j	[j] Bogan et al. (2007) considered this species observation as "unconfirmed"
White-nosed coati (or coatimundi)	*Nasua narica*				Reported by NPS employee in 1995 (King 1995)

[1] Valdez et al (2002) reported two additional bat species; Bogan et al. (2007) considered one of them as a misidentified species that is already in the table; the other species (Yuma myotis [*Myotis yumanensis*] is unconfirmed because it was observed only by ultrasonic recordings and may have been confused with another species (Bogan et al. 2007).

[2] Gray wolf was noted as extirpated by Bogan et al. 2007. However, as discussed in the text, Mexican gray wolves were documented in the park in 2014.

[3] Previously known as Western pipistrelle (*Pipistrellus hesperus*).

4.14.4. Condition and Trend

More than 50 species of mammals have been recorded at El Malpais NM during surveys by Bogan et al. (2007), Valdez et al. (2002), and Lightfoot et al. (1994). Several additional species were noted as "probably present" by Bogan et al. (2007) and are discussed in this section.

Species Occurrence: Presence/Absence

Of the more than 50 mammal species, 46 species were recorded during the 2003-2004 surveys by Bogan et al. (2007; Table 4.14.4-1; Figure 4.14.4-1). [Note that these authors stated they observed 45, but one additional species was included in a table showing the number of individuals observed during surveys]. They recorded 21 rodent species, 12 bat species, eight carnivore species, three ungulate species, and two lagomorh species. Thirty of these 46 species were also recorded by Lightfoot et al. (1994) in the early 1990s. All of the twelve bat species observed by Bogan et al. (2007) were also observed by Valdez et al. (2002), but Valdez et al. (2002) observed two additional bat species not reported by Bogan et al. (2007). Also note that Valdez et al. (2002) recorded two additional bat species that are addressed in the footnote to Table 4.14.4-1. Also, there are four species (shown in the table) reported only by Lightfoot et al. (1994); three of the species are considered either as "false reports" or unconfirmed by NPS (2014) or Bogan et al. (2007).

There are six additional species that are considered probably present at El Malpais NM (Table 4.14.4-1) per Bogan et al. (2007). One of these, American badger, has since been confirmed in the park. It was recorded at least two times in 2014-2015 on trail cameras (Eric Weaver, Acting Natural Resources Branch Chief, El Malpais NM, pers. comm.).

The USGS surveys in 2003-2004 are the most comprehensive mammal surveys at the national monument to date, and they provide a firm baseline for future monitoring. Bogan et al. (2007) also provided some information on the number of individuals of the various species captured or observed during their surveys. A few of the species observed in the highest numbers were: the Brazilian free-tailed bat (*Tadarida brasiliensis*, 64 counted) among the bats; deer mouse (*Peromyscus maniculatus*, 45) among the rodents; American black bear (*Ursus americanus*, 8) among the carnivores; and mule deer (*Odocoileus hemionus*, 16) among the hoofed mammals.

Table 4.14.4-2. Species detected at El Malpais NM that are Species of Greatest Conservation Need (SGCN) according to the New Mexico Department of Game and Fish (NMDGF 2006) and/or state or federally-designated as threatened or endangered.

Common Name	Scientific Name	Federally-listed (USFWS)	State-listed (NMDGF)	NM SGCN (NMDGF)
Abert's squirrel	*Sciurus aberti*			SGCN
American black bear	*Ursus americanus*			SGCN
Gunnison's prairie dog	*Cynomys gunnisoni (zuniensis)* [1]			SGCN
Mexican gray wolf [2]	*Canis lupus baileyi*	E	E	SGCN
Mule deer	*Odocoileus hemionus*			SGCN
Spotted bat	*Euderma maculatum*		T	SGCN

[1] = The list of SGCN for Cibola County (from BISON-M; NMDGF 2015a) provides the subspecies shown; the list of SGCN in the Comprehensive Wildlife Conservation Strategy (i.e., NMDGF 2006) does not designate a subspecies.

[2] = This species was not recorded by any of the surveys at the park, but wolves were observed and documented in 2014 (David Hays, former Natural Resources Branch Chief, El Malpais NM, pers. comm.).

In total, there are approximately 55 species that have been recorded in the park (or immediately adjacent to it, including the gray wolf that was considered unconfirmed and extirpated by Bogan et al. 2007), and five species that probably occur. There are several additional species that are unconfirmed but may occur. Also, a single white-nosed coati (or coatimundi; *Nasua narica*) was observed in the park by an NPS employee in 1995 (King 1995). Other new species may be discovered in the future. For example, Bogan et al. (2007) suggested that the grassy parcel near Grants may harbour more grassland species.

The Occurrence of Species of Conservation Concern

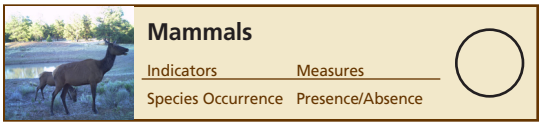
There are six species out of those documented at El Malpais NM that are listed as species of conservation concern on one or more of the lists described in Section 4.14.2 (Table 4.14.4-2). One species (subspecies), the Mexican gray wolf (*Canis lupus baileyi*), is listed as endangered with both the USFWS and the State of New Mexico. Another species, the spotted bat (*Euderma maculatum*), is listed as threatened with the State, and four additional species are considered Species of Greatest Conservation Need (SGCN) in New Mexico.

The Mexican gray wolf is a subspecies of the gray wolf (*Canis lupus*). Gray wolves (including the *baileyi* subspecies) were placed on the endangered species list by the USFWS in the 1970s. In 2013, the USFWS proposed to delist the gray wolf but maintain the Mexican gray wolf as endangered (USFWS 2015b). Although the gray wolf is noted by Bogan et al. (2007) as unconfirmed or extirpated, a few individuals were documented at the park in early 2014 (David Hayes, former Natural Resources Branch Chief, El Malpais NM, pers. comm.). The wolves (a pair) were captured in the park and transported to the Blue Range Wolf Recovery Area, because they were outside of the designated "primary recovery zones" and "recovery areas" for the nonessential experimental population (USFWS 2015c). Whether additional Mexican gray wolves will move into the park is unknown. If they do return, because the USFWS has recently revised the rules governing management of the experimental population within the Mexican Wolf Experimental Population Area (USFWS 2015c), they will not be removed again (D. Hayes, former Natural Resources Branch Chief, El Malpais NM, pers. comm.). Under the new rule, the park is within a zone where the wolves will be allowed to "naturally disperse into and occupy, and where Mexican wolves may be translocated" (USFWS 2015c).

Valdez et al.'s (2002) record of the spotted bat in 1999-2000 was the first known occurrence of the species in the county. Bogan et al. (2007) also observed the species in 2004 by way of their audible, conspicuous calls. The echolocation sound made by the species is low enough to be heard by the human ear (Arizona-Sonora Desert Museum 2015). The spotted bat also stands out because of its coloration and markings. It has a black body with two large white spots on its shoulders and one white spot on its rump, and its underbelly is white. Its ears and wings are pinkish. The bat has a large range but is considered one of the rarest bats in North America (Arizona-Sonora Desert Museum 2015).

Table 4.14.4-3. Indicator and measure of mammal condition.

Indicator	Measure of Condition	Condition	Rationale for Condition.
Species Occurrence	Presence/absence	Unknown	There is no current information available on mammals at the national monument. The most recent surveys were conducted in 2003-2004 (i.e., Bogan et al. 2007). Although condition can not be determined at this time, the 2003-2004 work, as well as earlier surveys by Lightfoot et al. (1994) and Valdez et al. (2002) provides baseline information for future monitoring and assessment. One of the species documented at the park is considered federally and state endangered, and another species is listed as threatened with the state. Six species, including these two endangered/threatened species, are listed as New Mexico Species of Greatest Conservation Need.



Overall Condition and Trend

To assess condition of mammals at El Malpais NM, we used one indicator/measure that is summarized in Table 4.14.4-3. Current condition can not be assessed due to the lack of recent data. The information presented in this condition assessment is from the most recent survey at the park, conducted in 2003-2004 by the USGS-University of New Mexico, as well as previous surveys by Lightfoot et al. (1994) and Valdez et al. (2002). Fifty-four mammal species have been recorded or are known to occur in the park, with an additional six that are probably present (Bogan et al. 2007). Trends in species occurrence can not be assessed due to the lack of available data. However, the 2003-2004 surveys provide good baseline information (or reference conditions) for future monitoring and condition assessment. Six of the species documented at the park are considered SGCN, including one species that is federally and state-listed and one species that is state-listed.

4.14.5. Sources of Expertise

No outside experts were consulted for this resource topic. This section was authored by biologist Patty Valentine-Darby.

4.14.6. Literature Cited

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4.15. Bats

Indicators/Measures

- Species Occurrence (1 measure)
- White-nose Syndrome/Fungus (1 measure)
- Habitat Availability/Condition (1 measure)

Condition – Trend - Confidence



Good - Insufficient Data - High

4.15.1. Background and Importance

World-wide, about one-fourth of all mammal species are bats (Tuttle 1988). Nearly 50 bat species inhabit the U.S. and Canada (USFWS 2015), and nearly 30 species occur in New Mexico (Valdez et al. 2002; Figure 4.15.1). Most bats in the U.S. and Canada are insectivorous (Tuttle 1988). Across the globe, bats consume large numbers of insects (some of which are agricultural and/or human pests), and they pollinate plants and disperse seeds (Bat Conservation International [BCI] 2015). Their droppings (or guano) are also a natural fertilizer. Bats are sometimes considered a keystone species (BCI 2015, Wynne 2013). When large numbers of bats inhabit a cave, they deposit a substantial amount of organic material (guano) into the cave system (Wynne 2013). In temperate areas, bats migrate or hibernate due to cold winter temperatures. Some species migrate long distances, such as from Canada to Mexico or the Gulf states, but more species migrate shorter distances (such as 300 miles or less) to find a suitable hibernation location (Tuttle 1988). Bats may hibernate for up to six months or more, during which time they survive on reserves of stored fat. This group of mammals tends to be "very loyal to their birthplaces and hibernating sites" (Tuttle 1998). Caves at El Malpais National Monument are used by bats for both hibernacula (winter hibernation sites) and maternity roosts (sites where female bats raise their young). During fieldwork in August of 2004, for example, Bogan et al. (2007) observed an estimated 15,000 to 20,000 bats emerging from Bat Cave in the El Calderon area of the national monument.

4.15.2. Data and Methods

As discussed in the previous section on Mammals, there have been only a small number of inventories/surveys of mammals



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Figure 4.15.1-1. Townsend's big-eared bat (Corynorhinus townsendii), one of the bat species occurring in New Mexico and El Malpais NM.

as a group in or in the immediate vicinity of El Malpais NM. There have been some additional surveys and studies on bats specifically, including those to survey/monitor for the presence of White-nose syndrome (WNS) and the fungus that causes the disease. White-nose syndrome, a recently-discovered disease that affects hibernating bats, has resulted in the mortality of nearly 6 million bats in eastern North America (USFWS 2014). [Note that a brief discussion of WNS was provided in Section 2.2.3, Resource Issues Overview, but we include additional details throughout this assessment].

This assessment is based on the handful of mammal/bat inventories/surveys that have been conducted at the national monument and studies/surveys on WNS and the fungus that causes the disease. Various sources of information from the park were also used. The indicators/measures and how they were assessed, as well as the data and information sources used, are described below.

We used three indicators, each with one measure, to assess the condition of bats at El Malpais NM.

Indicators/Measures

Species Occurrence: Presence or Absence

Species Occurrence : Presence or Absence

To examine bat species occurrence at the national monument, we compiled the list of bat species that have been documented at the park and determined whether any of the species that were recorded in older surveys have failed to be recorded in recent years. Unfortunately, the most recent surveys are now four years old, and they examined species occurrence within the park as a secondary objective (and therefore used some different methods than earlier surveys). However, the information presented provides a list of species documented during the various surveys/sampling. This information is also supplemented with current information from park staff on some of the species, such as the estimated number of Mexican (or Brazilian) free-tailed bats (*Tadarida brasiliensis*) using Bat Cave in the summer. Additionally, the occurrence of federally and/or state listed species, as well as Species of Greatest Conservation Need (SGCN), are discussed.

Data Sources

Note that the data sources below are not described in chronological order.

Bogan et al. (2007)

The most recently conducted inventory/survey of mammals in the national monument was that by the U.S. Geological Survey (USGS) in 2003 and 2004 (Bogan et al. 2007), and this inventory included bats. The main objective of this work was to document the occurrence of at least 90% of the mammal species expected to occur at the park using a field inventory and review of existing records. For bats, sampling methods included mistnetting and opportunistic observations. However, because the earlier work by Valdez et al. (2002; described below) was thorough, they did not emphasize bat surveys (Bogan et al. 2007). Their work included mistnetting in late May and late August of 2004, as well as cave emergence observations in late August, 2004. Even with their limited survey effort, they detected 12 species of bats.

Valdez et al. (2002)

In 1999 and 2000, Valdez et al. (2002) focused their work on bats in the national monument and adjacent lands. They surveyed bats with mistnets and echolocation detectors, and in addition to documenting the occurrence and distribution of bats, they collected information on relative abundance, reproduction, and seasonal activity. The researchers sampled and conducted visual searches for active bat roosts in the summer of each year. Mistnets were used in 17 locations in and near the park, within a variety of habitats, that had natural and man-made water impoundments. There were a total of 30 net-nights in 1999 and 56 in 2000. Bat calls were recorded at the mistnet sites and along transects. Roost searches were conducted in the summer of 2000 in lava tube caves. Valdez et al. (2002) documented a total of 15-16 species.

Valdez (2012)

Upon request of El Malpais NM personnel, the USGS sampled for evidence of WNS in bats in 2011 in the national monument and

surrounding areas (Valdez 2012). During the work, Valdez recorded eight species of bats, all of which had been recorded at the national monument previously. The work was carried out using mistnets at water sources near habitat that may be used for hibernation. Sampling was conducted during the spring (starting March 29) and summer (to August 5), but focused on the spring period (March 20 to June 20). Aspects of the study as related to the fungus and disease are included under the next indicator and measure discussion.

Lightfoot et al. (1994)
Lightfoot et al. (1994) conducted surveys for mammals at the national monument as part of a larger vegetation and wildlife inventory. Few details are presented in their report regarding survey methods for mammals, but bats were surveyed using mistnets and general observations. Lightfoot et al. (1994) also included additional information from an earlier study by Hooper (1941). Lightfoot et al. (1994) reported nine species of bats during their work.

Ongoing Survey Efforts by National Monument Personnel
Information on bats obtained through discussions with park personnel was also included where appropriate (for any of the three indicators/measures). This consists of two main efforts of park personnel: 1) a multi-year effort to monitor use of Bat Cave by Mexican free-tailed bats in summer; and 2) a December 2014-February 2015 survey of approximately 160 lava tube caves to search for use by hibernating bats.

In the first survey effort, park personnel are presently working on obtaining estimates of the population of bats using Bat Cave. They estimate the number of bats emerging in the evening approximately once per week from mid-June to early August (Eric Weaver, Acting Natural Resources Branch Chief, El Malpais NM, pers. comm.). Estimates are made primarily by making and reviewing visual recordings, although live visual counts (using night-vision goggles in the dark) are also conducted. Counts were also conducted in 2012, 2013, and 2014. There are also data on bat numbers from 1999, but park personnel are unclear at this time whether the 1999 count was conducted using the same or different methods.

In the second park survey effort, park personnel are surveying lava tube caves for use by hibernating bats (Eric Weaver, Acting Natural Resources Branch Chief, El Malpais NM, pers. comm.). The survey was conducted in December 2014-February 2015, and plans are for the same, and additional, caves to be surveyed in December 2015-January 2016. Note that according to E. Weaver, plans are to survey caves with a known bat population every year, and caves with the potential to support bats every other year.

Other Data/Information Sources
The NPSpecies List for the park (NPS 2014) was also used to assess this indicator/measure, primarily as supporting information for specific species. Additional reports (e.g., Wynne 2011 and 2013) used for other indicators/measures, were also reviewed.

Indicators/Measures

Occurrence of *Pseudogymnoascus destructans* and/or WNS: Presence/Absence

Occurrence of P. destructans and/or WNS: Presence/Absence
This indicator/measure includes the occurrence of the fungus that causes WNS and the occurrence of the disease (or symptoms) in bats. In some hibernacula in the Eastern U.S., all or nearly all of the bats have died from WNS (USFWS 2014). The disease is caused by a fungus, originally known as *Geomyces destructans*, but now called *Pseudogymnoascus destructans* (USFWS 2014). White-nose syndrome is named for the white fungus that grows on the muzzle and other parts of the bats' bodies (USFWS 2014). The disease is thought to spread primarily through direct contact between bats, but it is also believed possible to spread the fungus to new hibernacula on shoes, clothing or gear (USFWS 2015). Research is currently being conducted on how to control and prevent the spread of the fungus (USFWS 2014).

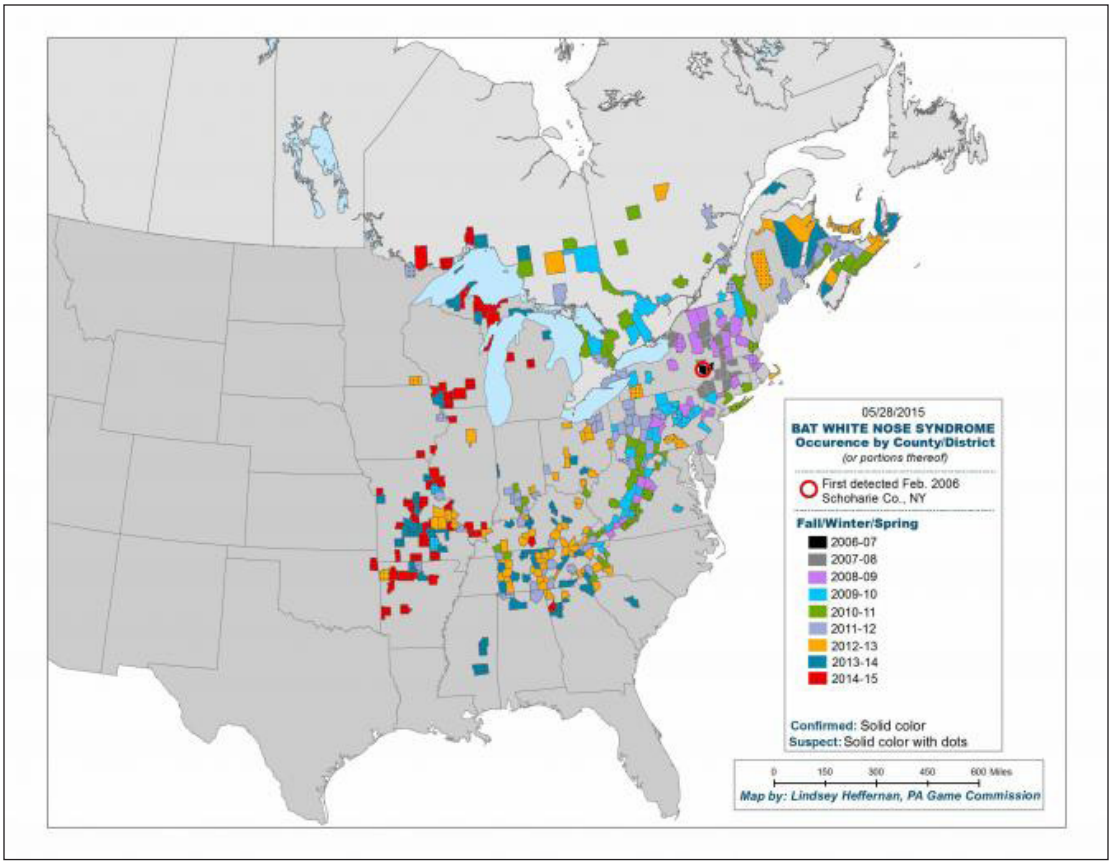


Figure 4.15.2-1. Map showing occurrence of WNS, dated 5/28/15. Occurrences with solid color are confirmed, while those with dots are suspected (this may be difficult to see at this scale). At this time, the closest known (confirmed) occurrence of WNS to New Mexico is in Arkansas, and the closest occurrence of the fungus (but not WNS) is Oklahoma. Map available online at https://www.whitenosesyndrome.org/resources/map.

In the U.S., the occurrence of WNS has been confirmed in seven species of bats that hibernate in caves, and the fungus has been observed on an additional five species (USFWS 2014). Of these species, one from each group is known to occur at El Malpais NM (big brown bat [*Eptesicus fuscus*] and silver-haired bat [*Lasionycteris noctivagans*], respectively). Based on the available information, large concentrations of these species have not been observed hibernating in the national monument's caves, but the park's recent hibernacula survey indicated that both species may hibernate in park caves in at least small numbers. Currently, the closest state with confirmed cases of WNS is Arkansas, although the fungus (but not yet WNS) was recently confirmed in eastern Oklahoma (Figure 4.15.2-1, USFWS 2015).

At El Malpais NM, efforts are being made to look for the fungus in caves that show evidence of bat use (Northup 2013), and to look for evidence of the fungus on bats or the disease in bats (Valdez 2012). We used the results of these surveillance/monitoring efforts (from 2010 and 2011, respectively) and more recent observations from the same researchers (i.e., Northup et al. 2015) to assess this indicator/measure of condition for bats.

Data Sources

Valdez (2012)

The Valdez (2012) work was described under the previous indicator/measure, although we provide a few additional details here. The period for sampling described above was used to focus sampling efforts around the time when bats emerge from their hibernacula (Valdez 2012). This time frame would also be conducive to observing signs of the fungus, such as hyphae (long, branching, filamentous structures of fungi) growing on the wings, nose, and ears of bats. Weather conditions were also a consideration. Sampling locations used were those near unobstructed water surfaces in proximity to areas of known or potential hibernacula (such as lava tubes). Most of the sites were along the western and northwestern edges of the national monument on Forest Service and Bureau of Land Management-managed lands. A total of 18 sites were sampled between March 29 and August 5, for a total of 88 net-nights.

Northup (2013)
The overal goal of Northup (2013) was to determine whether the fungus that causes WNS was present in caves at El Malpais NM. Ten lava caves with evidence of bat activity and/or microclimate conditions suitable for *P. destructans* were sampled in October and November of 2010 within the park (Northup 2013). The researchers sampled soils and guano deposits at regular distance intervals within the caves, for a total of two to 12 samples taken per cave. They used DNA analysis of the samples to look for sequences that matched *P. destructans*. Three levels of tests were used to analyze the samples, with the third test (real-time PCR test developed by Minnis et al. 2013) being the most accurate.

Northup et al. (2015)
In 2014-2015, Northup et al. (2015) conducted further research related to WNS in the caves at the national monument. There were three main goals of their research: 1) to find close relatives of *P. destructans* in park caves (that previous research showed were in some cave soils); 2) to develop a baseline of the bacteria and fungi that live on bats that do not have WNS; and 3) to test for natural defenses against WNS by culturing Actinobacteria (a group of bacteria known to produce natural antibiotics) from park bats (Northup et al. 2015). To meet these goals, soils were sampled from caves having conditions suitable for *P. destructans*, and bats were captured from six caves (with roosting bats) and on the surface using mistnets at sources of water. The researchers swabbed the bats to collect samples to determine the microbiota present, and while the bats were being handled, researchers examined bats (e.g., wings, ears, muzzle) for signs of *P. destructans* infection.

Indicators/Measures

Habitat Availability & Condition: Available Habitat with Minimal Disturbance

Habitat Availability & Condition: Available Habitat Free from/with Minimal Human Disturbance
The purpose of this indicator/measure is to examine the availability and condition of habitat for bats at the national monument. This is a general and descriptive aspect of the assessment. There are a number of caves at the park that are known to be used by bats for winter hibernacula and/or for raising young (i.e., maternity roosts). However, "... the vastness of the lava-tube system across the park and the amount of use by bats throughout is poorly known" (Valdez 2012). Therefore, there are probably more caves that are used by bats than are currently known, and some of them are probably relatively inaccessible (there are at least 290 lava tube caves in the national monument [Wynne 2013]). Because this is an area with incomplete information, in this section we focus on the caves for which information exists.

Also, bats require habitat for foraging and drinking, as well as for roosting (e.g., Taylor 2006). Although foraging and drinking requirements are discussed somewhat under this indicator, the focus is on roosting habitat. As reported by numerous studies (see Wynne 2011 Introduction), bats are very sensitive to disturbance by humans when roosting, in maternity colonies, and hibernating. Bats in maternity roosts may abandon the cave and/or their young if repeatedly disturbed (Valdez et al. 2002).

Roosting habitat addressed includes both caves and forests/woodlands, as some species roost in dead or dying and/or living trees. Information to support this aspect of the assessment comes primarily from on-site vegetation field assessments that were conducted in June 2015 for this report (described in more detail below), as well as from communications with national monument personnel.

Data Sources
For information on the caves that are used by bats and which bat species use the caves, we used the sources described under the first two indicators/measures, as well as a few additional sources (Carlton [1988], Wynne [2011 and 2013], and Buecher and Northup [2011]). See the Data Sources sections under the first two indicators/measures for descriptions of the following studies: Bogan et al. (2007), Valdez et al. (2002), Valdez (2012), Northup (2013), Northup et al. (2015), and Lightfoot et al.

Table 4.15.3-1. Reference conditions for bats at El Malpais NM.

Indicator/Measures	Significant Concern	Moderate Concern	Good
Species Occurrence: Presence or Absence	We consider condition to be of significant concern if the bat fauna (species) at the national monument in recent/current years is less than it has been in past years (species have been lost, especially those that were considered common in the past).	We consider condition to be of moderate concern if the bat fauna (species) at the national monument in recent/current years is less than it has been in past years (some species have been lost/not detected in recent years).	We consider condition to be good if the bat fauna (species) at the national monument in recent/current years is approximately the same as in past years (no species that would be expected to occur at the park appear to have been lost).
Occurrence of *Pseudogymnoascus destructans* (Fungus that Causes WNS) and WNS: Presence or Absence	We consider condition to be of significant concern if *P. destructans* has been detected, either the fungus itself or symptoms of WNS in bats, at El Malpais NM.	----------	We consider condition to be good if there is no known occurrence of *P. destructans* or WNS at El Malpais NM.
Habitat Availability & Condition: Available Habitat Free from or with Minimal Human Disturbance	We consider condition to be of significant concern if either important sites/locations are no longer available for roosting (including raising young and/or wintering), or human disturbance is at a level that is not conducive to bat use (or bat use has consistently decreased).	We consider condition to be of moderate concern if sites/locations are available for roosting (including raising young and/or wintering), but the number of known sites has decreased somewhat, or a low level of disturbance to them is occurring.	We consider condition to be good if sites/locations are available for roosting (including raising young and/or wintering), with minimal human disturbance.

(1994), and the two ongoing survey efforts by national monument personnel.

For information on the conditions of the caves, we used information from the national monument on cave closures and other miscellaneous sources (e.g., the park website, public pamphlets). Cave closures have been used at the park to minimize or avoid disturbance of bats by humans. This included a closure of all of the caves to the public in late 2010 due to the threat of WNS. Some of the caves were later reopened to the public, at least during certain times of the year.

Information on which bats use trees, caves, or other sites for roosting came from various sources, especially the *Stokes Beginner's Guide to Bats* (Williams et al. 2002). Additionally, as noted above, information on the condition of ponderosa pine and piñon-juniper habitats came primarily from the vegetation field assessments conducted on June 2-3, 2015 for the assessments of these vegetation types at the national monument (Sections 4.8 and 4.9). As discussed in greater detail in those sections of the report, we visited a number of areas within the park, primarily in the El Calderon area, the western end of the Zuni-Acoma Trail, the Sandstone Bluffs area, the Lava Falls area, and the Cerro Bandera area. As noted elsewhere in this document, much of the park is fairly inaccessible due to the various lava flows, so management, and hence our visits, were focused along the perimeter of the park.

4.15.3. Reference Conditions

Reference conditions for this assessment are shown in Table 4.15.3-1. Reference conditions are described for resources in good, moderate concern, and significant concern conditions for each of the three indicators and measures.

4.15.4. Condition and Trend

Up to 15 bat species have been recorded by one or more of the four surveys/inventories that have been conducted on bats/mammals at El Malpais NM (Table 4.15.4-1). Seven of the species were recorded by all four studies. One of the species, the spotted bat (*Euderma maculatum*), is listed as threatened with the State of New Mexico (New Mexico

Table 4.15.4-1. Bat species recorded in El Malpais NM during surveys by Valdez (2012), Bogan et al. (2007), Valdez et al. (2002), and Lightfoot et al. (1994). Notes/entries with a letter are explained in the Comments column, and notes with a number are found below the table. All of these species were also listed in Table 4.14.4-1 in the previous section on Mammals.

Common Name	Scientific Name	Lightfoot et al. (1994) in early 1990s	Valdez et al. (2002)[1] in 1999-2000	Bogan et al. (2007) in 2003-2004	Valdez (2012) in 2011	Comments
Big brown bat [2]	*Eptesicus fuscus* [2]	X	X	X	X	
Big free-tailed bat [3]	*Nyctinomops macrotis* [3]		X			
Mexican (or Brazilian) free-tailed bat [2]	*Tadarida brasiliensis* [2]	X	X	X	X	
California myotis [4]	*Myotis californicus* [4]	X	X	X		
Cave myotis	*Myotis velifer*	a				[a] NPS (2014) considers this a mistake (i.e., a "false report"), as does Valdez (2012)
Fringed myotis [2]	*Myotis thysanodes* [2]	X	X	X	X	
Hoary bat [2]	*Lasiurus cinereus* [2]		X	X		
Long-eared myotis [2]	*Myotis evotis* [2]	X	X	X	X	
Long-legged myotis [2]	*Myotis volans* [2]		X	X	X	
Pallid bat [2]	*Antrozous pallidus* [2]		X	X		
Silver-haired bat [2]	*Lasionycteris noctivagans* [2]	X	X	X	X	
Spotted bat [3]	*Euderma maculatum* [3]		X	X	b	[b] A single bat was heard during sampling
Townsend's big-eared bat [2]	*Corynorhinus townsendii* [2]	X	X	X	X	
Canyon bat [4, 5]	*Parastrellus hesperus* [4, 5]		X			
Western small-footed [2] myotis	*Myotis ciliolabrum* [2]	X [c]	X	X	X	[c] Lightfoot et al. recorded as *M. subulatus*

[1] Valdez et al. (2002) reported two additional bat species; Bogan et al. (2007) considered one of them as a misidentified species that is already in the table; the other species (Yuma myotis [*Myotis yumanensis*] is unconfirmed because it was observed only by ultrasonic recordings and may have been confused with another species (Bogan et al. 2007).

[2] Species has been documented at the park by net capture and voucher specimen (Valdez 2012).

[3] Species has been documented at the park by distinct audible and ultrasonic calls and flight observations (Valdez 2012).

[4] Valdez (2012) reports that there are no voucher representatives for this species; he suggests the species may occur at the park, but probably in small numbers.

[5] Previously known as Western pipistrelle (*Pipistrellus hesperus*).

Department of Game and Fish [NMDGF] 2015). This species was recorded for the first time in Cibola County by Valdez et al. (2002). This species, but none of the others, is also considered a Species of Greatest Conservation Need (SGCN) in New Mexico (NMDGF 2015).

Species Occurrence: Presence or Absence

Although it would be preferable to have bat surveys from the last year or two, no such information is available. The most recent mistnet sampling was conducted in 2011 (except for some limited mistnet sampling in 2014 for specific purposes [i.e., Northup et al. 2015]). Comparing the bat species observed in 1999-2000 by Valdez et al. (2002) and in 2003-2004 by Bogan et al. (2007; the lists were nearly the same) to that by Valdez (2012) in 2011, six species were not observed in 2011 that had been observed previously. These are the big free-tailed bat (*Nyctinomops macrotis*), California myotis (*Myotis californicus*), hoary bat (*Lasiurus cinereus*), pallid bat (*Antrozous pallidus*), spotted bat, and canyon bat (*Parastrellus hesperus*). Valdez explains some of these differences as being due to the differences in sampling locations between the efforts and the "uncommon species" captured by Valdez et al. (2002). The pallid


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Figure 4.15.4-1. Bat Cave, in the El Calderon area of El Malpais NM. The cave is closed to the public to protect roosting bats.

bat, for example, was captured in a location by Valdez et al. (2002) that was not sampled in 2011. The hoary bat was captured in low numbers by the earlier studies, and it may be uncommon at the national monument (Valdez 2012); the species may only be present when it migrates through the park. Valdez (2012) questioned the occurrence of two of the species (California myotis and canyon bat; see footnote to the table), suggesting they may have been misidentified by the earlier studies. Although the spotted bat was not captured in 2011, Valdez reported that a single spotted bat was heard overhead during sampling. No discussion was provided by Valdez (2012) on the absence of the big free-tailed bat, but neither was concern expressed for the lack of capture of this species. NPS (2014) notes the spotted bat as rare and the big free-tailed bat as of unknown abundance. Based on the information presented here, we do not have any particular concerns for species occurrence.

Valdez et al. (2002) indicated that the bats they observed were using the area for foraging, roosting, or stopover points during migration. They identified a handful of dominant species based on their mistnet sampling (Western small-footed myotis [*Myotis ciliolabrum*], long-eared myotis [*M. evotis*], long-legged myotis [*M. volans*], and big brown bat [*Eptesicus fuscus*]); the species were common in habitats at middle and high elevations. The three species captured most frequently during the 2011 sampling by Valdez (2012) were long-eared myotis (most abundant), Western small-footed myotis, and fringed myotis (*M. thysanodes*; third most abundant). Four of these five species were documented by all of the four studies, and the fifth (long-legged myotis) was documented by three of the studies. Valdez et al. (2002) considered El Malpais NM to have a moderately diverse bat community.

Most of the species in Table 4.15.4-1 are residents in the area, but a few are known to migrate in the spring and fall (Barbour and Davis 1969, as cited by Valdez 2012). The species known to migrate include the hoary bat, Mexican free-tailed bat, big free-tailed bat, and, possibly, silver-haired bat.

Mexican (or Brazilian) free-tailed bats have been known to use Bat Cave in the summer months for a number of years (Carlton 1988; Figure 4.15.4-1). Carlton (1988) reported that, based on a personal communication with a Dr. Alton Lindsey, the size of the maternity colony in Bat Cave may once have been much larger than it is today (on the order of a few million bats). It was suggested that the decrease in numbers began in the early 1950s with the onset of guano mining. As described previously, park personnel have been estimating the number of bats using the cave in summer over the last few years. From the 2012 to 2015 estimates, a conservative estimate of the peak population is 45,000-50,000 bats (Eric Weaver, Acting Natural Resources Branch Chief, El Malpais NM, pers. comm.).

The four main surveys for species occurrence (shown in the table) were conducted in the spring and summer months (although Lightfoot et al. may have included observations in other months). The park's recent effort to survey lava tube caves for use by hibernating bats was conducted in winter months (December 2014-February 2015). At least five species listed in the table were observed during the hibernacula survey: big brown bat, long-eared myotis, long-legged

myotis, silver-haired bat, and Townsend's big-eared bat (*Corynorhinus townsendii*). Additional species of *Myotis* may also have been present, but the survey protocol does not call for reporting them by species. In this case, observations of long-eared and long-legged myotis were recorded because it represents the first time that the species have been observed hibernating in caves in the national monument (Eric Weaver, Acting Natural Resources Branch Chief, El Malpais NM, pers. comm.). Overall, bats were observed in approximately 30 of the caves surveyed. The greatest count was of 226 Townsend's big-eared bats in one cave in February. Also, based on her work on bats at the national monument, Debbie Buecher has also observed fringed myotis and western small-footed myotis roosting in lava tube caves (Buecher, unpublished results, as cited in Northup 2013)].

In summary, although the species occurrence comparison made here is limited, it does not point to particular concerns for any species at this time. Additionally, seven of the species listed in Table 4.15.4-1 (those observed by three or four of the inventories) have also been observed by one or more of the survey efforts in 2014 and/or 2015 (i.e., big brown bat, Mexican free-tailed bat, long-eared myotis, long-legged myotis, silver-haired bat, Townsend's big-eared bat, and Western small-footed myotis). We therefore consider condition of bats under this indicator/measure to be "good." We do not have sufficient information to report a trend in condition.

Occurrence of *P. destructans* and/or WNS: Presence/Absence

The ten caves at the national monument tested by Northup (2013) for the presence of *P. destructans* included some of those specifically mentioned in this condition assessent as having known summer or winter bat roosting colonies (e.g., Bat Cave, Junction Cave). Based on the results of the most accurate test used (Level 3 Test), all ten of the caves were negative for the presence of *P. destructans*. Northup (2013) reported that, of the caves sampled, Junction Cave was at the greatest risk due to microclimate conditions, presence of hibernating bats, and the presence of a *P. destructans* relative with similar genetic sequences. Concern was also expressed for Cave #108 and Four Windows Cave.

Managers at El Malpais NM close Junction Cave every winter to protect the hibernating Townsend's big-eared bats. Access to all caves, including Junction Cave, was prohibited in 2010 due to WNS concerns, and when Junction Cave was reopened in 2013 it was done so only in the non-winter months. Northup (2013) also discussed the importance of educating the public on WNS and efforts to minimize its spread (which NPS and the national monument are doing), and continued monitoring of the caves with the most conducive microclimate conditions for the fungus and the presence of roosting bats. Both of these activities are being done at the national monument. For example, both Valdez and Northup have continued their research/monitoring on WNS at the park in 2014 and 2015 (Eric Weaver, Acting Natural Resources Branch Chief, El Malpais NM, pers. comm.; Northup et al. 2015). The park is also requiring staff and visitors to the caves to follow the USFWS White-Nose Syndrome Decontamination Protocol.

The goals of the Northup et al. (2015) work were described in Section 4.15.2. During their work, which included handling captured bats from caves and the surface at El Malpais NM, they found no evidence of *P. destructans* or WNS. However, they did observe, for the first time in four years of capturing bats at the national monument, a bat (a Western small-footed myotis) that had visible colonies of fungus. These fungal colonies contained close relatives of *P. destructans*, but no *P. destructans*. Close relatives of *P. destructans* were also found in cave soil/guano cultures (as had been previously reported; Northup 2013).

During the USGS sampling described in Valdez (2012), 421 bats of eight species were documented on the national monument and adjacent lands (see Table 4.15.4-1 for species). None of the captured bats showed evidence of the fungus or WNS. However, Valdez

noted that it is possible that subtle signs of the disease or fungus may have gone undetected, such as due to negative impacts to spring sampling by cold, snowy weather and winds. Valdez (2012) stressed the importance of continued monitoring for the disease through the use of mistnetting and cave monitoring.

Based on the results of these three studies (Northup 2013, Northup et al. 2015, and Valdez 2012), we consider the condition for this indicator/measure to be good at this time. However, awareness and concern for bats at the national monument remains high as this fungus and disease continues to be studied and monitored. Furthermore, only a small proportion of the lava tube caves at El Malpais NM have been/are being monitored for *P. destructans*, and it is possible that other important (and as of yet undiscovered) winter hibernacula exist. It is also worth keeping in mind that at least some caves within the national monument have microclimate conditions suitable for the WNS fungus, and relatives of *P. destructans* have been found in park cave soil/guano and on at least one bat.

Habitat Availability & Condition: Available Habitat Free from/with Minimal Human Disturbance

As mentioned in the *Data and Methods* section, we primarily addressed bat roosting in caves and/or trees in this indicator (Table 4.15.4-2), but bats in general, and some of the bats that occur at the national monument, may also roost in other sites. Bats may roost in or on a variety of structures, such as beneath exfoliating bark, in tree cavities, amongst tree foliage, in abandoned insect and bird nests, in rock crevices, in small and large caves, and in a variety of man-made structures (Murray and Kunz 2004). Table 4.15.4-2 also shows which bat species that have been reported at El Malpais NM have been documented in the park's caves. Note, however, that as the hibernaculum survey and other future work continues to be conducted, additional species may be observed and added to the list. Based on the various reports and surveys reviewed, at least eight species have been observed using caves at the national monument.

Based on the available information, including the continued, observed use of some of the caves by bats, we consider that habitat availability and condition for bats with respect to caves is good. National monument management allows only a small number of caves to be visited by the public, and before the public is allowed to enter a cave they must obtain a free permit and speak with a ranger about cave protection/visitation rules. Further, the park uses cave closures of some caves during times that the bats are present and sensitive. For example, Bat Cave is closed to the public, including during the spring and summer months when Mexican free-tailed bats are in their maternity roost. Junction Cave is closed during the winter (~October through mid-April; Wynne 2013) to protect hibernating Townsend's big-eared and other bats, and a gate was recently installed to prevent unauthorized human entry during the closed period (Eric Weaver, Acting Natural Resources Branch Chief, El Malpais NM, pers. comm.). Additionally, although an area of great uncertainty, we can suppose that other caves within the park that are in relatively inaccessible locations are quite free from human disturbance. The uncertainty, however, is how many such caves exist that are used by bats for roosting.

With regards to bats that roost in trees, the only information available for this assessment are results and general impressions from the field visit on June 2-3, 2015, to the park. The piñon-juniper and ponderosa pine-dominated areas of the park were generally considered to be in good condition. Both living and dead trees were observed and could serve as potentially suitable roosting sites. Although not present in alarming numbers at this time, dead/dying trees, such as ponderosa pines and piñon pines, were observed. Tree deaths were believed to be due to dry conditions over the past several years (Romme and Jacobs 2015).

Some of the bat species that occur at the national monument are known to roost in piñon-juniper and ponderosa pine woodlands. For example, fringed myotis (*Myotis thysanodes*) and long-legged myotis (*Myotis volans*) were found roosting (in maternity roosts) with 30 to more than

Table 4.15.4-2. Bat species recorded in El Malpais NM, showing whether they roost or hibernate in caves or trees, and whether they have been observed in caves at the national monument. Note that a lack of observation/documentation does not mean that they do not occur. Also, cave names are included in only a few instances.

Common Name	Scientific Name	Roosts in Caves (C), Roosts in Trees (T) [1]	Documented Cave Roost at ELMA? [2]	Cave-use Sources [3]	Comments:
Big brown bat	*Eptesicus fuscus*	C, T	Yes	Wynne 2011 and 2013; ELMA 2015	Junction Cave, hibernaculum
Big free-tailed bat	*Nyctinomops macrotis*	rock crevices			
Mexican (or Brazilian) free-tailed bat	*Tadarida brasiliensis*	C	Yes	Carlton 1988; Valdez et al. 2002; Bogan et al. 2007; Wynne 2011 and 2013; ELMA 2015	summer, maternity roost in Bat Cave. Number of bats using the cave in summer has been estimated at various times, and is being done currently by park staff. Peak (conservative) estimate from 2012-2015 is 45-50,000 bats.
California myotis	*Myotis californicus*	C, T	Maybe [4]		see footnote "4" below.
Cave myotis	*Myotis velifer*	C			
Fringed myotis	*Myotis thysanodes*	C, T	Yes	Northup 2013 (citing Buecher unpublished)	
Hoary bat	*Lasiurus cinereus*	T			
Long-eared myotis	*Myotis evotis*	C, T	Yes	ELMA 2015	
Long-legged myotis	*Myotis volans*	C,T	Yes	ELMA 2015	
Pallid bat	*Antrozous pallidus*	C, T			
Silver-haired bat	*Lasionycteris noctivagans*	C, T	Yes	ELMA 2015; Buecher & Northup 2011	hibernating in winter
Spotted bat	*Euderma maculatum*	C			
Townsend's big-eared bat	*Corynorhinus townsendii*	C	Yes	Wynne 2011 and 2013; Valdez et al. 2002; Buecher and Northup 2011; ELMA 2015	both hibernaculum (e.g., Junction Cave) and summer (Braided Cave, Bat Cave); largest known hibernaculum ~100 bats (per Wynne 2011); maternity up to a few hundred.
Canyon bat	*Parastrellus hesperus*	C			
Western small-footed myotis	*Myotis ciliolabrum*	C, T	Yes	Valdez et al. 2002;	summer, Braided Cave, 75-100 individuals; winter, see footnote "3" below.

[1] Although we mention only caves and trees as potential roost sites here, some species may also use rock crevices or cliffs, rock piles, mines, or other man-made structures (e.g., buildings and bridges). We also did not specify whether bats that use trees use live or dead trees, or foliage. This information is based primarily on Williams et al. (2002) and Chung-MacCoubrey (1996).

[2] Note that this is a working list of the species that have been documented in the national monument's caves based on park reports/sources, and that other species may use the caves; and ELMA (2015) does not generally distinguish between species of Myotis.

[3] ELMA (2015) is the park's winter hibernacula survey (results from Dec. 2014-Feb. 2015).

[4] Buecher and Northup (2011) observed hibernating myotis in a few caves; the bats were either Western small-footed myotis or California myotis (species identification could not be made without disturbing the bats).


NPS

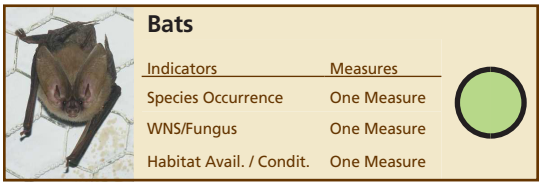
Figure 4.15.4-2. Laguna de Juan Garcia, an important pool of water for bats at El Malpais NM, located in the northwest corner of the park.

200 bats in ponderosa pine snags and live ponderosa pines having long, vertical cracks (Chung-MacCoubrey 1996). The roost trees, in the Cibola National Forest south of the national monument, were located in the ecotone of ponderosa pine and piñon-juniper habitats or in drainages with piñon-juniper on the slopes. The same researcher observed long-eared myotis (*Myotis evotis*) roosting in live and dead junipers.

Although we have no specific information on bat use of piñon-juniper, ponderosa pine, or other vegetation at El Malpais NM, we consider condition good for this aspect of the assessment because of the availablity and condition (see above) of these areas at the park.

Although we have little current information on it (most recent is from Valdez (2012), Valdez (2012) points out the importance of a large pool of water, Laguna de Juan Garcia, situated in the northwest corner of the park, for bats (Figure 4.15.4-2). The pool, used for drinking and possibly foraging, is "the only known water source in the park that appears to hold water throughout the year" (Valdez 2012). The pool, within ponderosa pine forest and near piñon-juniper woodland, is also important because it is accessible to all of the bat species, even those that are less maneuverable. During sampling in 2011, this sampling location had the greatest number of captures during a single night and the highest species diversity; it was also the location where the spotted bat was heard calling overhead (Valdez 2012). Valdez (2012) also reported that the ponderosa pine forest surrounding Laguna de Juan Garcia probably provides foraging habitat for species that are able to maneuver amongst the vegetation (e.g., long-eared myotis).

In summary, for the reasons stated in this section, we consider condition under this indicator/measure to be good at this time. However, some concern has been expressed for potential disturbance to some caves due to their easily accessible location and considerable use by bats.



Overall Condition and Trend

For assessing the condition of bats, we used three indicators with one measure each. All three indicators are summarized in some detail in Table 4.15.4-3. Each of the indicators/measures was judged to be in good condition. Although we are not comfortable judging an overall trend in condition due to insufficient information in some areas, one could make a case for a stable trend in at least the second and third indicators/measures (and the first indicator/measure for the more common species).

Although some of the bat species that have been documented at the national monument have not been observed in recent years (possibly due to their relative rarity or the areas of the park they use), many of the species are observed regularly during surveys of caves during winter, during mistnet sampling for WNS surveillance, or during summer roost counts (in the case of the Mexican free-tailed bat). The spotted bat, a species listed as threatened with the State, was recorded in the national monument and in the county for the first time by Valdez et al. (2002).

The threat of WNS is a concern for bats throughout North America, although to date its closest confirmed presence to El Malpais NM is in Arkansas (see Figure 4.15.2-1). Based on three monitoring efforts at the park, Valdez (2012), Northup (2013), and Northup et al. (2015), neither *P. destructans* nor WNS have been detected in caves or bats within

Table 4.15.4-3. Indicators and measures of bat condition.

Indicator	Measure of Condition	Condition	Rationale for Condition
Species Occurrence	Presence / Absence	Good	Comparing the bat species observed in 1999-2000 by Valdez et al. (2002) and in 2003-2004 by Bogan et al. (2007; the lists were nearly the same) to that by Valdez (2012) in 2011, six species were not observed in 2011 that had been observed previously. However, some of the differences were probably due to differences in sampling locations between the efforts and the fact that some of the species are not common. Also, at least seven species have been documented by park staff and/or Northup et al. (2015) in 2014-2015. Based on the information available, we do not have any particular concerns for species occurrence at this time. There is insufficient data to judge trends.
Occurrence of *P. destructans* and/or WNS	Presence / Absence	Good	The monitoring work of Valdez (2012) captured >400 bats of eight species, and none of the captured bats showed evidence of the fungus or WNS. Valdez noted, however, that some subtle signs of the disease or fungus could have gone undetected. Samples collected and analyzed by Northup (2013) from 10 caves in the national monument were negative for the presence of *P. destructans* using the most accurate test available. Based on these results (and those of Northup et al. 2015), we consider the condition for this indicator/measure to be good at this time. However, awareness and concern for bats at the national monument remains high as this fungus and disease continues to be studied and monitored. Furthermore, only a small proportion of the lava tube caves at El Malpais NM have been/are being monitored for *P. destructans*, and it is possible that other important (and as of yet undiscovered) winter hibernacula exist.
Habitat Availability & Condition	Available Habitat Free from/with Minimal Human Disturbance	Good	We addressed primarily bat roosting (in winter and summer) in caves and/or trees in this indicator. At least eight species have been observed using caves at the national monument, some for hibernating and some for maternity roosts. Based on the available information, including the continued, observed use of some of the caves by bats, we consider habitat availability and condition for bats with respect to caves to be good. Only a small number of caves are open to the public, and prior to cave entrance the public must obtain a permit and speak with a ranger about cave protection/visitation. Also, the park uses cave closures of some caves at especially sensitive times for bats. Additionally, more caves (fairly free from human disturbance) are probably used for roosting than are currently known. Although we have no specific information on bat use of piñon-juniper, ponderosa pine, or other vegetation at El Malpais NM, some of the species that occur at the park are known to roost in trees in these habitats. We consider condition good for this aspect of the assessment because of the availability and condition (judged to be good) of these areas at the park. Additionally, one relatively large and open pool of water on the northeast corner of the park is known to be a valuable resource for drinking and possibly foraging. Overall, we consider condition to be good for this indicator/measure.

the national monument to date. National monument staff are well-alerted, however, to the threat from WNS and the fact that, based on recent research and monitoring efforts, some park caves have microclimate conditions suitable for *P. destructans*.

With regards to habitat availability and condition for bats, we also consider the condition to be good. As described, different caves have various microclimate conditions that are suitable for use by different species, and very few of the park's caves are open to the public. The entrance to Junction Cave was recently gated to assure that people can not enter the cave during its winter closure. Some concern, however, does exist for bats using Bat Cave for their summer maternity roost; this cave is closed to human entry throughout the year, but a gate can not be used to secure the entrance due to issues this species has with gates (Eric Weaver, Acting Natural Resources Branch Chief, El Malpais NM, pers. comm.). To deal with this, however, in 2016, park managers will be installing sensors to detect human movement in the cave, which will then notify law enforcement of the unauthorized entry (Eric Weaver, Acting Natural Resources Branch Chief, El Malpais NM, pers. comm.).

Bats that use trees for roosting also have habitat in good condition available to them.

Overall, the condition of bats at El Malpais NM is good, but continued concern will exist over the westward expansion of WNS. Other positive results of the Northup et al. (2015) research at the national monument is that bacteria (belonging to the genus *Streptomyces*) from bats at the park (sampled from at least three different caves) inhibited the growth of *P. destructans* in laboratory tests. These bacteria may represent a potential natural defense against WNS (Northup et al. 2015).

Level of Confidence/Key Uncertainties

Bats are an interesting and significant component of the wildlife at El Malpais NM, and they have been the subject of a number of inventories/surveys and studies in recent years. Although we based our assessment on these studies, there are some uncertainties related to the assessment (described below). Still, overall, we have high confidence in our assessment.

Some of the key uncertainties include that there has been no comprehensive mistnet sampling in recent years with the purpose of inventorying the species that occur at the park. If we had such information, we could have assessed condition under the first indicator with more confidence. Another area of uncertainty is that many of the lava tube caves have not yet been surveyed for roosting bats. Also, only a small proportion of the lava tube caves (10 caves) have been/are being monitored for the fungus that causes WNS. It also appears that little work has been done on habitat in the national monument used by bats above ground. In our assessment under the third indicator/measure for bats, we relied on the piñon-juniper and ponderosa pine vegetation assessments conducted for this natural resource condition assessment.

El Malpais NM staff also have concerns for the park due to its location relative to the most western-known occurrence of WNS (Arkansas, as of May 2015). The microclimate conditions in some caves at El Malpais NM are suitable for sustaining the WNS fungus, and the caves also provide optimal locations for bats to hibernate during the winter. An additional factor is the heavy visitation of some of the caves by U.S. and international travelers. Together, these factors may put the caves at risk of being the "first contact" for *P. destructans* in New Mexico (Eric Weaver, Acting Natural Resources Branch Chief, El Malpais NM, pers. comm.). However, this is an uncertainty at this time, and El Malpais NM managers are taking precautions against the disease.

4.15.5. Sources of Expertise

No experts were consulted for this resource topic. However, the assessment was based on studies and monitoring conducted for the national monument, and many questions were answered and information supplied by Eric Weaver, Cave Management Specialist and Acting Natural Resources Branch Chief, El Malpais NM. This section was authored by biologist Patty Valentine-Darby.

4.15.6. Literature Cited

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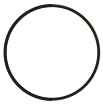
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4.16. Landbirds

Indicators/Measures

- Species Occurrence (1 measure)

Condition – Trend - Confidence



Unknown - Insufficient Data - Medium

4.16.1. Background and Importance

Hundreds of species of birds occur in the American Southwest, as do some of the best birdwatching opportunities. Bird watching is a popular, longstanding recreational pastime in the United States and forms the basis of a large and sustainable industry (Sekercioglu 2002). Birds are a highly visible component of many ecosystems (Figure 4.16.1-1). They are considered good indicators of ecosystem health because they can respond quickly to changes in resource and environmental conditions (Canterbury et al. 2000, Bryce et al. 2002). Relative to other vertebrates, birds are also highly detectable and can be efficiently surveyed with the use of numerous standardized methods (Bibby et al. 2000, Buckland et al. 2001). Like other wildlife, birds are also inherently valuable.

Only a few studies of birds at El Malpais NM have been conducted. Before the early 1990s, birds in the park were "poorly known and undocumented" (Lightfoot et al. 1994); during this time, the most extensive information on birds in the general vicinity of the park were records for the entire county (from the New Mexico Department of Game and Fish [NMDGF], as described by Lightfoot et al. 1994). However, in the early 1990s the University of New Mexico (i.e., Lightfoot et al. 1994) conducted observational surveys at the national monument, recording over 100 species of birds. The next, and most recent standardized inventory of birds at El Malpais NM was conducted by the U.S. Geological Survey (USGS) Biological Resources Division, in 2002-2003 (i.e., Johnson et al. 2007). Johnson et al. (2007) carried out surveys mainly during the breeding season, but also during the winter. No comprehensive avian inventories or monitoring at the park have been conducted since the 2002-2003 Johnson et al. (2007) work, although informal observations by park personnel along some



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Figure 4.16.1-1. Juniper Titmouse (*Baeolophus ridgwayi*) is one of the many species of birds known to inhabit El Malpais NM.

roads at the park exist for more recent years (and are discussed below). Due to the lack of current, standardized data, condition and trends of landbirds cannot be determined at this time.

4.16.2. Data and Methods

For this limited assessment, we used one indicator/measure of condition-- species occurrence: presence/absence, focusing on which landbird species have been observed at the national monument by the three survey/observation efforts.

Indicators/Measures
Species Occurrence: Presence/Absence

Species Occurrence: Presence/Absence

To assess species occurrence at the national monument, we used the 2002-2003 USGS bird surveys, as well as the observational surveys conducted by Lightfoot et al. (1994) and the observational sightings along roads conducted by park personnel in the past few years. We also reviewed the NPSpecies list of birds for the park (NPS 2014a).

The 2002-2003 work was based on standardized bird surveys (primarily during the breeding season), while the other two sources of information used more informal methods. Because the methods used were not the same, it would be inappropriate to compare the results of the surveys directly. With the use of the three sources of information, we evaluated species occurrence by assembling a list of species that have been recorded at the national monument. Because the resources used to compile the list included periods throughout the year, the list of species is not confined to species that breed within the park.

The Occurrence of Species of Conservation Concern

Our intent for this aspect of the assessment was to determine which species that occur or have occurred at El Malpais NM are considered species of conservation concern at either national or local scales. Note that we use the phrase "species of conservation concern" in a general sense; it is not specifically tied to use by any one agency or organization. We took the overall list of species for the national monument recorded by Johnson et al. (2007), Lightfoot et al. (1994), and park staff (from 2011-early 2015), and compared it to multiple species of conservation concern lists (e.g., a federal/state list of endangered and threatened species, those of Greatest Conservation Need in New Mexico, and those used by other organizations). The specific lists we used are described below.

There have been a number of such organizations that focus on the conservation of bird species. Such organizations may differ, however, in the criteria they use to identify and/or prioritize species of concern based on the mission and goals of their organization. They also range in geographic scale from global organizations, such as the International Union for Conservation of Nature (IUCN), who maintains a "Red List of Threatened Species," to local organizations or chapters of larger organizations. This has been, and continues to be, a source of confusion, and perhaps frustration, for managers and others who need to make sense of and apply the applicable information. In recognition of this, the U.S. North American Bird Conservation Initiative (NABCI) was started in 1999; it represents a coalition of government agencies, private organizations, and bird initiatives in the United States working to ensure the

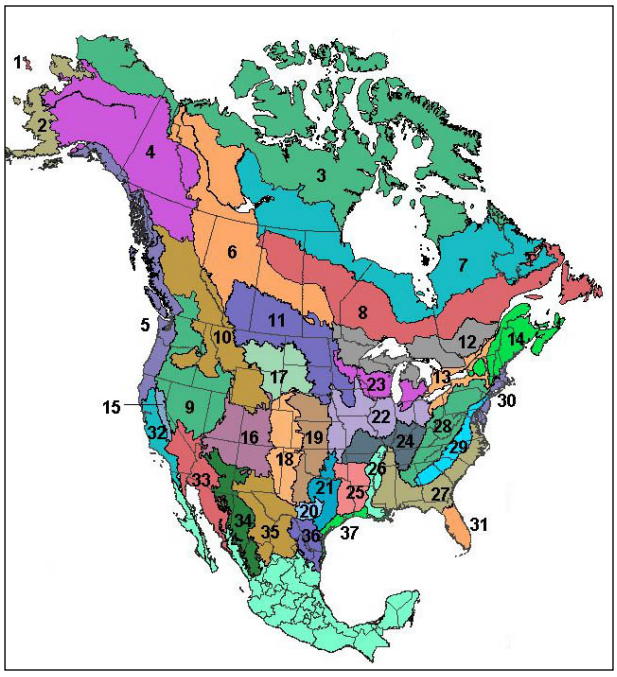


Figure 4.16.2-1. Bird Conservation Regions in North America.

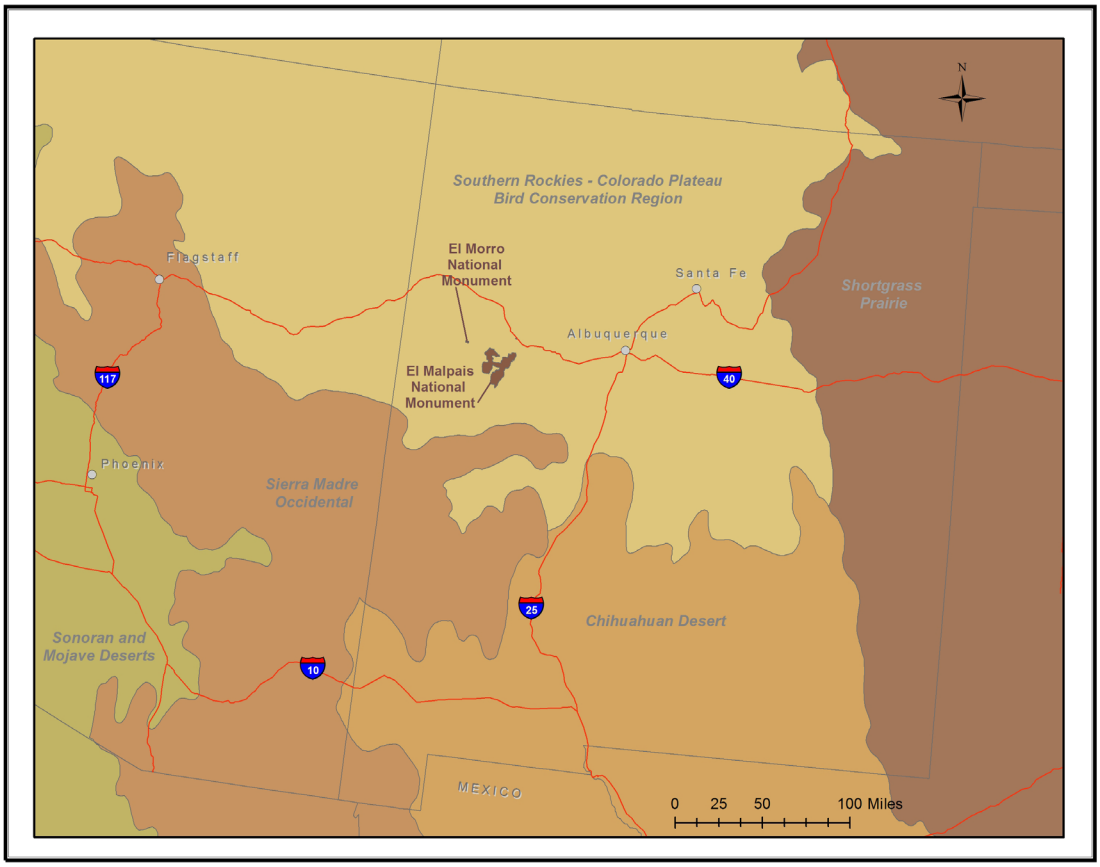


Figure 4.16.2-2. Bird Conservation Regions in the vicinity of El Malpais NM and El Morro NM. Both parks are within the Southern Rockies - Colorado Plateau BCR (BCR 16).

conservation of North America's native bird populations. Although there remain a number of sources at multiple geographic and administrative scales for information on species of concern, several of which are presented below, the NABCI has made great progress in developing a common biological framework for conservation planning and design.

One of the developments from the NABCI was the delineation of Bird Conservation Regions (BCRs) (U.S. North American Bird Conservation Initiative 2014). Bird Conservation Regions are ecologically distinct regions in North America with similar bird communities, habitats, and resource management issues (Figure 4.16.2-1). El Malpais NM, as well as El Morro NM, lie within the Southern Rockies - Colorado Plateau BCR (BCR-16; Figure 4.16.2-2).

Conservation Organizations Listing Species of Conservation Concern

Below we identify some of the organizations/efforts that list species of conservation concern; these are the listings we used for this condition assessment. Appendix G presents additional details on each of the organizations/efforts. Note that in addition to the U.S. Fish and Wildlife Service (USFWS) maintaining a list of endangered and threatened species (first bullet below), they maintain a list of species protected under the Migratory Bird Treaty Act (MBTA; USFWS 2016). This Act, which protects 1,026 birds, regulates "the taking, possession, transportation, sale, purchase, barter, exportation, and importation of migratory birds" (USFWS 2013a). Although we did not compare the list of birds that have been recorded at El Malpais NM to this extensive list, the MBTA is discussed in Appendix G. An updated list of species protected under the Act can be found in USFWS (2013a).

- U.S. Fish & Wildlife Service: Under the Endangered Species Act, the USFWS lists species as threatened, endangered, or candidates for listing.
- New Mexico Department of Game and Fish (NMDGF): In New Mexico, wildlife species are designated as threatened and endangered under the

New Mexico Wildlife Conservation Act (NMDGF 2015a). For each endangered or threatened species, the NMDGF develops a recovery plan. A database of all vertebrate species in New Mexico, including threatened and endangered species, is maintained and can be searched online (NMDGF 2015b). The database is called the Biota Information System of New Mexico (BISON-M).

- USFWS: This agency also developed lists of birds of conservation concern according to: the Nation, USFWS Region, and BCR.
- The National Audubon Society (NAS) and American Bird Conservancy (ABC): These groups combined efforts to produce a "Watch List," based on, but not identical to, the Partners in Flight approach to species assessment (see below). The 2007 WatchList has two primary levels of concern: a "Red Watchlist," which identifies what these organizations consider as species of highest national concern; and a "Yellow WatchList," which is made up of species that are somewhat less critical.
- Partners in Flight (PIF): This is a cooperative effort among federal, state, and local government agencies, as well as private organizations. PIF has adopted BCRs as the geographic scale for updated regional bird conservation assessments. At the scale of the individual BCRs, there are species of Continental Importance (Continental Concern [CC] and Continental Stewardship [CS]) and Regional Importance (Regional Concern [RC] and Regional Stewardship [RS]). We did not include the CS or RS species in our assessment. The list for BCR 16 was be obtained online (Rocky Mountain Bird Observatory 2015).
- NM Species of Greatest Conservation Need (SPGN): Under the Comprehensive Wildlife Conservation Strategy (CWCS) for New Mexico, SGCN have been designated in the state (NMDGF 2006). Of the 452 vertebrate, mollusc, and arthropod SGCN statewide, about 74 are birds. There are lists of SGCN for the entire state, as well as those for each of the individual ecoregions in New Mexico. The ecoregion in which El Malpais NM occurs is the Arizona-New Mexico Mountains (NMDGF 2006). The BISON-M database maintains information on which species are SGCN, and it provides lists of species so designated for Cibola County (and other counties; NMDGF 2015b). Note that we obtained both the ecoregion list from NMDGF (2006) and the county list from NMDGF (2015b), and the lists differed somewhat. To take a conservative approach in our assessment, we compared both lists to our list of species for the national monument.

Data Sources

Data/information used as part of this assessment include: surveys conducted by Lightfoot et al. (1994) in 1991-1993; surveys conducted by Johnson et al. (2007) in 2002-2003; and observations made by park personnel along roads in 2011-early 2015. These efforts to collect information on occurrence of birds at El Malpais NM are described below.

Lightfoot et al. (1994)

Lightfoot et al. (1994) made routine observations of birds at the national monument as part of a larger vegetation and wildlife inventory. This group of animals was surveyed by making observations during study site visits (in general, multiple visits to 101 study sites) and while driving at the park, particularly along state highways 117 and 53 and county road 42. The overall survey was conducted over three years in the early 1990s (1991-1993); birds were observed during all three years at various times throughout the calendar year. Lightfoot et al. (1994) reported observing more than 100 bird species.

Johnson et al. (2007) Avian Inventory

In 2002-2003, the USGS conducted avian inventories at El Malpais NM primarily during the breeding season (Johnson et al. 2007). From May 19-July 10, three breeding season surveys were conducted each year. The researchers used point-count surveys in the main habitat types at the national monument-- ponderosa pine, pinyon-juniper, mixed pinyon-juniper/ponderosa

pine, grassland, and shrubland. Both random and non-random points were used, for a total of 207 point-count surveys at 69 point-count stations. Incidental observations and area-search surveys were also conducted during each breeding season, emphasizing habitat not covered well during point-count surveys. In February of 2003, a one-day, non-breeding winter survey was conducted. For each species recorded during the breeding season, they reported evidence of breeding (e.g., bird seen carrying nesting material, adults seen carrying food, pair observed in suitable nesting habitat). Johnson et al. (2007) reported a total of more than 70 species during their work.

El Malpais NM eBird Data

No comprehensive, park-wide or habitat-specific surveys of birds have occurred at the park since that by Johnson et al. (2007) in 2002-2003. However, park personnel and trained volunteers have conducted observations (i.e., recorded sightings) of birds along Highway 53 and/or 117 regularly from January/February until May/June, and more sporadically throughout the remainder of the year, since 2011 (David Hays, former Natural Resources Branch Chief, El Malpais NM, pers. comm.). The sightings are uploaded and maintained in eBird (Audubon and Cornell Lab of Ornithology 2015). Records used for this condition assessment were provided by park staff in March, 2015.

eBird is an online checklist program that was launched in 2002 by the Cornell Lab of Ornithology and National Audubon Society (Audubon and Cornell Lab of Ornithology 2015). eBird reports on the occurrence (presence or absence) of bird species, as well as other information, using data from checklists provided by recreational and professional bird watchers. Cumulative lists of bird species are available for El Malpais NM based on observations from park personnel (see above) and others. Lists are available for several locations along Highways 117 on the east side of the park and 53 along the northwest side of the park. eBird data for the park from the eBird website include years prior to 2011; we examined data from the pre-2011 years for records on additional bird species.

NPSpecies List

The list of birds for the national monument from NPSpecies was also reviewed (NPS 2014a; obtained from IRMA in November 2014). We used the list as supporting information and for the inclusion of additional species not recorded in the three park survey/observation efforts.

4.16.3. Reference Conditions

No reference conditions were developed for this resource topic. This is because no two similar studies or surveys to compare species occurrence exist (e.g., to examine changes in species occurrence over time), and no comparable recent information is available. For example, surveys by Johnson et al. (2007) were conducted during the breeding season only, while observations by Lightfoot et al. (1994) occurred throughout the year. However, the information presented from the surveys/inventories that do exist provides a good baseline for future monitoring and assessment for bird species occurrence at the national monument. In other words, if standardized surveys of birds are conducted in the future, the new survey results could be compared to the survey/inventory results from the early 2000s (and the results of Lightfoot et al. 1994). The survey results from the early 2000s could become the reference conditions for the future assessments. Even if we had presented the results of the Johnson et al. (2007) work as our reference conditions now, we would not have had any current information on species occurrence to judge condition.

4.16.4. Condition and Trend

There have been a total of approximately 183 bird species reported at El Malpais NM from the 2002-2003 USGS surveys, the 1991-1993 University of New Mexico surveys, and/or the 2011-early 2015 observations by national monument staff/volunteers (Appendix H). Note that a number of additional species appear on the NPSpecies list for the park (NPS 2014a), and they are discussed below.

Starting with the earliest of the three survey/observation efforts, Lightfoot et al. (1994) recorded a total of 109 species. Johnson et al. (2007) recorded 75 species, 70 during their point count surveys and five during the additional area searches and incidental observations. Recall that the USGS/Johnson et al. (2007) surveys were conducted almost entirely during the breeding season. Park staff/volunteers have reported a total of 168 species during their observations (subspecies are excluded from this number, as are cases where the genus but not species was identified). Because the entire list of species recorded from these three survey efforts is lengthy, it is presented in the appendix. However, note that 76 species were reported from one survey only, 46 species were reported by two surveys, and 61 species were reported by all three surveys.

Prior to obtaining the eBird data from park personnel, a search of data from the eBird site revealed that 91 bird species had been recorded for the park from 1993 to 2014. There were only six species that appeared in this dataset but not that from the park for 2011-early 2015; these six species are shown in a footnote in Appendix H. The park eBird dataset for 2011-early 2015 included many species not included in the 1993-2014 eBird dataset.

For the 70 species recorded by Johnson et al. (2007) during point count surveys, analyses were also conducted to examine species distribution and relative abundance across habitats. A brief summary of some of this information is presented here because they are the only such analyses that have been conducted at the national monument, and they are of interest. For example, the greatest number of species were detected in ponderosa pine habitat (54), followed by pinyon-juniper and mixed pinyon-juniper/ponderosa pine habitats (47 and 45, respectively). Twenty-two species were observed in grassland habitat. Overall (for all habitat types combined), species recorded in the highest numbers during point counts were: Cassins's Kingbird (*Tyrannus vociferans*), Ash-throated Flycatcher (*Myiarchus cinerascens*), Pinyon Jay (*Gymnorhinus cyanocephalus*), Rock Wren (*Salpinctes obsoletus*), Mourning Dove (*Zenaida macroura*), Northern Mockingbird (*Mimus polyglottos*), and Chipping Sparrow (*Spizella passerina*), respectively.

Additional Species from NPSpecies List

The NPSpecies list for the park (NPS 2014a) contained 33 additional bird species (excluding those only "probably present") that were not recorded by the three surveys/observation efforts used for the assessment. The vast majority of these species are noted as rare or uncommon migrants, but four of the species are noted as rare breeders (Common Grackle [*Quiscalus quiscula*], Northern Saw-whet Owl [*Aegolius acadicus*], Painted Redstart [*Myioborus pictus*], and Western Screech-Owl [*Megascops kennicottii*]). Note that we did not include these birds when compiling the list of species of conservation concern, and they do not appear in Appendix H.

Species of Conservation Concern

There are 46 species that have been recorded during one or more of the three surveys/observation efforts at El Malpais NM that are listed as species of conservation concern on one or more of the lists described in Section 4.16.2 and Appendix G (Table 4.16.4-1). Table 4.16.4-2 indicates in which surveys the species were observed. Only eight of the species were detected in all three survey efforts.

- USFWS / Listed Species: There are no bird species listed by the USFWS as endangered or threatened (USFWS 2015) that are known to occur at the national monument (Table 4.16.4-1). However, as discussed below (under Federally-listed Species), there are three species that may occur outside the park and/or within the county (and could pass through the park) and of which park personnel are aware (NPS 2014b).
- State of New Mexico / Listed Species: Three state-listed birds, all threatened, have been recorded at the national monument (Gray Vireo [*Vireo vicinior*], Bald Eagle [*Haliaeetus leucocephalus*], and Peregrine Falcon [*Falco peregrinus*]; Johnson et al. 2007, NPS 2014a, NMGFD 2015b).

Table 4.16.4-1. Summary of species detected during the three sets of surveys/observations (Johnson et al. 2007, Lightfoot et al. 1994, and the park's eBird data for 2011-early 2015) at El Malpais NM of conservation concern, as listed by government agencies and non-governmental organizations.

Common Name	Listed Species		Species of Conservation Concern Lists							Notes
	Federal[1]	State[2]	US Fish & Wildlife Service			NAS/ ABC[3]	Partners in Flight National Conservation Strategy[4]		State (NMDGF) [5]	
	USFWS	NMDGF	National	Region 2	BCR 16	2007 Watch List	BCR 16 CC	BCR 16 RC	Species of Greatest Conservation Need	
Bald Eagle		T	●	●	●				●	
Band-tailed Pigeon									●	
Bendire's Thrasher			●	●	●	●	●	●	●[A]	A=on SGCN *county* list only.
Black-chinned Sparrow			●	●		●	●			
Black-throated Gray Warbler									●	
Brewer's Sparrow			●		●	●		●		
Burrowing Owl				●	●				●	
Calliope Hummingbird			●			●				
Cassin's Finch					●		●	●		
Chestnut-collared Longspur				●	●	●				
Clark's Nutcracker								●		
Common Nighthawk								●		
Common Poorwill								●		
Eared Grebe									●[A]	A=on SGCN *county* list only.
Ferruginous Hawk					●			●	●	
Flammulated Owl			●	●	●	●	●			
Golden Eagle				●	●			●	●	
Grace's Warbler			●	●	●	●			●	
Gray Vireo		T	●	●	●	●	●	●	●	
Juniper Titmouse					●				●	
Lark Bunting				●		●				
Lazuli Bunting								●		
Lewis's Woodpecker			●	●	●	●		●	●[A]	A=on SGCN *county* list only.
Loggerhead Shrike			●	●				●	●	
Long-billed Curlew			●	●	●	●			●[A]	A=on SGCN *county* list only
Mountain Bluebird								●		

[1] **Federal Listed Species Codes**
T = Threatened PT= Proposed Threatened
E = Endangered

[2] **State Listed Species Codes**
T = Threatened
E = Endangered

[3] **NAS/ABC - 2007 Watchlist**
● = Red List
● = Declining or Rare

[4] **PIF NCS Categories**
CC = Continental Concern RC = Regional Concern

[5] **Species of Greatest Conservation Need**
in Cibola County / Arizona-New Mexico Mountains ecoregion)

Table 4.16.4-1. Summary of species detected during the three sets of surveys/observations (Johnson et al. 2007, Lightfoot et al. 1994, and the park's eBird data for 2011-early 2015) at El Malpais NM of conservation concern, as listed by government agencies and non-governmental organizations (continued).

Common Name	Listed Species		Species of Conservation Concern Lists							Notes
	Federal[1]	State[2]	US Fish & Wildlife Service			NAS/ ABC[3]	Partners in Flight National Conservation Strategy[4]		State (NMDGF) [5]	
	USFWS	NMDGF	National	Region 2	BCR 16	2007 Watch List	BCR 16 CC	BCR 16 RC	Species of Greatest Conservation Need	
Mountain Plover			●	●	●	●			●	
Mourning Dove									●	
Northern Goshawk									●	
Northern Harrier									●[A]	A=on SGCN *county* list only
Olive-sided Flycatcher			●				●	●	●	
Peregrine Falcon		T	●	●	●				●	
Pinyon Jay			●	●	●	●	●	●	●	
Prairie Falcon								●		
Rufous Hummingbird			●							
Sage Sparrow						●		●		
Sage Thrasher									●[A]	A=on SGCN *county* list only
Scaled Quail						●			●	
Solitary Sandpiper			●	●						
Swainson's Hawk			●			●				
Virginia's Warbler			●			●	●			
Western Sandpiper						●				
White-faced Ibis									●[A]	A=on SGCN *county* list only; Observed just outside park by Lightfoot et al. 1994.
Williamson's Sapsucker						●			●	
Wilson's Phalarope									●	
Yellow Warbler									●	

[1] **Federal Listed Species Codes**
T = Threatened PT= Proposed Threatened
E = Endangered

[2] **State Listed Species Codes**
T = Threatened
E = Endangered

[3] **NAS/ABC - 2007 Watchlist**
● = Red List
● = Declining or Rare

[4] **PIF NCS Categories**
CC = Continental Concern RC = Regional Concern

[5] **Species of Greatest Conservation Need**
in Cibola County / Arizona-New Mexico Mountains ecoregion)

Table 4.16.4-2. Species of conservation concern detected during one, two, or three of the three sets of surveys/observations at El Malpais NM. Note that Lightfoot et al. (1994) included some species that were observed just outside of national monument boundaries.

Common Name	Johnson et al. (2007) in 2002-2003	Lightfoot et al. (1994) in 1991-1993	eBird/Park Observations 2011-early 2015
Bald Eagle			•
Band-tailed Pigeon		•	•
Bendire's Thrasher			•
Black-chinned Sparrow			•
Black-throated Gray Warbler	•	•	•
Brewer's Sparrow		•	•
Burrowing Owl		•	•
Calliope Hummingbird			•
Cassin's Finch		•	•
Chestnut-collared Longspur			•
Clark's Nutcracker		•	•
Common Nighthawk	•	•	•
Common Poorwill		•	•
Eared Grebe			•
Ferruginous Hawk			•
Flammulated Owl			•
Golden Eagle		•	•
Grace's Warbler	•	•	•
Gray Vireo	•		•
Juniper Titmouse	•	•	•
Lark Bunting			•
Lazuli Bunting			•
Lewis's Woodpecker		•	•
Loggerhead Shrike		•	•
Long-billed Curlew			•
Mountain Bluebird	•	•	•
Mountain Plover		•	•
Mourning Dove	•	•	•
Northern Goshawk		•	•
Northern Harrier		•	•
Olive-sided Flycatcher			•
Peregrine Falcon			•
Pinyon Jay	•	•	•
Prairie Falcon			•
Rufous Hummingbird		•	•
Sage Sparrow		•	
Sage Thrasher		•	•
Scaled Quail		•	
Solitary Sandpiper			•
Swainson's Hawk		•	
Virginia's Warbler	•	•	•
Western Sandpiper			•

Table 4.16.4-2. Species of conservation concern detected during one, two, or three of the three sets of surveys/observations at El Malpais NM (continued).

Common Name	Johnson et al. (2007) in 2002-2003	Lightfoot et al. (1994) in 1991-1993	eBird/Park Observations 2011-early 2015
White-faced Ibis		•	
Williamson's Sapsucker			•
Wilson's Phalarope			•
Yellow Warbler		•	•

- USFWS / Birds of Conservation Concern: There are 26 species that have been recorded at the national monument that have been identified by USFWS as having the greatest conservation need at a National, USFWS Regional, or BCR geographic scale (USFWS 2008).
- NAS / ABC: There are 19 species that occur or have occurred at the national monument that are included on the NAS/ABC 2007 WatchList. Four species, Bendire's Thrasher (*Toxostoma bendirei*), Black-chinned Sparrow (*Spizella atrogularis*), Lewis's Woodpecker (*Melanerpes lewis*), and Mountain Plover (*Charadrius montanus*), are on the Red List. The other 15 species are on the Yellow List, either because of population declines (7) or because they are rare (8).
- PIF: Twenty of the 46 bird species in Table 4.16.4-1 are listed by PIF as either CC or RC (recall we did not include the stewardship categories). Eight of the species are listed as Continental Concern and 17 of the species are listed as Regional Concern (some species are listed as both).
- New Mexico Species of Greatest Conservation Need: Twenty-seven of the species recorded during one or more of the survey/observation efforts are considered Species of Greatest Conservation Need in Cibola County / the Arizona-New Mexico Mountains ecoregion (NMDGF 2006, 2015b).Ten of the species appear only on this list (i.e., as only a SGCN).

Federally-listed Species

There are three federally-listed bird species that are not known to occur within the national monument but are known from or may occur in Cibola County (USFWS 2015; NMDGF 2015b); these are the Mexican Spotted Owl (*Strix occidentalis lucida*; threatened), Southwestern Willow Flycatcher (*Empidonax traillii extimus*; endangered), and Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*, western population; threatened).

Two areas of critical habitat have been designated for the Mexican Spotted Owl in the Cibola National Forest north of the national monument (one north of Interstate 40 and one south of the interstate [but north of Highway 53]; USFWS 2004). To date, no Mexican Spotted Owls have been recorded in the national monument (David Hays, former Natural Resources Branch Chief, El Malpais NM, pers. comm). The park informally consulted with the USFWS in the 1990s concerning the owl, and it was concluded that the monument did not contain habitat suitable (in composition, density, or aspect) for nesting or roosting (Lujan 1999); occasional visits by foraging owls, however, were not ruled out. This was based on two field trips by USFWS and NPS personnel to potential owl habitat within the monument.

Information from BISON-M for the Southwestern Willow Flycatcher indicates that the species is rare in Cibola County. Additionally, critical habitat has been designated for the species in the state (in nearby counties), but the habitat is not in close proximity to the national monument (USFWS 2013b); critical habitat was designated in the two counties south of Cibola County, Catron and Socorro, but not close to the southern Cibola County border. The critical habitat in Socorro County extends north into Valencia County (the county to the east of Cibola) to the east of Interstate 25.



Landbirds

Indicator	Measure
Species Occurrence	Presence/Absence

Overall Condition and Trend

To assess condition of landbirds at El Malpais NM, we used one indicator/measure that is summarized in Table 4.16.4-3. The information presented in this assessment is from the most recent standardized surveys at the park, conducted in 2002-2003 by the USGS (Johnson et al. 2007), as well as previous surveys by the University of New Mexico (Lightfoot et al. 1994) and observations by national monument staff/volunteers in 2011-early 2015.

At least 183 bird species have been recorded in the national monument; this number does not include subspecies, which park staff have been recording in recent years. Current condition and trends can not be assessed due to the lack of recent data from standardized sampling (or at least comparable efforts). However, the three surveys/efforts conducted to date provide good information on species occurrence in general. The Johnson et al. (2007) work focused on species breeding within the park, while the other efforts included numerous observations outside of the breeding season. Forty-six of the species documented at the park appear on one or more various lists of species of conservation concern. Three species, including the Bald Eagle (Figure 4.16.4-1), are listed as threatened with the State of New Mexico.



NPS

Figure 4.16.4-1. A pair of Bald Eagles (*Haliaeetus leucocephalus*) at a snag in the North Pastures at El Malpais NM.

Although we judge the condition unknown due to insufficient data in the context of the condition assessment, it seems clear that El Malpais NM is inhabited by a diverse array of birds, at least some of which breed in the park.

Level of Confidence/Key Uncertainties

The key uncertainties related to this assessment are the overall lack of data (e.g., no two sources of information/data of comparable methods and effort). Additionally,

Table 4.16.4-3. Indicator/measure of landbirds condition.

Indicator	Measure	Condition	Condition Rationale
Species Occurrence	Presence/ absence	Unknown	We used one indicator/measure, species occurrence, to assess the condition of landbirds at El Malpais NM. There are no current data representative of the entire park to assess current condition of birds at the national monument. The most recent standardized surveys were conducted in 2002-2003 during the breeding season (i.e., Johnson et al. 2007). Recent observations (2011-early 2015) have been conducted by park personnel from January/February until May/June and throughout the remainder of the year along roads bordering the monument (Highway 53 and 117). Although condition can not be determined at this time, the three efforts to survey/observe birds at the park have led to a substantial list of birds. At least 183 bird species have been recorded (and more if subspecies are included), including 46 species that appear on one or more lists of birds of conservation concern. This list includes three state-listed (threatened) bird species (Bald Eagle, Gray Vireo, and Peregrine Falcon).

only the 2002-2003 surveys by Johnson et al. (2007) were conducted primarily during the breeding season, and this was the only study that provided evidence of breeding by birds observed.

4.16.5. Sources of Expertise

No outside experts were consulted for this resource topic. This section was authored by biologist Patty Valentine-Darby.

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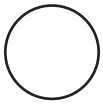
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4.17. Herpetofauna

Indicators/Measures

- Species Occurrence (1 measure)

Condition – Trend – Confidence



Insufficient Data - Insufficient Data - Medium

4.17.1. Background and Importance

The American Southwest is well known for its abundance and diversity of reptiles. The region is less well known for its amphibians, but they are abundant in some habitats, particularly during favorable weather conditions. Amphibians and reptiles are, together, referred to as herpetofauna or "herps." At least 123 species of herpetofauna (166 including subspecies) occur in the state of New Mexico (Degenhardt et al. 1996; Figure 4.17.1-1).

Amphibians and reptiles are important members of aquatic and terrestrial ecosystems. Amphibians constitute an important part of the food web; they consume insects and other invertebrates, and they are prey for a long list of fish, reptile, bird, and mammal species. Reptiles too serve as both predators and prey for many animals, such as small mammals, birds, and other reptiles. Amphibians are also viewed as indicators of wetland ecosystem health (U.S. Environmental Protection Agency 2002). They are sensitive to a variety of threats due to their permeable skin and complex life histories, and, thus, can serve as early indicators of ecosystem change when monitored over long time scales. Like birds, reptiles and amphibians are also of aesthetic value to visitors of national park units.

El Malpais NM is located in west-central New Mexico on the slopes of the Zuni Mountains. Much of the park is surrounded by Cibola National Forest and the El Malpais National Conservation Area. Plant communities found at the park include ponderosa pine forests and pinyon-juniper woodlands, as well as grasslands and shrublands. Substantial portions of the park's lava flows are sparsely vegetated. The park contains little surface water. Sources of water for wildlife include ponding at the edges of lava flows due to



NPS / MURPHY)

Figure 4.17.1-1. Canyon treefrog, one of the herpetofaunal species found at El Malpais NM; the treefrog shown here is resting on lava.

runoff from rain or snowmelt, tinajas in sandstone outcrops, and a few intermittent drainages (Thomas et al. 2006).

No current information is available on the herpetofauna of El Malpais NM. The most recent information is from surveys conducted at the park (and 11 other Southern Colorado Plateau Network parks) by the U.S. Geological Survey (USGS) Southwest Biological Science Center in 2002-2003 (Nowak and Persons 2008). As it is the most recent, comprehensive source of information on herpetofauna for the park, this chapter summarizes the Nowak and Persons (2008) report. Unfortunately, current condition and trends cannot be assessed due to the lack of current data.

Prior to the 2002-2003 Nowak and Persons (2008) surveys, two other surveys of reptiles and amphibians were conducted within the park (Lightfoot et al. 1994) or in the vicinity of the park (Gehlbach 1965), and the results of these studies are also discussed here.

4.17.2. Data and Methods

This limited assessment is based on the 2002-2003 amphibian and reptile surveys conducted by the USGS (i.e., Nowak and Persons 2008). We used one indicator/measure of condition-- species occurrence: presence/absence.

Indicators/Measures

Species Occurrence: Presence/Absence

Species Occurrence: Presence/Absence

Because there is no recent information to assess current condition, we used the 2002-2003 surveys to assess the occurrence of amphibian and reptile species at the national monument. We also included information on species reported in the park during the earlier inventory by Lightfoot et al. (1994).

The Occurrence of Species of Conservation Concern

The surveys by Nowak and Persons (2008) and Lightfoot et al. (1994) were used to generate a list of species of conservation concern (note that we use this term in a general sense). The list was compiled by comparing the list of species observed during the two surveys to a federal/state list of endangered and threatened species (described later) and those of Greatest Conservation Need in New Mexico (described later). We also reviewed the NPSpecies list for the park (i.e., NPS 2014) to see whether any additional species should be included.

Primary Data Sources

Nowak and Persons (2008)

The primary objectives of this work were to provide a baseline inventory of herpetofauna and document 90% of the herpetofauna species present at the park, identify species of special concern, and make recommendations for a monitoring program (Nowak and Persons 2008). In order to observe as many species as possible, a variety of sampling methods were used: general surveys, night driving, time-area constrained searches (TACS), and nocturnal general surveys. About 119 person-hours were spent on the surveys in 2002-2003. General surveys were visual encounter surveys that were not defined or limited by area or time; they were conducted primarily during the daytime. The TACS were visual encounter surveys that involved moving through each habitat in a systematic manner within the sampling area and for a predefined period of time, while searching potential habitats within the sampling area. Random TACS plot surveys were conducted within both 1 and 10-hectare areas. Finally, night driving surveys were used and are especially effective for snakes and amphibians. Additional details on these methods are provided in Nowak and Persons (2008). These researchers also named several additional species that probably occur or may occur at the park.

Lightfoot et al. (1994)

Lightfoot et al. (1994) conducted surveys for reptiles and amphibians at the national monument as part of a larger vegetation and wildlife inventory. Not many details are presented in the report regarding survey methods for amphibians and reptiles. This group of animals was recorded during study site visits (in general, multiple visits to 101 study sites) and while driving at the park, particularly along state highways 117 and 53 and county road 42. Lightfoot et al. (1994) included additional information on the earlier

study by Gehlbach (1965), which focused on amphibians and reptiles of the Zuni Mountains area, including land around the present-day park (Lightfoot et al. 1994).

Protected/Rare Species Lists

In New Mexico, wildlife species are designated as threatened and endangered under the New Mexico Wildlife Conservation Act (New Mexico Department of Game and Fish [NMDGF] 2015a). For each endangered or threatened species, the NMDGF develops a recovery plan. A database of all vertebrate species in New Mexico, including threatened and endangered species, is maintained and can be searched online (NMDGF 2015b). The database is called the Biota Information System of New Mexico (BISON-M). Under the Endangered Species Act, the U.S. Fish and Wildlife Service (USFWS) lists species as threatened, endangered, or candidates for listing. Lists of federal and state-listed species (i.e., USFWS 2015 and NMDGF 2015b) were obtained and compared to the list of amphibian and reptile species recorded at the national monument.

Under the Comprehensive Wildlife Conservation Strategy (CWCS) for New Mexico, Species of Greatest Conservation Need (SGCN) have been designated in the state (NMDGF 2006). Of the 452 vertebrate, mollusc, and arthropod SGCN statewide, 47 are reptiles and amphibians. There are lists of SGCN for the entire state, as well as those for each of the individual ecoregions in New Mexico. The ecoregion in which El Malpais NM occurs is the Arizona-New Mexico Mountains. The BISON-M database maintains information on which species are SGCN, and lists of species so designated for Cibola County (and other counties) are available (NMDGF 2015b).

4.17.3. Reference Conditions

No reference conditions were developed for this resource topic.

4.17.4. Condition and Trend

A total of 21 species of amphibians and reptiles were recorded at El Malpais NM during 2002-2003 surveys by USGS (Nowak and Persons 2008) and/or during the early 1990s surveys by University of New Mexico (Lightfoot et al. 1994). Several additional species are noted as "probably present" or "unconfirmed" by Nowak and Persons (2008) and NPS (2014). These species are discussed in this section as appropriate.

Species Occurrence: Presence/Absence

Of the 21 species, 18 were recorded during the 2002-2003 surveys (Table 4.17.4-1). Five of the 18 species are amphibians, and 13 of the species are reptiles. Seventeen of the 21 species were recorded during the early 1990s surveys by Lightfoot et al. (1994; three amphibians and 14 reptiles). Fourteen of the 21 species were observed in both surveys.

There were only three species that were recorded by Lightfoot et al. (1994) but not by Nowak and Persons (2008), with the occurrence/identification of one of the species (Chihuahuan whiptail [*Cnemidophorus exsanguis*]) questioned by Nowak and Persons (2008). The other two species were canyon treefrog (*Hyla arenicolor*) and many-lined, or variable, skink (*Eumeces multivirgatus*). Nowak and Persons (2008) suggested the drought conditions during their sampling may have affected their detection of the canyon treefrog. NPS (2014) noted both of these species as uncommon in the park.

Most of the herpetofauna species recorded at El Malpais NM during 2002-2003 are widespread and common species (Nowak and Persons 2008). One exception to this is the mountain treefrog, which was detected by Nowak and Persons (2008) at only one location. It was found in the northwestern portion of the monument, and this is about 90 miles (145 km) north of the closest known population. This species was not observed by Lightfoot et al. (1994).

Both Nowak and Persons (2008) and Lightfoot et al. (1994) provide some information on where particular species were observed, as well as which species were observed in the highest total numbers.

The authors of the 2002-2003 inventory estimated that inventory completeness at the park was 78%, meaning that additional

Table 4.17.4-1. Amphibian and reptile species recorded in El Malpais NM during surveys in 2002-2003 by Nowak and Persons (2008) and in the early 1990's by Lightfoot et al. (1994). For the species recorded by one or both of these surveys, we also indicate whether they were reported by Gehlbach (1965).

Common Name	Scientific Name	Nowak and Persons (2008)	Lightfoot et al. (1994)	Gehlbach (1965) [1]	NPSpecies (NPS 2014)
Amphibians					
Canyon treefrog	*Hyla arenicolor*		X	X	X
Mexican spadefoot	*Spea multiplicata*	X	X	X	X
Mountain treefrog	*Hyla eximia*	X			X
Plains spadefoot	*Spea bombifrons*	X		X	X
Tiger salamander	*Ambystoma tigrinum*	X	X	X	X
Western chorus frog	*Pseudacris triseriata*	X		X	X
Reptiles: Lizards					
Chihuahan whiptail	*Cnemidophorus exsanguis*		X [2]		X [2]
Eastern collared lizard	*Crotaphytus collaris*	X	X	X	X
Eastern fence Lizard	*Sceloporus undulatus*	X	X	X	X
Great Plains skink	*Eumeces obsoletus*	X	X	X	X
Greater short-horned lizard	*Phrynosoma hernandesi*	X	X	X	X
Lesser earless lizard	*Holbrookia maculata*	X	X	X	X
Ornate tree lizard	*Urosaurus ornatus*	X	X	X	X
Plateau striped whiptail	*Cnemidophorus velox*	X	X	X	X
Variable skink / Many-lined skink	*Eumeces multivirgatus*		X	X	X
Reptiles: Snakes					
Black-necked garter snake	*Thamnophis cyrtopsis*	X		X	X
Gopher snake (or Bull snake)	*Pituophis catenifer*	X	X	X	X
Striped whipsnake	*Masticophis taeniatus*	X	X	X	X
Western diamond-backed rattlesnake	*Crotalus atrox*	X	X	X	X
Western rattlesnake	*Crotalus viridis*	X	X	X	X
Western terrestrial garter snake	*Thamnophis elegans*	X	X	X	X

[1] Information from Gehlbach (1965) was only included for species that were recorded by Nowak & Persons (2008) and/or Lightfoot et al. (1994).

[2] Persons and Nowak (2008) questioned the identification (and occurrence) of this species by Lightfoot et al. (1994); therefore, the NPSpecies list shows it as "unconfirmed."

Additional Notes: There are also five species noted by Nowak & Persons/NPSpecies as "probably present," and six additional species as "unconfirmed."

species are likely to be found at the national monument with additional surveys. Although not shown in the table, five additional species are probably present at the national monument (with a high probability of occurrence) according to Nowak and Persons 2008): Woodhouse's toad (*Bufo woodhousii*), ring-necked snake (*Diadophis punctatus*), night snake (*Hypsiglena torquata*), mountain patch-nosed snake (*Salvadora grahamiae*), and black-tailed rattlesnake (*Crotalus molossus*). Nowak and Persons (2008) used information provided by Gehlbach (1965) and Degenhardt et al. (1996) to conclude that these species probably occur in the park.

No comprehensive surveys or monitoring of amphibians and reptiles have been conducted at the park since the 2002-2003 surveys. Therefore, we can not provide any additional information as to which species occur in the park at this time.

Table 4.17.4-2. Species detected during 2002-2003 and early 1990s surveys at El Malpais NM that are SGCN according to NMDGF (NMDGF 2006). None of the species are federally or state-listed as endangered/threatened.

Common Name	Scientific Name	NM SGCN (NMDGF)
Tiger salamander [1]	*Ambystoma tigrinum*	SGCN
Eastern collared lizard	*Crotaphytus collaris*	SGCN
Western diamond-backed rattlesnake	*Crotalus atrox*	SGCN

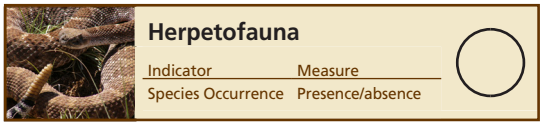
[1] = In the list of SGCN for Cibola County, the scientific name given for tiger salamander is *Ambystoma mavortium mavortium*; however, additional information provided in BISON-M reports the scientific name *Ambystoma tigrinum* (and this name is used in NMDGF 2006).

Table 4.17.4-3. Indicator and measure of herpetofauna condition.

Indicator of Condition	Measure	Condition	Rationale for Condition.
Species Occurrence	Presence/absence	Unknown	There is no current information available on amphibians and reptiles at the national monument. The most recent surveys were conducted in 2002-2003 (i.e., Nowak and Persons 2008). Although condition can not be determined at this time, the 2002-2003 work, as well as earlier surveys by Lightfoot et al. (1994) provides baseline information for future monitoring and assessment.

The Occurrence of Species of Conservation Concern

There are three species that have been observed at El Malpais NM during 2002-2003 surveys and/or early 1990s surveys that are listed as species of conservation concern on one or more of the lists described in Section 4.17.2 (Table 4.17.4-2). Although none of the species are federally or state-listed as endangered or threatened, three species are considered Species of Greatest Conservation Need (SGCN) in New Mexico (USFWS 2015, NMDGF 2015b; Table 4.17.4-2). These three species are the tiger salamander, Eastern collared lizard, and Western diamond-backed rattlesnake (Figure 4.17.4-1). The appendix of NMDGF (2006) also lists the Western chorus frog and mountain treefrog as SGCN for the state, and these species have been recorded at the national monument; however, these two species are not on the SGCN list for the ecoregion in which the park occurs (Arizona-New Mexico Mountains; NMDGF 2006).



Overall Condition and Trend

To assess condition of herpetofauna at El Malpais NM, we used one indicator/measure, summarized in Table 4.17.4-3. Current condition cannot be assessed due to the lack of recent data. The information presented in this section (4.17) is from the most recent survey at the park, conducted in 2002-2003 by the USGS Southwest Biological Science Center, as well as previous surveys by Lightfoot et al. (1994). Combined, the studies documented 21 species in the national monument. Trends



NPS / MURPHY

Figure 4.17.4-1. Western diamond-backed rattlesnake is a SGCN in New Mexico.

in species occurrence cannot be assessed due to the lack of available data. However, the 2002-2003 surveys provide good baseline information for future monitoring and condition assessment.

4.17.5. Sources of Expertise

No outside experts were consulted for this resource topic. This section was authored by biologist Patty Valentine-Darby.

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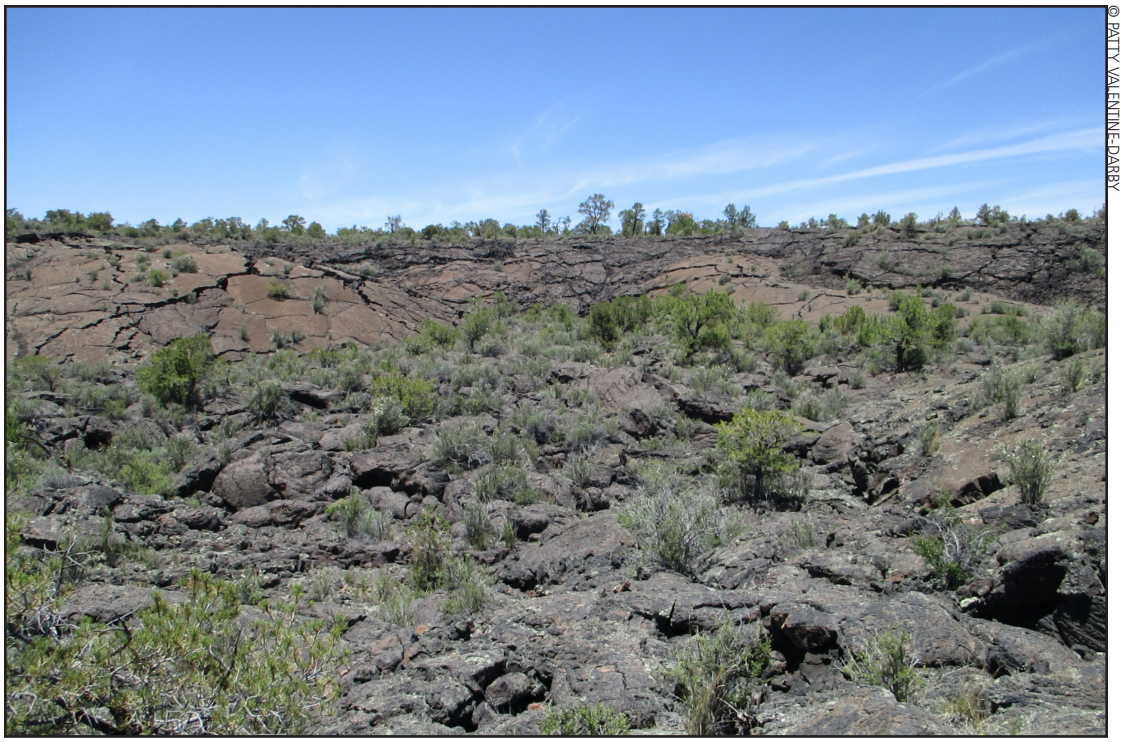
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El Malpais National Monument preserves the surface and subsurface geologic features, and provides opportunities to experience these resources in their natural setting (NPS 2014a).

Chapter 5: Discussion of Natural Resource Condition Assessment Findings and Considerations for Park Planning

5.1. Introduction

The primary purpose of the Natural Resource Condition Assessment (NRCA) Chapter 5 is to provide a "big picture" - broader application of resource condition findings for El Malpais National Monument (Albright 2010). We will fulfill this purpose by:

- creating a framework that connects the natural resource findings to El Malpais National Monuments's purpose and significance statements (refer to Table 5.2-1),
- delivering completed *State of the Park* natural resource condition summary tables for each of the topics assessed (refer to sections 5.3-5.20); and
- providing resource condition briefs for each assessed topic, highlighting potential management and project considerations with park staff input.

These Chapter 5 reporting pieces are *value added* products that can be used by park managers for a variety of resource planning and comprehensive park management purposes (Jeff Albright, NRCA Program Coordinator, pers. comm. August 23, 2013). Efficiency is gained by providing these products because they deliver information to park staff that directly meet other reporting requirements, such as those for the *State of the Park* report.

5.2. Connecting Natural Resource Condition Assessment Topics to Park Purpose, Significance, and Fundamental Resources & Values

Managing the natural resources at El Malpais NM is inextricably tied to its purpose and significance. It is most often within this interdisciplinary perspective that managers consider potential actions and alternatives when addressing resource issues or needs. During the park's on-site NRCA scoping meeting, participants reviewed resource topics selected for the condition assessment

and identified how those resources were connected to the park's purpose, significance and fundamental resources and values, as identified in the park's foundation document (NPS 2014a). Table (Table 5.2-1) summarizes the results of this exercise and provides a "snapshot" overview of how each natural resource topic assessed ties into the park's primary reasons for establishment. The geologic features and associated lava-influenced ecosystems are strongly connected to the reasons the monument was established as a national park unit.

5.3. State of the Park Reporting

As part of the stewardship of national parks for the American people, the NPS has begun to develop *State of the Park* reports to assess the overall status of each park's resources.

The key purposes of each *State of the Park* report are to:

- Provide to visitors and the American public a snapshot of the status and trend in the condition of a park's priority resources and values.
- Summarize and communicate complex scientific, scholarly, and park operations factual information and expert opinion using non-technical language and a visual format.
- Highlight park stewardship activities and accomplishments to maintain or improve the *State of the Park*.
- Identify key issues and challenges facing the park to help inform park management planning (NPS 2012).

Table 5.3-1 provides an overall summary of natural resource conditions based upon NRCA findings. The viewshed and soundscape landscape-scale resources were in good condition, and the night sky condition was good to moderate. The physical resources were in moderate condition, if rated. And all of the biological resources that were rated were in good condition. With the monument being a relatively young park unit, established on December 31, 1987, it has yet to have the same breadth and depth of research and inventory and monitoring efforts as older parks have, which was reflected in several of the unknown condition ratings.

Resource Condition Briefs

Each resource condition summary brief, (5.4-5.20) details these condition ratings by including a *State of the Park* summary table of indicators and measures. Condition rationale, noteworthy highlights, management opportunities and considerations may also be included in each resource brief.

For all but the bats, caves, including paleoclimate research, and vegetation resource topics, ELMA has not developed specific project statements or written planning/management documents. Resource issues, threats, and disturbances change as does the budget request system and criteria for making budget requests – often annually. The NR staff submits budget requests for project funds to assist with management priorities and/or to mitigate resource threats and impacts. The process for making budget requests is the NPS Project Management Information System (PMIS). NR staff uses PMIS to address management issues (as projects) and to conduct research – project ideas. Project statements for research have been developed for the resource topics below. All other research topic areas would be handled through the same budget request process and research proposals developed accordingly based on current resource status/condition, current knowledge, partner contributions/researcher interest, if available, staffing levels, and other needs that could change annually with the budget cycle.

Table 5.2-1. Summary of natural resource topic relevance (denoted by black dots) as it relates to El Malpais National Monument's purpose and significance statements identified in the park's Foundation Document (NPS 2014a).

Natural Resource Condition Assessment Topics	Viewshed	Night Sky	Soundscape	Air Quality	Surface Geology	Caves and Cave Ice	Tinajas	Piñon-Juniper	Ponderosa Pine	Distinct Vegetation	Exotic Plants	Cave Ecology	Mammals	Bats	Birds	Herpetofauna
I. Park Purpose																
Preserves, protects, and interprets natural and cultural resources that are an integral part of the volcanic wilderness, including the Grants Lava Flow and Chacoan great house community of Las Ventanas.	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•
I. Park Purpose																
Preserves, protects, and interprets natural and cultural resources that are an integral part of the volcanic wilderness, including the Grants Lava Flow and Chacoan great house community of Las Ventanas.	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•
II. Park Significance																
Volcanic Processes: Protects many lava flows, young and old, that are home to a rich diversity of associated volcanic geologic features including one of the longest lava tube systems in the world.					•											
Caves: Preserves a high density and diversity of ecologically significant lava tube caves, including the southernmost ice caves in the United States. Access to a number of these caves provides a rare self-guided recreational and educational experience.			•			•						•	•	•	•	•
Lava-influenced ecosystem: Produced uncommon vegetation associations, unusual growth forms, and plant communities sheltered from modern disturbances.				•	•		•	•	•	•			•	•	•	•
Lava-influenced cultural landscape: preserves and protects a cultural landscape influenced by volcanic landforms, including the Chacoan great house community of Las Ventanas, ancient and historic trail networks, basalt architecture, and ritual landscapes.	•	•	•		•	•	•	•	•	•			•	•	•	•
Wilderness: The wilderness-a vast volcanic landscape, provides opportunities for inspiration and solitude, physical and navigational challenges, and scientific discovery.	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•
III. Fundamental Resources and Values																
Lava surface features (and associated landscapes)					•		•	•	•	•						
Lava subsurface features (and associated cave-dependent)			•			•						•	•	•	•	•

Table 5.2.1. Summary of natural resource topic relevance (denoted by black dots) as it relates to El Malpais National Monument's purpose and significance statements identified in the park's Foundation Document (NPS 2014a) continued.

Natural Resource Condition Assessment Topics	Viewshed	Night Sky	Soundscape	Air Quality	Surface Geology	Caves and Cave Ice	Tinajas	Piñon-Juniper	Ponderosa Pine	Distinct Vegetation	Exotic Plants	Cave Ecology	Mammals	Bats	Birds	Herpetofauna
Unusual vegetation (islands of undisturbed vegetation, or kipukas, which are rare to the Southwest.)					•					•						
Archeology and other heritage resources	•	•	•		•	•	•	•	•	•			•	•	•	•
IV. Other Important Resources and Values																
Wilderness character	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•
Other Heritage Resources	•	•	•		•	•	•	•	•	•			•	•	•	•
Recreation and education	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

Table 5.3-1. State of the Park Natural Resource Summary Table

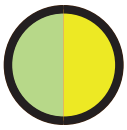
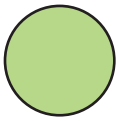
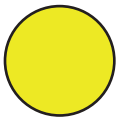
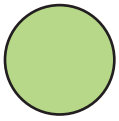
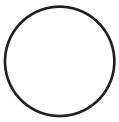
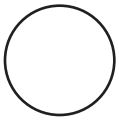
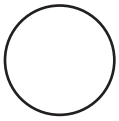
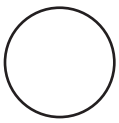
Priority Resource or Value	Condition Status/Trend	Summary of Overall Condition Rating
Natural Resources		
Viewshed		Viewsheds are considered an important part of the visitor experience. Features on the visible landscape influence the enjoyment, appreciation, and understanding of a park. We used one indicator, scenic and historic integrity, to assess viewshed condition at the national monument. The indicator had two measures, 1) intactness of view, and 2) conspicuousness of noncontributing features, both of which were judged to be in good condition. The vast majority of the landscape seen from the assessment vantage points appears intact with few noncontributing features.
Night Sky		Quantitative measures of sky brightness (all-sky light pollution ratio, maximum vertical and horizontal illuminance, and zenith sky brightness) and an assessment of sky quality (the Bortle Dark Sky Scale) were used to assess the condition of the night sky at El Malpais NM. Data collected from Cerro Encierro and the lower meadow indicates good night sky conditions while data collected at Sandstone Bluffs indicate moderate night sky conditions. Overall, the night sky condition at El Malpais is considered good to moderate depending on location within the national monument.
Soundscape		We used one indicator, with two measures to assess soundscape condition. Both the percent time above reference sound levels and the L_{50} impact measure were in very good condition.
Air Quality		The air quality assessment included visibility, ozone for human and vegetation health, and wet deposition for total nitrogen, total sulfur, and mercury- all of which were in moderate condition, except for total sulfur, which was good, based upon NPS Air Resources Division reference criteria.
Surface Geology		We used four indicators to assess the condition of surface geology in El Malpais NM. Lava flow surface features were in good condition, and volcanic vents and edifices were in moderate condition. Paleontological resources were in good condition for freeze-thaw impact and unknown condition for human impacts. Disturbed lands were in the condition of significant concern. Overall, the condition of surface geology is moderate with a stable trend.
Caves and Cave Ice		The overall condition and trend of the caves and cave ice in El Malpais NM is unknown. Although, areas of concern exist including a warming climate trend and visitor impacts.
Tinajas		One indicator, with two measures, was used to assess tinaja condition. Since no formal inventories have been conducted to assess the presence of water-dependent organisms, climate variables of mean annual precipitation and the Reconnaissance Drought Index were used as proxies for condition. Even though the park received a high amount of rainfall in 2015, the effects from the previous years' drought warranted a moderate condition rating.
Piñon-Juniper		Piñon-juniper vegetation within the national monument is of two types based on a functional classification: persistent piñon-juniper woodlands, and juniper-piñon savannas. Although there are a few concerns, such as the increase in tree density in savannas, the overall condition of each type and of the types combined is considered to be good. At this time, we consider the overall trend in condition as unchanging.
Ponderosa Pine		Ponderosa pine vegetation within the national monument is of two types based on a functional classification: ponderosa pine-piñon-juniper woodland/savanna, and ponderosa pine-piñon-juniper rocky woodland. Although there are a few concerns, such as the increase in fire intervals in both types and the higher stand densities compared to pre-1900 in the woodland/savanna type, the overall condition of each type and of the types overall was considered to be good. At this time, we consider the overall trend in condition as unchanging.
Grasslands and Shrublands		Grasslands at El Malpais NM occur on the older, more eroded flows, while shrublands occur on the more recent flows (at relatively low elevations) and cinder cones. We used two indicators (soil/site stability and biotic integrity), with a total of seven measures to assess grassland condition at the national monument. Of the seven measures, sixwere determined to be in good condition and the condition of one was unknown. Overall, grassland condition was found to be good.

Table 5.3.1. State of the Park Natural Resource Summary Table continued.

Priority Resource or Value	Condition Status/Trend	Summary of Overall Condition Rating
Distinct Vegetation		The overall condition of the distinct vegetation communities in El Malpais NM is unknown. However, the condition of aspects of the monument's distinct vegetation that are part of the broad ecological categories (i.e., pinyon-juniper and ponderosa pine assessed in Sections 4.8 and 4.9, respectively), are likely to be the same as that for the broader ecosystem (e.g., good).
Exotic Plants		We used two indicators, potential to alter native plant communities and prevalence of exotic plants, to assess the condition of exotic plants in El Malpais NM. The condition for the significance of exotic impact measure was of significant concern. Information about the prevalence of exotic plant species in the monument was extremely limited, consisting of observations during vegetation mapping (Muldavin et al. 2013). Therefore, the prevalence of exotic plants was unknown. Overall, the condition of exotic plants is unknown with an unknown trend.
Cave Ecology and Species		The overall condition of cave ecology and species in El Malpais NM is unknown. Only a small portion of the total number of species that live in or utilize El Malpais caves most likely have been documented, but the park recently submitted a proposal for 2018 funding to map of the moss gardens and inventory the invertebrates contained in them to learn more about these resources.
Mammals		We used one indicator/measure, species occurrence (presence/absence), to assess the condition of mammals at the national monument. Although a relatively comprehensive inventory effort was conducted in 2003-2004 by the USGS Southwest Biological Science Center, current condition is unknown because no recent information is available. However, the 2003-2004 work (and an earlier, less comprehensive study) provides baseline information for future monitoring and condition assessment. More than 50 mammal species have been documented in the park.
Bats		We used three indicators with one measure each to assess the condition of bats at El Malpais NM. Each of the three indicators/measures was judged to be in good condition at this time. Although condition was judged to be good for each indicator/measure and overall, some concerns do exist due to the westward expansion of white-nose syndrome from the eastern U.S. As of May 2015, this disease was confirmed in bats as far west as Arkansas.
Birds		To assess the condition of landbirds at El Malpais NM, we used one indicator/measure, species occurrence (presence/absence). Although standardized surveys were conducted in 2002-2003 by the USGS Southwest Biological Science Center, we were unable to assess current condition because there is no current information available. The 2002-2003 work (and an earlier, less comprehensive study) provides baseline information for future monitoring and condition assessment. More than 180 bird species have been recorded in the national monument.
Herpetofauna		We used one indicator/measure, species occurrence (presence/absence), to assess the condition of herpetofauna at the national monument. Although a substantial survey effort was conducted in 2002-2003 by the USGS Southwest Biological Science Center, we were unable to assess current condition because there is no current information available. The 2002-2003 work (and an earlier study) provides baseline information for future monitoring and condition assessment.

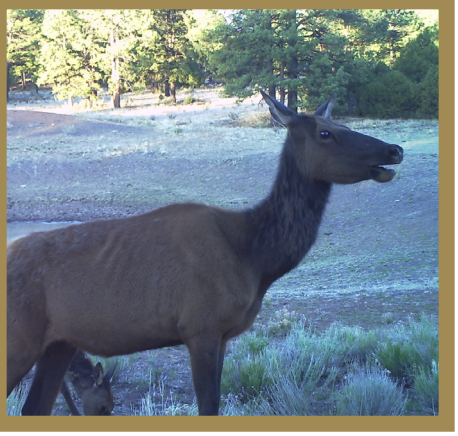
Landscape-scale Resources Summary



Viewshed from Sandstone Bluffs



Stars in the night sky



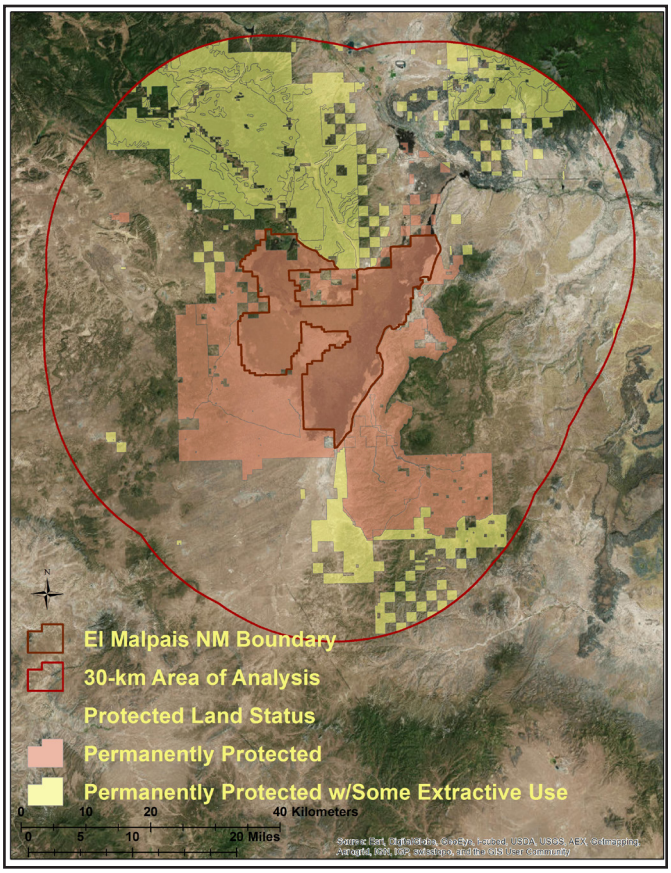
Female elk

Viewshed	Night Sky	Soundscape
		

El Malpais National Monument contains approximately 39,255 hectares (ha) (97,000 acres) of recommended wilderness, which encompasses 85% of the park's area. The other undeveloped areas within the park that were not considered suitable as wilderness are currently managed as backcountry (NPS 2014b).

The NPS' NPScape Program uses the percent area of land protected as an indication of conservation status that "offers insight into potential threats (e.g., how much land is available for conversion and where it is located in relation to the park boundary) as well as opportunities (e.g., connectivity and networking of protected areas)" (Monahan et al. 2012). Adjacent to the park's eastern and south-central boundaries lie 24,929 ha (61,600 acres) of Bureau of Land Management's (BLM) Cebolla Wilderness and 16,001 ha (39,540 acres) of BLM's West Malpais Wilderness. Monahan et al. (2012) cite that for the majority of parks, < 20% of the surrounding local landscape within an ecologically-meaningful 30 km buffer (NPS 2011) is protected. Using USGS' Protected Areas Database (2012), 20.5% of the area surrounding the monument is designated as permanently protected land. An additional 18.3% of the area is designated as land that is protected but some extractive uses are permitted (e.g., U.S. Forest Service land).

This high percentage of protected area preserves the park's landscape-scale resources— viewshed, night sky, and soundscape. Even though the park's viewshed and soundscape are in excellent condition, certain areas of the night sky are impacted by both Albuquerque and Santa Fe, New Mexico's light pollution, underscoring the need for surrounding landscapes to remain within their natural states.



Protected area surrounding El Malpais NM.

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A sweeping view towards the south from Sandstone Bluffs Overlook.

5.4. Viewshed Resource Condition Brief

The contents of sub-chapter 5.4 were designed to be placed into a stand-alone viewshed resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards and include the contact information of at least one NPS employee as a point contact for the public.

5.4.1. Noteworthy Highlights

El Malpais NM was established to preserve, protect, and interpret natural and cultural resources that are an integral part of the volcanic wilderness, including the Grants Lava Flow and Chacoan great house community of Las Ventanas. The Pueblos of Zuni, Acoma, and Laguna, and the Ramah Navajo, consider El Malpais an important part of their history and culture. The majority of the landscape as seen from the three vantage points used in the assessment is dominated by natural features, so there are no major impediments to experiencing a "sense of place." Impressive views are available to the visitor at the three vantage points used (El Calderon, Bandera Volcano/Crater, and the Sandstone Bluffs overlook).

5.4.2. Condition Rationale

To assess viewshed condition at El Malpais NM, we used one indicator with two measures (Table 5.4.2-1). The scenic and historic integrity of the viewshed is in good condition, with both measures being found to be in good condition. From the vantage points, the small number of noncontributing features seen are relatively minor and inconspicuous, leaving the national monument intact from a scenic standpoint. This allows the visitor to imagine the landscape from an historic and cultural point of view. The main noncontributing feature is the parking area and entrance road at the Sandstone Bluffs overlook, but most visitors to this location are probably facing away from the noncontributing features to take in the impressive view of the lava flows, vegetation, and distant mountains. The visitor to the national monument has mostly excellent views of the landscape from the three vantage points used in the assessment.

Table 5.4.2-1. Summary of overall viewshed condition, indicators and measures, and rationale for assigning condition assessment at El Malpais National Monument.

Viewshed			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Scenic and Historic Integrity	Intactness of View		Overall, the vast majority of the landscape appears intact. Views are mainly intact with few noncontributing features, consistent with good condition.
	Conspicuousness of Non-contributing Features		Noncontributing features are relatively inconspicuous, consistent with good condition. The most conspicuous non-contributing feature is the parking area and entrance road at the Sandstone Bluffs overlook. However, most visitors to this location are probably facing away from the noncontributing feature to take in the impressive view of the lava flows, vegetation, and distant mountains. Overall, condition is good for this measure.



NPS NSNSD

A view of the starry night sky.

5.5. Night Sky Resource Condition Brief

The contents of sub-chapter 5.5 were designed to be placed into a stand-alone night sky resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards and include the contact information of at least one NPS employee as a point contact for the public.

5.5.1. Noteworthy Highlights

The light domes from nearby cities minimally affect night skies in the national monument. The dark night skies within the monument provide an opportunity to engage visitors from nearby cities that might not otherwise have the opportunity to view dark night skies or learn about the celestial environment.

5.5.2. Condition Rationale

Approximately 85% of El Malpais National Monument is recommended wilderness. Therefore, the national monument is considered a non-urban NPS unit, or park with at least 90% of its property located outside an urban area (Moore et al. 2013). For non-urban NPS units, the thresholds separating reference of conditions good, moderate, and significant concern are more stringent than those for urban NPS units because these areas are generally more sensitive to the effects of light pollution. The majority of qualitative and quantitative measures of night sky indicators (Table 5.5.2-1) is within the good to moderate thresholds, but depends somewhat on the location where data were gathered.

Table 5.5.2-1. Summary of overall night sky condition, indicators and measures, and rationale for assigning condition assessment at El Malpais National Monument.

Night Sky			
Indicators of Condition	Specific Measures	Condition Status/ Trend	Rationale
Sky Brightness	All-sky Light Pollution Ratio		Sky brightness, as measured by ALR, indicates good to moderate condition overall at El Malpais NM. This condition is based on NPS NSNSD benchmarks for non-urban parks, on ground-based measurements taken at three locations within the park, and a modeled estimate for the entire park. Ground-based data from Cerro Encierro (0.20) and the lower meadow (0.09) indicate good condition while data from Sandstone Bluffs (0.35) indicate moderate condition. The modeled ALR, derived from the 2001 World Atlas of Night Sky Brightness, was 0.17 and indicates good condition. Confidence level is high.
	Maximum Vertical Illuminance		Sky brightness as measured by maximum vertical illuminance was 0.19 milli-Lux at Cerro Encierro and 0.08 milli-Lux at the lower meadow. These values reflect a rating of 48% above average natural conditions for Cerro Encierro and 20% above average natural conditions for the lower meadow. At Sandstone Bluffs maximum vertical illuminance was 0.36 milli-Lux, or 90% above average natural conditions. Specific benchmarks for condition classes have not been set; however, condition is estimated as good at Cerro Encierro and the lower meadow, and moderate at Sandstone Bluffs (J. White, personal communication, Nov. 2015).
	Horizontal Illuminance		Sky brightness as measured by horizontal illuminance was 0.06 milli-Lux at Cerro Encierro and 0.07 milli-Lux at the lower meadow. These values reflect a rating of 8% above average natural conditions for both Cerro Encierro and the lower meadow. At Sandstone Bluffs horizontal illuminance produced a value of 0.09 milli-Lux, or 11% above average natural conditions. Specific benchmarks for condition classes have not been set; however, condition is estimated as good for all three locations (J. White, personal communication, Nov. 2015).
	Zenith Sky Brightness		Zenith sky brightness indicates good to moderate condition overall at El Malpais NM. This condition is based on NPS Natural Sounds and Night Skies Division benchmarks for non-urban parks and on ground-based measures of zenith sky brightness at Cerro Encierro (21.74), the lower meadow (21.84), and at Sandstone Bluffs (21.54). Condition is good at Cerro Encierro and the lower meadow, and moderate at Sandstone Bluffs. Confidence level is high.
Sky Quality	Bortle Dark Sky Scale		Sky quality as assessed by the Bortle dark sky scale indicates good to moderate condition overall at El Malpais NM. This condition is based on NPS NSNSD benchmarks for non-urban parks and on the qualitative assessment of Bortle class 3 at Cerro Encierro (good condition), Bortle class 2 at the lower meadow (good condition), and Bortle class 4 at Sandstone Bluffs (moderate condition). These classes are consistent with a rural sky at Cerro Encierro, a typical dark sky at the lower meadow, and the transition from rural to suburban skies at Sandstone Bluffs. Because this measure is qualitative, it has low confidence level.


NPS - ELK

Female elk and calf.

5.6. Soundscape Resource Condition Brief

The contents of sub-chapter 5.5 were designed to be placed into a stand-alone soundscape resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards and include the contact information of at least one NPS employee as a point contact for the public.

5.6.1. Noteworthy Highlights

Most of El Malpais NM is comprised of an area >100 km^2 without roads (NPS 2014c, ESRI 2005/2010). In addition, the monument is primarily surrounded by the even larger El Malpais National Conservation Area, managed by the Bureau of Land Management, which contains two areas of designated wilderness and a third wilderness study area. These protected areas will most likely contribute to maintaining the monument's excellent soundscape condition.

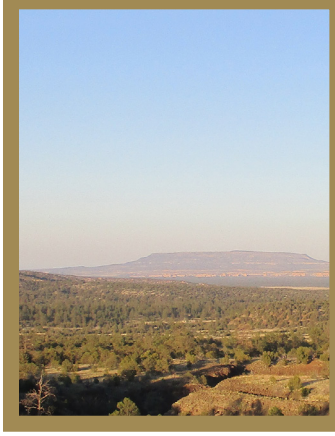
5.6.2. Condition Rationale

Soundscape condition was assessed using sound level as an indicator of condition (Table 5.6.2-1). We used the on-site results from the NPS Natural Sounds and Night Skies Division acoustical monitoring effort (NPS NSNSD 2009) to determine percent time above reference sound levels, and the geospatial sound modeling result for the impact between natural and existing acoustic conditions at the monument (Mennitt et al. 2013). The majority of existing sound levels recorded at the monument was <44.99 dBA, suggesting a very quiet environment, resulting in a good condition rating. In addition, the modeled average impact sound level for the national monument was within the good condition rating threshold for non-urban parks based on Turina et al. (2013) reference conditions. Overall, we considered the monument's soundscape to be in very good condition.

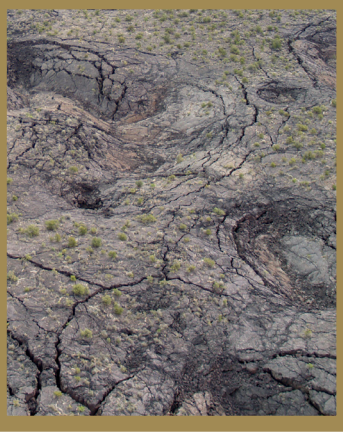
Table 5.6.2-1. Summary of overall soundscape condition, indicators and measures, and rationale for assigning condition assessment at El Malpais National Monument.

Soundscape			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Sound Level	% Time Above Reference Sound Levels		The majority of existing sound levels heard at all sites were <44.99 dBA, suggesting a relatively quiet environment. We consider this measure to be in good condition.
	L_{50} Impact		The modeled average impact sound level for the national monument of 0.38 dBA, which is considered to be in good condition based on threshold values for non-urban parks (Turina et al. 2013).

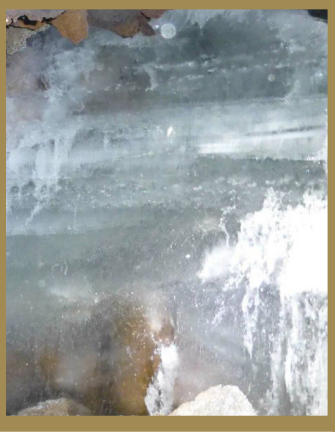
Physical Resources Summary



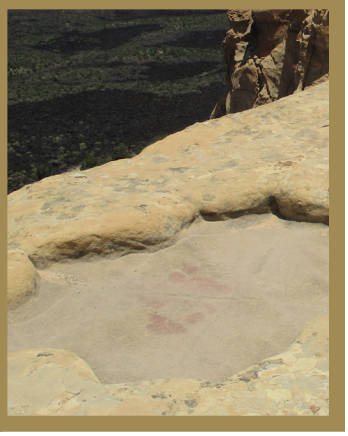
View of sky



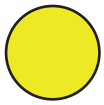
Inflation pits



Cave ice



Dry tinaja

Air Quality	Surface Geology	Caves and Cave Ice	Tinajas
			

El Malpais is a Spanish word for "the badlands," which is evident in the rugged landscape comprised of lava tubes, cinder cones, ice caves, and a surprising amount of distinct vegetation due to the volcanic substrate. Most of the physical resources assessed for the El Malpais National Monument's NRCA are reliant upon processes that originate far outside the park's jurisdictional boundary and at global scales (e.g., climate change).

Recent climate results for El Malpais NM indicate that conditions have already begun shifting beyond the historical range of variability, with the 2003-2012 decade representing the warmest one on record (Monahan and Fisichelli 2014). Garfin et al. (2014) expects more sustained extreme heat and fewer and less extreme cold periods. Overall, it's likely that future climate change will increasingly affect all aspects of park resources and operations (Monahan and Fisichelli 2014), especially on physical resources such as cave ice and tinaja water availability.

Climate change vulnerability assessment planning can help park managers identify and develop potential management actions to manage for inevitable change. The National Wildlife Federation (Stein et al. 2014) suggests that a climate-smart approach to management includes the following overarching themes:

- *Act with intentionality* – be deliberate and transparent in management actions and link direct and indirect climate impacts to management actions;
- *Manage for change, not just persistence* – change is likely the only constant. Focus on sustaining ecological functions, rather than historical assemblages of plants and animals;
- *Reconsider goals, not just strategies* – conservation goals are the ends and the strategies are the means to achieve those goals. Goals may need to be considered within a climate-related context answering the what, why, where, and when of the intended goals;
- *Integrate adaptation into existing work*– use adaptation strategies while considering natural resource decision processes.

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A photo of the sky and vegetation at El Malpais NM.

5.7. Air Quality Resource Condition Brief

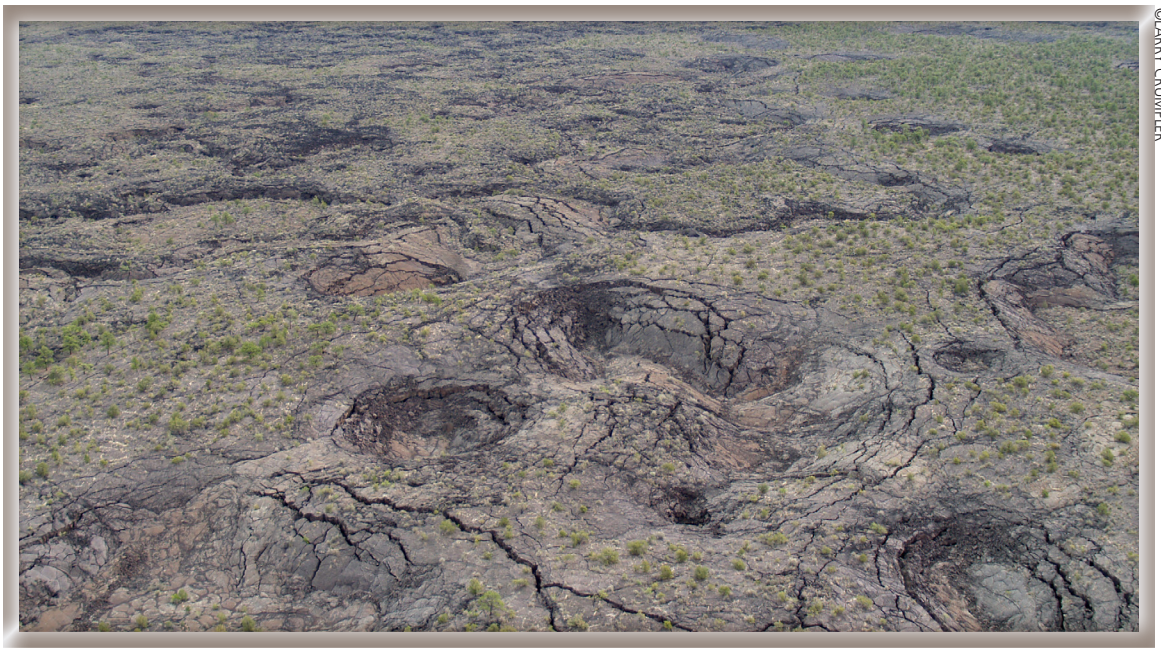
The contents of sub-chapter 5.7 were designed to be placed into a stand-alone air quality resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards and include the contact information of at least one NPS employee as a point contact for the public.

5.7.1. Condition Rationale

We used three indicators and seven measures to assess air quality condition at El Malpais NM, including ozone levels, visibility, and wet deposition of sulfur, nitrogen, and mercury (Table 5.7.1-1). All indicators and measures were in moderate condition, except for total sulfur, which was good, based on NPS Air Resources Division reference conditions. For 2004–2013, the trend in visibility at the park improved on the 20% clearest days and remained relatively unchanged (no statistically significant trend) on the 20% haziest days (IMPROVE Monitor ID: BALD1, AZ). The Clean Air Act visibility goal requires visibility improvement on the 20% haziest days, with no degradation on the 20% clearest days. Like most airsheds, the park's air quality is largely influenced by activities and operations that occur outside its boundaries, making its condition dependent on local, regional, and national planning.

Table 5.7.1-1. Summary of overall air quality condition, indicators and measures, and rationale for assigning condition assessment at El Malpais National Monument.

Air Quality			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Visibility	Haze Index		Visibility warrants moderate concern, with medium confidence based on the 2009–2013 estimated visibility on mid-range days of 4.1 deciviews (dv) above estimated natural conditions. For 2004–2013, the trend in visibility at El Malpais NM improved on the 20% clearest days and remained relatively unchanged (no statistically significant trend) on the 20% haziest days (IMPROVE Monitor ID: BALD1, AZ). The degree of confidence is high because there is an on-site or nearby visibility monitor.
Level of Ozone	Human Health: Annual 4th-Highest 8-hour Concentration		Human health risk from ground-level ozone warrants moderate concern, with medium confidence based on the 2009–2013 estimated ozone of 67.3 parts per billion (ppb). No trend information is available because there are not sufficient on-site or nearby ozone monitoring data.
	Vegetation Health: 3-month maximum 12hr W126		Vegetation health risk from ground-level ozone warrants moderate concern, with medium confidence based on the 2009–2013 estimated W126 metric of 12.4 parts per million-hours (ppm-hrs). The W126 metric relates plant response to ozone exposure. A risk assessment concluded that plants in El Malpais NM were at low risk for ozone damage (Kohut 2007; Kohut 2004). No trend information is available because there are not sufficient on-site or nearby ozone monitoring data.
Wet Deposition	Total N		Wet nitrogen deposition warrants moderate concern, with medium confidence based on the 2009–2013 estimated wet nitrogen deposition of 1.6 kilograms per hectare per year (kg/ha/yr). Ecosystems in the park were rated as having low sensitivity to nutrient-enrichment effects relative to all Inventory & Monitoring parks (Sullivan et al. 2011a,b). No trend information is available because there are not sufficient on-site or nearby deposition monitoring data.
	Total S		Wet sulfur deposition is in good condition, with medium confidence based on the 2009–2013 estimated wet sulfur deposition of 0.8 kilograms per hectare per year (kg/ha/yr). Ecosystems in the park were rated as having low sensitivity to acidification effects relative to all Inventory & Monitoring parks (Sullivan et al. 2011a). No trend information is available because there are not sufficient on-site or nearby deposition monitoring data.
	Mercury		The 2011–2013 estimated wet mercury deposition is moderate at the park, ranging from 5.1 to 7.5 micrograms per square meter.
	Predicted Methylmercury Concentration		The predicted methylmercury concentrations in surface waters is moderate, at 0.07 nanograms per liter.



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A photo of McCartys flow inflation pits.

5.8. Surface Geology Resource Condition Brief

The contents of sub-chapter 5.8 were designed to be placed into a stand-alone surface geology resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards and include the contact information of at least one NPS employee as a point contact for the public.

5.8.1. Noteworthy Highlights

El Malpais NM's surface geology is mostly the result of recent basaltic volcanic activity that produced a series of lava flows and volcanic vents and edifices. The characteristics of and structures found within these features provide important information about volcanological processes and have great education and research significance. Most notably, research conducted on the McCartys Flow has provided great insight into inflation, a lava flow emplacement process that was only identified relatively recently (Walker 1991), and has subsequently identified as having taken place in planetary bodies (Zimbelman et al. 2013).

5.8.2. Condition Rationale

Overall, the condition of surface geology at El Malpais NM is moderate. Lava flow surface features are in good condition as they are largely intact, although the Lava Falls area shows sign of impact from visitor use. Some volcanic vents and edifices have been impacted by quarrying, and McCartys Crater has significant impacts from its use as Kirkland Demolition Bombing Range in World War II. The vent and edifice intactness measure is in moderate condition. The freeze-thaw index is decreasing, and paleontological resources are in good condition for the freeze-thaw index. However, El Malpais' fossil resources are poorly known and are not being monitored, so they are in an unknown condition for the human use measure. Disturbed lands are of significant concern because two sites are ranked as high priority for mitigation by the NPS AML program.

Table 5.8.2-1. Summary of overall surface geology condition, indicators and measures, and rationale for assigning condition assessment at El Malpais National Monument.

Surface Geology			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Lava flow surface features	Lava flow intactness		The lava flow surface features are largely intact; e.g., in natural condition, in El Malpais NM. Heavy use in the Lava Falls area of the McCartys flow has impacted the surface of the flow there. Additionally, detonations in the Kirkland Demolition Bombing Range have impacted the surface of the flow, especially in the vicinity of the vent. Unexploded ordinance and munitions may remain in the area.
Volcanic vents and edifices	Vent and edifice intactness		Overall, volcanic vents and edifices are in moderate condition. While some edifices such as Hoya de Cibola and the vents that produced the Twin Craters Flows are in natural condition, others have been significantly impacted by human activities prior to the establishment of El Malpais NM. The McCartys Crater was used as a range for aerial bombing in World War II, and metal bomb fragments and small craters from explosions remain. Cinder quarrying occurred at El Calderon and in the Bandera Cinder Field.
Disturbed lands	Abandoned Mineral Lands Prioritization Ranking		Two AML sites in El Malpais are ranked as high priority for mitigation by the NPS AML program because of their hazards or high resource impact and easy access for visitation. Four additional sites are assigned a moderate priority for mitigation by the NPS AML program.
Paleontological resources	Freeze-Thaw Impact		The freeze-thaw index is decreasing because of fewer number of days per year that go through the freeze-thaw cycle. A lower freeze-thaw index should mean that frost weathering has less of an impact on fossils.
	Human Impacts		The monument's fossil resources are poorly known and are not being monitored. However, tree mold fossils, while rare and unusual, would be difficult to remove from the encompassing lava flow, and most caves in El Malpais are closed to visitation, protecting the fossils therein.


NPS

Big Skylight cave is one of four lava tube caves open to recreational caving in El Malpais National Monument.

5.9. Caves and Cave Ice Resource Condition Brief

The contents of sub-chapter 5.9 were designed to be placed into a stand-alone caves and cave ice resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards and include the contact information of at least one NPS employee as a point contact for the public.

5.9.1. Noteworthy Highlights

El Malpais contains among the longest lava tube systems in the world, with a cumulative length of more than 95 km (60 mi) (Marinakis 1997). The monument also contains the southernmost ice caves on the continent.

5.9.2. Condition Rationale

We used five indicators to assess the condition of caves and cave ice at El Malpais NM as summarized in Table 5.9.2-1. Conditions are currently unknown due to lack of current monitoring data. Park staff are developing inventory and monitoring strategies that will help inform their future management of the park's cave and cave ice resources.

5.9.3. Management and Project Considerations

Cave and Paleoclimate Research

Project Title: Climate and Vegetation Reconstructions Using Ice and Guano Cores in Lava Tubes at El Malpais NM

Project Abstract: Various research projects at El Malpais and El Morro National Monuments have documented climate changes within our parks. Since the early 1980s ELMA and ELMO have experienced a change in temperature of over 3 degrees Fahrenheit and additional increases in temperature are expected (Monahan and Fisichelli 2014). The period between 2012 and 2014 was the driest in the region since the 1950s (Romme and Jacobs 2015). As our climate continues to warm and drought/fire conditions increase in frequency, we can expect important changes in vegetation at the Monuments. ELMA has several potentially significant archives for understanding the paleoclimate of both Monuments. The use of dendrochronology is the most established climate proxy at ELMA, providing a climate history up to 137 BC (Grissino-Mayer 1995). Other potential proxies (stable isotopes, pollen, trace elements) that can be measured

in perennial ice and guano cores, can further help calibrating the climatic signal with existing dendrological studies. Thoroughly studying these cores have the potential to significantly expand our knowledge of the environment and climate evolution of the region. The perennial ice deposits in our lava tubes likely contain a record back to the early Holocene (Dickfoss et al. 1997). Likewise, bat guano (accumulated in lava tubes) can be precisely dated using the radiocarbon method and contains several environmental proxy indicators such as pollen grains, stable isotopes, and charcoal, which can be analyzed and provide "snapshots" of the vegetation and precipitation changes, as well as natural fires during different climate regimes.

Table 5.9.2-1. Summary of overall caves and cave ice condition, indicators and measures, and rationale for assigning condition assessment at El Malpais National Monument.

Caves and Cave Ice			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Cave Meteorology	Temperature and Humidity		Temperature and humidity conditions in El Malpais caves are unknown. However, because the lava tube caves are shallow and because many caves have more than one opening, there is a connectivity between conditions at the surface and conditions inside caves. The annual mean temperature at El Malpais has risen significantly since the 1980s, suggesting that temperatures inside caves also may be increasing.
Permanent and Seasonal Ice	Presence/Absence		The condition of permanent and seasonal cave ice in El Malpais is unknown. Cave ice has been documented in 40 caves within the national monument. Monitoring in 15 of these caves in 2015 found at least seasonal ice in each cave, but the relative quantity of ice in these caves is not known. Warming climatic conditions at the surface may lead to warmer conditions inside caves, potentially decreasing the amount of cave ice.
Direct Visitor Impacts	Degree of Impact		The Impact Assessment Map for Junction Cave showed that the majority of the cave had significant impact. However, the impact assessment for Junction Cave is the only assessment completed to date in El Malpais, and this cave has more visitor impacts than the other lava tubes open to recreational caving (Eric Weaver, personal communication, 2015). Therefore, the condition for direct visitor impact is unknown.
Stability-Breakdown	n/a		Breakdown is a common feature of El Malpais caves. Much of the breakdown probably formed during cooling after cave formation, but heavily jointed ceilings and walls can be unstable causing additional breakdown events. Formation of new breakdown has been documented, but the condition of stability-breakdown at El Malpais is unknown.
Rare Minerals	n/a		El Malpais contains several minerals that very rarely occur in caves, including burkeite, cristobalite, glaserite, thenardite and trona. Many of these minerals occur as part of fragile speleothems or deposits such as angel hair, loose powder, "snowballs," or moonmilk. The rare minerals in El Malpais caves are not being monitored, so their condition is unknown.



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Dry tinajas in sandstone.

5.10. Tinajas Resource Condition Brief

The contents of sub-chapter 5.10 were designed to be placed into a stand-alone tinajas resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards and include the contact information of at least one NPS employee as a point contact for the public.

5.10.1. Noteworthy Highlights

The water and associated organisms found in tinajas may have cultural relevance for the park. Branchiopods have been used as a food source in various cultures, and fairy shrimp can aggregate, forming large populations. This would likely have provided an easy source of protein for indigenous people on an otherwise harsh landscape (Driver 1981 as cited in Graham 2002).

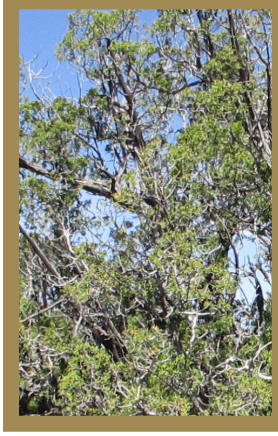
5.10.2. Condition Rationale

Given the lack of data to assess condition of organisms that use tinajas, we used two climate-related measures to assess water conditions (Table 5.10.2-1). The average annual precipitation measure for the period of record (1938-2015) was well above average in 2015, with 17.45 inches, which is one of the highest amounts on record, suggesting an improvement in the recent drought conditions that occurred from 2012-2014. However, the western half of Cibola County New Mexico, where the park is located, is still considered to be abnormally dry, which resulted in a good to moderate condition rating. The normalized Reconnaissance Drought Index (RDI) value for 2015 was 0.25, which indicates near normal conditions, however, the longer-term trend in the region for several years preceding 2015 were either negative (i.e., 1999, 2002-2004, 2007-2008, 2011, 2013) or very low (i.e., 2005-2006, 2009-2010), suggesting overall drier conditions, warranting a moderate condition rating for the RDI measure.

Table 5.10.2-1. Summary of overall tinajas condition, indicators and measures, and rationale for assigning condition assessment at El Malpais National Monument.

Tinajas			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Climate Variables	Amount of Precipitation		Precipitation was well above average in 2015 but below in several of the most recent years, warranting a good to moderate condition rating.
	Reconnaissance Drought Index		Even though drought conditions improved in 2015, drought conditions have prevailed in the region most recently, warranting a moderate condition rating.

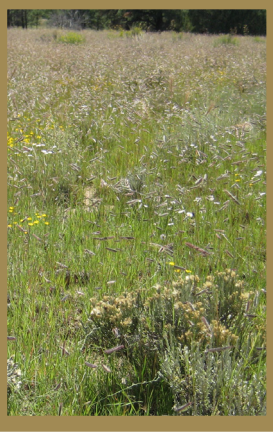
Vegetation Resources Summary



Juniper tree



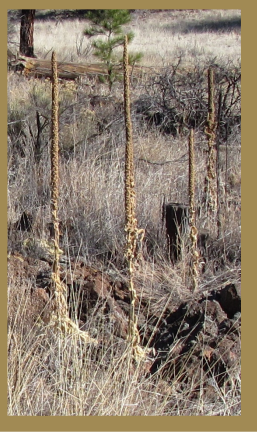
Ponderosa pine forest



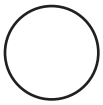
Flowers in grasslands



Old Douglas fir



Common mullein

Piñon-Juniper	Ponderosa Pine	Grasslands and Shrublands	Distinct Vegetation	Exotic Plants
				

Even though the landscape throughout El Malpais National Monument is rugged, and at times barren with little to no soil development, strong alliances between geologic substrate and vegetation exist. The vegetation communities assessed for the park's NRCA are key aspects of the lava flow-influenced ecosystem of the monument, supporting many types of vegetation, including endemic and vulnerable plant associations and species.

While the conditions of piñon-juniper , ponderosa pine, and grass/shrublands were considered to be good, some areas of concern and uncertainty pertain to the increase in density of trees in grasslands, to the potential change in fire interval/frequency in the grasslands, and to the increased tree density in places within the woodland/savanna vegetation community type (Romme and Jacobs 2015). Increased tree densities can lead to an increased potential for spreading crown fires, but the high-density stands observed during a 2015 field visit were patchily distributed rather than continuous. According to Romme and Jacobs (2015), the increase in tree densities "is in large part a manifestation of the climate of the 20th century, which was especially favorable for tree establishment and survival. But we are now moving rapidly out of the climate that characterized the 20th century. Higher temperatures, more frequent and severe droughts, and more frequent and difficult to control wildfires are in our future. Worldwide, trees are dying at an accelerated rate, especially old trees (Allen et al. 2010, Anderegg et al. 2013). We see this at El Malpais NM where the venerable 650+ year-old *Pseudotsuga menziesii* named Yoda recently succumbed to the drought of the last several years. Thus, we may find that a new 21st century management priority will be retaining trees in the face of deteriorating climate, rather than the imperative to reduce tree densities that probably made sense back in the climatically benign days of the late 20th century."

This concept will require a shift in the traditional fire management approach to incorporate ecologically-based objectives rather than a hazard fuel reduction paradigm. Restoration treatments need to be better understood at the local level by evaluating models that are adapted for local conditions, such as those found throughout El Malpais NM.

Another area of concern and uncertainty park-wide is the occurrence of the exotic plant, cheatgrass (*Bromus tectorum*), While its occurrence was low in or near persistent woodlands on El Calderon during the 2015 field visit, Romme and Jacobs (2015) considered it of potentially major ecological significance if it should spread. Increases in nitrogen have been found to promote invasions of fast-growing annuals (e.g., cheatgrass), which in turn, can increase the risk of fire (Rao et al. 2010). All of these factors need to be considered within the context of a rapidly changing climate.

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Juniper tree.

5.11. Piñon-Juniper Resource Condition Brief

The contents of sub-chapter 5.11 were designed to be placed into a stand-alone piñon-juniper resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards and include the contact information of at least one NPS employee as a point contact for the public.

5.11.1. Noteworthy Highlights

Piñon pine (*Pinus edulis*) and one-seed juniper (*Juniperus monosperma*) (piñon-juniper) is a major habitat type found within the boundaries of El Malpais NM, comprising about 20% of the park's total area (Muldavin et al. 2013). Piñon-juniper habitats have considerable value to wildlife, serving as cover, nesting and roosting habitat, and a source of food (e.g., juniper berries and piñon nuts). Based on a functional classification scheme, there are two fundamentally different kinds of piñon-juniper habitats within the national monument: persistent piñon-juniper woodlands, and juniper-piñon savannas. The first type is characterized by centuries-old trees and fire intervals that are very long (at least multi-decadal, but more often measured in centuries). The second type usually has a low- to moderate-density canopy within a well-developed grassland matrix, and more frequent fires.

5.11.2. Condition Rationale

The overall condition of piñon-juniper vegetation at the national monument is good, although there are some areas of concern. Of the six indicators/measures for the two vegetation types (12 indicators/measures total, Table 5.11.2-1), ten are considered to be in good condition. Two (both for juniper-piñon savannas) are considered to be of moderate concern. Overall, the main areas of concern are the increase in tree densities in savannas, and the potential change in fire intervals in the savannas. Another area of concern, although we considered the condition good overall for the indicator/measure, is the occurrence of the exotic plant, cheatgrass, in or near persistent woodlands on El Calderon; the plant's current occurrence appeared to be low. Based on our analysis, the condition of piñon-juniper vegetation in the park appears to have been generally stable over the last half century, and we consider the overall trend in condition as unchanging at this time.

5.11.3. Management and Project Considerations

Resource Topic Vegetation

The results of the following project could apply to several for the vegetation resources discussed in the NRCA, but primarily to vegetation associations on the lava flows since previous studies focused on the flow margins.

Project Title: Vegetation monitoring in remote locations of ELMA

Project Abstract: El Malpais National Monument is roughly 114,000 acres of rugged lava flows; 94% of this land is backcountry or wilderness. Not only has it been nearly 10 years since the last vegetation survey, but the majority of the 2006-2009 survey was completed along the edges of the park as more remote areas were considered too difficult to access. This left extensive areas of land uninvestigated, and while previous surveyors were confident in their work, it is difficult to accept assumptions about such a unique landscape. We believe that an in-house team familiar with the terrain could safely and efficiently hike out to the more remote areas and establish several survey plots during overnight trips. The previous study indicated it would be necessary to use a helicopter to get to any remote area that was without established trails. To mitigate this issue, GPS routes will be created using the specialized knowledge that the Natural Resource division has accumulated of access points and pathways into the deeper portions of the lava. These routes could easily be created in advance and would benefit many future projects. The proposed project would expand upon the previous vegetation inventory and classification project and would include three major parts: plant survey plots, vegetation classification map development, and accuracy assessments. Park staff will create new plots as well as visit original plots to observe changes to the landscape in the last decade; an especially important task as the impacts of climate change cumulate. The previous vegetation inventory and classification project found 17 plant associations classified as “park specials”. These plant associations were not previously established in the National Vegetation Classification System and many are likely to be specific to the lava flows and cinders of El Malpais. An additional 6 plant associations are regionally endemic, found only in very restricted regions. Continued assessments will give valuable insight on these unique plant groups, and assist in management decisions of the 7 plant associations considered to be vulnerable. We have limited knowledge of the health or potential threats, such as exotic species, to these areas. Increased plant inventories of El Malpais will provide a quantitative measure of the floral health of our park. This data will back up any potential management decisions such as restoration or preservation projects, weed removal, or habitat conservation.

In addition, park staff are drafting a vegetation and fire management environmental assessment for future planning efforts. The plan will include all vegetation types found throughout the monument.

Table 5.11.2-1. Summary of overall piñon-juniper condition, indicators and measures, and rationale for assigning condition at El Malpais National Monument.

Piñon-Juniper Vegetation			
Community Type	Indicators/Measures	Condition Status/Trend	Rationale
Persistent Piñon-Juniper Woodland	Is species presence & distribution within natural range of variability?		The condition is generally good, but some concern exists due to low levels of exotic species occurring in some locations. Both cheatgrass and mullein were observed, with cheatgrass being of particular concern due to its potential effect on fire frequency. Condition could change if species expand after soil disturbance.
	Are stand densities within their range of natural variability for their growing conditions?		Condition is good, although there has probably been an increase in tree density over the 20th century due to climate conditions conducive to tree establishment/growth.
	Are age class distributions of trees consistent with expected range of variability?		Although based on limited data, condition appeared good for this indicator. Centuries-old trees are present in most places, along with younger trees <100 yr old, resulting in all-aged population structures which are typical of this vegetation type.
	Do the trees and understory plants appear vigorous and healthy?		Most individual trees and understory plants appeared healthy. However, some dead piñon trees were observed and probably died in the last 5-10 yrs due to drought conditions. Such small-scale mortality events are natural and do not appear to threaten ecological integrity.
	Are ecological processes operating within natural range of variability?		Condition is good, although fire intervals may have lengthened somewhat due to 20th century fire exclusion. However, intervals remain within the historical range of variability for this vegetation type as this type rarely burns, with centuries long intervals between recurrent fires.
	Are the current levels of insects/ disease within the normal range?		Condition is good. There was little evidence of tree mortality or morbidity due to insects or disease.
Persistent Piñon-Juniper Woodland Summary	Overall condition based on all six indicators/ measures		Overall condition is good, with all of the indicators/ measures good. Some concern does exist under the first indicator/measure; although current occurrence appears low, an increase in the exotic species present could increase fire frequency in this vegetation type.

Table 5.11.2-1. Summary of overall piñon-juniper condition, indicators and measures, and rationale for assigning condition at El Malpais National Monument continued.

Piñon-Juniper Vegetation			
Community Type	Indicators/Measures	Condition Status/Trend	Rationale
Juniper-Piñon Savanna	Is species presence & distribution consistent with conditions and within natural range of variability?		Species presence and distribution generally appears to be within the natural range of variability, and is in good condition. The dominant tree species in most of these savannas is one-seed juniper, as was probably the case historically.
	Are stand densities within their range of natural variability for their growing conditions?		Tree densities probably are greater in most stands observed than before 1900, and trees also appear to have expanded into former grasslands in many areas. The mechanism driving these changes is uncertain, but may be the result of a century of fire exclusion and 20th century climate which was favorable for tree establishment/survival. Tree densities naturally wax and wane in this vegetation type over century-long time scales; current densities probably are at or above maximum typical densities. Condition is considered to be of moderate concern. However, current densities are much less dramatic than in other places in the state and do not appear to pose a serious threat to ecological integrity.
	Are age class distributions of trees consistent with expected range of variability?		Condition is good. Based on limited data, the age classes appear to be approximately within their natural range of variability, although 10 to 100-yr-old trees probably constitute a greater proportion of the population than was typical before 1900. Some centuries-old trees are present.
	Do the trees and understory plants appear vigorous and healthy?		Most trees and understory, including grasses and forbs, are healthy in appearance. This is the case even though tree densities are greater than probably existed prior to 1900. Condition is good for this indicator/measure.
	Are ecological processes operating within natural range of variability?		Historical fire regimes of juniper-piñon savannas are not well understood. Spreading fires may have been relatively frequent, given the continuous fine-fuel cover (grasses) and frequent occurrence of dry weather. If so, then the modern fire regime (essentially no fire) is quite different. However, empirical data are lacking, which makes this an area of major uncertainty. Based on the available information, we consider condition to be of moderate concern. Some juniper trees have been killed due to recent prescribed and/or wild fires.
	Are the current levels of insects/ disease within the normal range?		Condition is good. There was little evidence of tree mortality or morbidity due to insects or disease.
Juniper-Piñon Savanna Summary	**Overall condition based on all six indicators/ measures**		**Overall condition is good, with four of the indicators/ measures good and two of moderate concern. The increased tree density within savannas could increase the risk of high-severity crown fires under extremely dry and windy conditions.**



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Ponderosa pine woodland.

5.12. Ponderosa Pine Resource Condition Brief

The contents of sub-chapter 5.12 were designed to be placed into a stand-alone ponderosa pine resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards and include the contact information of at least one NPS employee as a point contact for the public.

5.12.1. Noteworthy Highlights

Areas dominated by ponderosa pine make up a significant proportion of El Malpais NM- about 56% of the total area (Muldavin et al. 2013). Ponderosa pine habitats are of considerable value to wildlife, with at least 250 species of vertebrates inhabiting them in the Southwest (Allen et al. 2002). Based on a functional classification, there are two fundamentally different kinds of ponderosa pine habitats at the park: ponderosa pine-piñon-juniper woodland/savanna, and ponderosa pine-piñon-juniper rocky woodland. The first type is found primarily in areas with gentle topography and where soils are fine-textured and relatively deep, while the second type is found in areas having rugged topography (especially young lava flows with bare rock and little soil development).

5.12.2. Condition Rationale

The overall condition of ponderosa pine vegetation at the national monument is good. There are, however, some areas of concern. Of the twelve indicators/measures for the two ponderosa pine types (six for each type; Table 5.12.2-1), ten are considered to be in good condition. Two (for the woodland/savanna type) are considered to be of moderate concern; these main areas of concern are the increase in fire intervals, which generally exceed the historical range for the type, and higher stand densities occurring today compared to pre-1900. Although all measures were considered good for the rocky woodland type, an increase in fire intervals was noted. Fire managers at the park are reintroducing fire to the system where and when possible. The condition of ponderosa pine vegetation in the park appears to have been generally stable over the last half century, and we consider the overall trend in condition as unchanging at this time.

5.12.3. Management and Project Considerations

Park staff are drafting a vegetation and fire management environmental assessment for future planning efforts. The plan will include all vegetation types found throughout the monument.

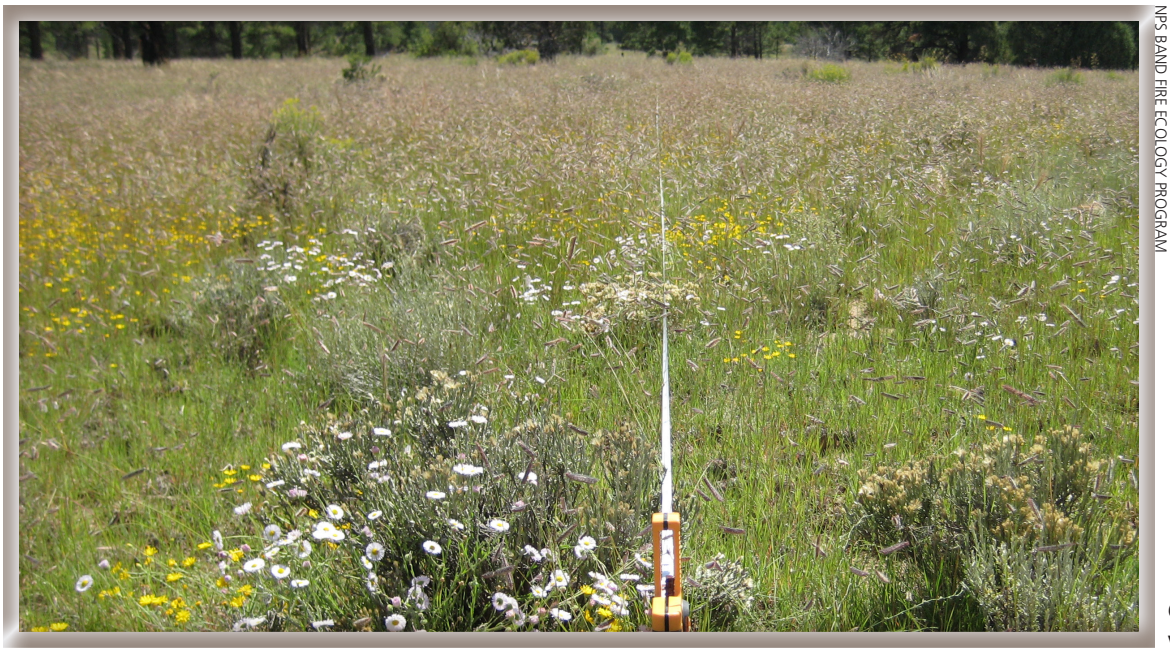
Table 5.12.2-1. Summary of overall ponderosa pine vegetation condition, indicators and measures, and rationale for assigning condition at El Malpais National Monument.

Ponderosa Pine Vegetation			
Community Type	Indicators/Measures	Condition Status/Trend	Rationale
Ponderosa Pine-Piñon-Juniper Woodland-Savanna	Is species presence & distribution within natural range of variability?		n general, the species present and their distribution appear to be in good condition. Some exotic species are present in local areas, but native species predominate in most places.
	Are stand densities within their range of natural variability for their growing conditions?		Stand densities probably are greater in some areas today than before 1900 due to few fires and favorable climatic conditions for trees during the past century. These higher stand densities do not appear to pose any serious threat to ecological integrity, but they may make some areas more susceptible to somewhat larger and more severe wildfires than occurred historically. Overall, condition is of moderate concern.
	Are age class distributions of trees consistent with expected range of variability?		With limited data, the age classes appear to be within their natural range of variability in many areas. However, where heavy logging was conducted in the 20th century, many of the oldest trees were removed, and the oldest trees today are generally <150 yrs old. This departure from historical conditions, however, does not appear to pose any serious threat to ecological integrity, and overall, we considered condition good.
	Do the trees and understory plants appear vigorous and healthy?		Most individual trees and understory plants appeared healthy. However, dead ponderosa pine trees were observed in many areas and probably died in the last 5-10 yrs due to drought conditions. Such small-scale mortality events are natural and do not appear to threaten overall ecological integrity. Therefore, we considered condition good.
	Are ecological processes operating within natural range of variability?		Fire intervals have lengthened considerably due to 20th century fire exclusion, and generally exceed the historical range of variation for this vegetation type. Condition, therefore, is of moderate concern. However, the fire management program at the national monument is reintroducing fire to this vegetation type via manager-ignited prescribed fire and allowing wildfires to burn when/where possible.
	Are the current levels of insects/ disease within the normal range?		Condition is good. We looked for, but saw, little evidence of tree mortality or morbidity due to insects or disease. Insects/ disease appear to pose no serious threat at this time.
Ponderosa Pine-Piñon-Juniper Woodland-Savanna Summary	**Overall condition based on all six indicators/ measures**		**Overall condition is good, with four of the indicators/ measures good and two of moderate concern. Longer fire intervals are of relatively greatest concern, followed by patches of increased tree densities.**

Table 5.12.2-1. Summary of overall ponderosa pine vegetation condition, indicators and measures, and rationale for assigning condition at El Malpais National Monument continued.

Ponderosa Pine Vegetation			
Community Type	Specific Indicators/ Measures	Condition Status/Trend	Rationale
Ponderosa Pine-Piñon-Juniper Rocky Woodland	Is species presence & distribution consistent with conditions and within natural range of variability?		In general, the species present and their distribution appear to be in good condition. Although they may exist, no exotic species were observed during the site visit. Therefore, native species predominate in most places.
	Are stand densities within their range of natural variability for their growing conditions?		Stand densities probably are somewhat greater in some areas today than before 1900 due to few fires and favorable climatic conditions for trees during the past century. However, on the most unfavorable substrates (e.g., young lava flows), tree density probably is limited by harsh environmental conditions. Where they occur, higher stand densities than were typical of historical conditions do not appear to pose any serious threat to ecological integrity. Condition is considered good.
	Are age class distributions of trees consistent with expected range of variability?		Condition is good. With limited data, the age classes appear to be within their natural range of variability in many areas. Although logging in the 20th century removed many of the old trees in some places, much of this habitat is inaccessible and still retains all-aged tree population structures including centuries-old trees. Past logging in these areas does not appear to pose any serious threat to ecological integrity.
	Do the trees and understory plants appear vigorous and healthy?		Most individual trees and understory exhibit healthy appearances. However, dead ponderosa pine trees are seen in many areas. These dead trees appear to have died within the past 5-10 yrs, probably as a result of recent drought conditions. Small-scale mortality events of this kind are natural, and ecological integrity of this vegetation type is not threatened. Overall, condition is good for this indicator/measure.
	Are ecological processes operating within natural range of variability?		Fire intervals have lengthened due to 20th century fire exclusion, even in areas of rugged topography and discontinuous fine fuels, and now generally exceed the historical range of variability for this vegetation type. However, a paucity of 20th century fire does not appear to have compromised overall ecological integrity, and fire is probably less important to stand structure than in the woodland/ savanna type. Also, the fire management program at the park is reintroducing fire to this vegetation type (via prescribed fire and allowing wildfires to burn where/when possible). Condition was judged to be good.
	Are the current levels of insects/ disease within the normal range?		Condition is good. We looked for, but saw, little evidence of tree mortality or morbidity due to insects or disease. Insects/ disease appear to pose no serious threat at this time.
Ponderosa Pine-Piñon-Juniper Rocky Woodland Summary	Overall condition based on all six indicators/ measures		Overall condition is good, with all six of the indicators/ measures good. The are some minor concerns over increased fire intervals, as well as increased tree density in some places and the potential occurrence of exotic plants.

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NPS, BAND, FIRE ECOLOGY PROGRAM

Grassland with wildflowers.

5.13. Grasslands and Shrublands Resource Condition Brief

The contents of sub-chapter 5.13 were designed to be placed into a stand-alone grasslands and shrublands resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards and include the contact information of at least one NPS employee as a point contact for the public.

5.13.1. Noteworthy Highlights

Based on the data used for the assessment, high-value, iconic grassland species appear to be amply represented at the national monument; few exotics were commonly found, and many sites exhibited high species diversity. Also, there was a good diversity of grasses, forbs, subshrubs and shrubs, with only a low level of woody encroachment. With livestock grazing now a much rarer occurrence, conditions are expected to improve.

5.13.2. Condition Rationale

Two indicators were used to assess the condition of grasslands and shrublands at El Malpais NM: those of soil/site stability and biotic integrity. For the soil/site stability indicator, one measure was found to be in good condition, while the other was unknown. For the biotic integrity measure, all five measures were found to be in good condition. Overall, the condition of grasslands at the national monument is good. This condition appears to be stable at the present time, with the cessation of livestock grazing almost 20 years ago.

5.13.3. Management and Project Considerations

Park staff are drafting a vegetation and fire management environmental assessment for future planning efforts. The plan will include all vegetation types found throughout the monument.

Table 5.13.2-1. Summary of overall grasslands and shrublands vegetation condition, indicators and measures, and rationale for assigning condition at El Malpais National Monument.

Grasslands and Shrublands 			
Community Type	Specific Indicators/ Measures	Condition Status/Trend	Rationale
Soil/Site Stability	Soil Cover		Bare soil predominates as would be expected in this location, given substrate and sparse vegetation cover. These conditions, while not ideal for slowing erosion and slowing water flow are normal in this setting. Gravel, rocks, biological soil crusts (moss and lichen), bedrock, and some litter contribute to ground cover (30%) and help protect the soil surface.
	Biological Soil Crust		Some biological soil crusts (moss and lichen) were found, but data were scant. Condition of this measure could not be assigned.
Biotic Integrity	Landscape-scale Diversity		Species composition is consistent with expected species based on spatial patterns of soils and geology; vegetation communities reflect the natural range of variation.
	Local Species Composition		Species composition is consistent with expected species; few exotics were commonly found, and many sites exhibited high diversity.
	General Life Cycles Relative to Disturbance		The proportion of annual, biennial and perennial species relative to the time since disturbance was not obviously consistent. There are sites with ruderal species for which the disturbance mechanism is unknown to the authors.
	Relative Proportion of Functional Groups (e.g., graminoid, forbs, shrubs, etc.)		The relative proportions of functional groups are consistent with what would be expected; there was a good diversity of grasses, forbs, subshrubs, and shrubs. Only slight and occasional woody encroachment was evident.
	Relative Proportion of C3 and C4 Species		The relative proportions of C3 and C4 plants are consistent with what would be expected based on site characteristics and local climate variables.



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Phacelia serrete **(cinders phacelia) (shown here) is an endemic species that grows on volcanic cinders in only two areas - one of those areas includes El Malpais National Monument.**

5.14. Distinct Vegetation Resource Condition Brief

The contents of sub-chapter 5.14 were designed to be placed into a stand-alone distinct vegetation resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards and include the contact information of at least one NPS employee as a point contact for the public.

5.14.1. Noteworthy Highlights

Important biogeographic aspects and characteristics of the monument's distinct vegetation include ancient trees growing on the young lava flows, the endemic plant species *Phacelia serrete* (cinders phacelia), endemic and vulnerable plant associations, including ones that have only been found at El Malpais, and the vegetation communities found on kipukas.

5.14.2. Condition Rationale

The overall condition of the ecological integrity indicator for the distinct vegetation at the national monument is currently unknown. (Table 5.14.2-1). The types of distinct vegetation included the condition aspects evaluated for condition in the broad vegetation community assessments (i.e., pinyon-juniper and ponderosa pine assessed in Sections 4.8 and 4.9, respectively), where conditions are likely to be the same (e.g., good) where they overlap.

5.14.3. Management and Project Considerations

Park staff are drafting a vegetation and fire management environmental assessment for future planning efforts. The plan will include all vegetation types found throughout the monument.

Table 5.14.2-1. Summary of overall distinct vegetation condition, indicators and measures, and rationale for assigning condition at El Malpais National Monument.

Distinct Vegetation			
Community Type	Indicators/Measures	Condition Status/Trend	Rationale
Ecological Integrity	n/a		The ancient trees, cinders phacelia, endemic and vulnerable plant associations, and vegetation communities growing on kipukas are not being monitored. Therefore, their current condition is unknown.



© ALYSON MATHIS - COMMON MULLEIN

Common mullein.

5.15. Exotic Plants Resource Condition Brief

The contents of sub-chapter 5.15 were designed to be placed into a stand-alone exotic plants resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards and include the contact information of at least one NPS employee as a point contact for the public.

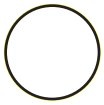
5.15.1. Condition Rationale

The overall condition of exotic plants at El Malpais NM is unknown (Table 5.15.1-1). The condition of the potential to alter native plant communities indicator is of significant concern since six species with the highest rankings for exotic plant impact and five species with high rankings for exotic plant impacts have been documented in the park. Thirteen additional species had medium rankings. *Verbascum thapsus* is of special concern since this species typically grows in disturbed areas but is invasive in open landscapes, especially in areas with basaltic substrates. The prevalence of exotic plants is unknown. Information on the occurrence of exotic plant species was limited to only vegetation mapping plots that were sampled between 2006 and 2009 (Muldavin et al. 2013).

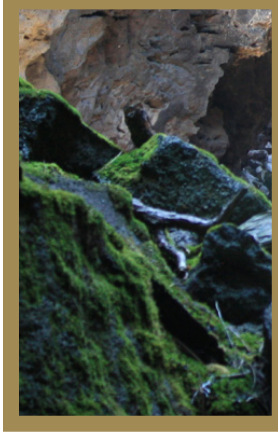
5.15.2. Management and Project Considerations

Park staff are drafting a vegetation and fire management environmental assessment for future planning efforts. The plan will include all vegetation types found throughout the monument

Table 5.15.1-1. Summary of overall exotic plants condition, indicators and measures, and rationale for assigning condition assessment at El Malpais National Monument.

Exotic Plants			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Potential to Alter Native Plant Communities	Significance of Exotic Plant Impact		This measure is based on the premise that species with the highest innate ability to become a pest generally cause the most severe problems in natural ecosystems. Six of the 38 species of exotic plants documented in El Malpais were ranked as having the highest innate ability to become a pest, and 5 species were ranked as high. There was one species of special concern. Therefore, we consider this measure to be of significant concern.
Prevalence of Exotic Plants	Number of observations in vegetation mapping plots		The prevalence of exotic plants at El Malpais is unknown. The reporting of exotic plant observations in vegetation mapping and classification plots in 2006-2009 provides limited information on the occurrence of exotic plants. However, specific information about exotic plants in the interior of the monument and along vectors is unknown.

Wildlife Resources Summary



Cave moss



Bobcat



Townsend's Big-eared bat



Scott's oriole



Plateau striped whiptail

Cave Ecology and Species	Mammals	Bats	Birds	Herpetofauna
○	○	●	○	○

Many data gaps in long-term monitoring and research have been identified for the wildlife resources group of topics assessed for the NRCA as shown by the unknown condition ratings, except for bats, which are in good condition. However, El Malpais National Monument, within the greater El Malpais Conservation Area and adjacent U.S. National Forest land, provides large tracts of unfragmented habitat and connectivity for species found throughout the region. In addition, the rugged terrain of the volcanic landscape and restricted or difficult access to most caves and areas of the park, affords a layer of protection that will help park managers achieve conservation goals.

A key area of uncertainty is that many of the lava tube caves have not yet been surveyed for roosting bats and other cave-dependent species. Also, only a small proportion of the lava tube caves (10 caves) have been/are being monitored for the fungus that causes White-nose syndrome (WNS), a recently-discovered disease that affects hibernating bats resulting in the mortality of nearly 6 million bats in eastern North America (USFWS 2014). El Malpais NM staff also have concerns for the park due to its location relative to the most western-known occurrence of WNS (Arkansas, as of May 2015). The microclimate conditions in some caves at El Malpais NM are suitable for sustaining the WNS fungus, and the caves also provide optimal locations for bats to hibernate during the winter. An additional factor is the heavy visitation of some of the caves by U.S. and international travelers. Together, these factors may put the caves at risk of being the "first contact" for *P. destructans* in New Mexico (Eric Weaver, Acting Natural Resources Branch Chief, El Malpais NM, pers. comm.). However, this is an uncertainty at this time, and El Malpais NM managers are taking precautions against the disease. Park staff are also currently developing a comprehensive cave monitoring program, which will help reduce some of the existing data gaps.

There are likely several additional wildlife species that are currently unconfirmed but may be discovered in the future with additional monitoring. For example, Bogan et al. (2007) suggested that the grassy parcel near Grants may harbor more grassland species than what is currently included in the park's species lists.

Overall, the natural and undeveloped qualities that the monument preserves, along with additional wilderness areas managed by the Bureau of Land Management and protected land with some extractive uses, managed by the U.S. Forest Service, provides structural and functional corridors for species to persist. It may be necessary to identify which corridors and areas are most important to maintaining intact trophic levels of species.

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Cave entrance flora includes moss gardens at cave entrances and under skylights. These areas contain distinct vegetation assemblages and also are extremely important for invertebrates (Wynne 2013).

5.16. Cave Ecology and Species Resource Condition Brief

The contents of sub-chapter 5.16 were designed to be placed into a stand-alone cave ecology and species resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards and include the contact information of at least one NPS employee as a point contact for the public.

5.16.1. Noteworthy Highlights

Cave biodiversity is generally low compared to other environments because of fewer food resources, less habitat diversity and decreased ecotones (Baker et al. 2015). However, caves provide distinct ecological resources for species that are partially or wholly dependent on caves for their survival. El Malpais caves contain known endemic species and most likely contain others that have yet to be documented.

5.16.2. Condition Rationale

One indicator, with two measures was used to assess the overall condition of cave ecology and species in El Malpais NM (Table 5.16.2-1). Since only a small portion of the total number of species that live in or utilize El Malpais caves most likely have been documented, and a cave entrance flora inventory has yet to be completed, the condition is unknown at this time. However, park staff recently submitted a proposal for 2018 funding to map the moss gardens and inventory the invertebrates contained in them. They will begin the process of mapping the moss gardens beforehand, which will be a significant resource management focus in 2016 (E. Weaver, pers. comm. 2016).

5.16.3. Management and Project Considerations

Moss Garden Management, Protection, and Research

Project Title: Inventorying and assessing risk of habitat loss for invertebrates in moss gardens at ELMA

Project Abstract: The moss gardens in the entrance and skylights of the lava tubes at ELMA are one of the Park's most significant and largely undervalued resource, containing unique and isolated ecosystems that often provide a habitat that supports endemic species (Wynne

and Shear 2016; Wynne 2013). There are 28 species of moss that have been identified at ELMA, including an arctic-alpine moss (Lindsey 1951) supported in a low elevation region by the cool cave environment. Unfortunately, due to their remote locations, we have limited information about this resource and the life that it supports. The few studies of the ecology of moss gardens conducted at ELMA (Northup and Welbourn 1997; Wynne 2013) have been limited in extent to the more accessible caves of ELMA. Results of these studies suggest that a more extensive survey would provide substantial and significant results. Beyond these studies, our records indicate the presence/absence of moss gardens without any inventory of the invertebrates; additionally, photomonitoring of a select few moss gardens was conducted briefly in the 1990s. This project seeks to 1) document, identify, and measure moss gardens at ELMA, 2) establish permanent photomonitoring sites to monitor change in health and area size of moss gardens, 3) inventory invertebrate and bryophyte species contained within the moss gardens, 4) increase our knowledge on how external climatic changes affect the microclimates in lava tube caves (hereafter "lava tubes"), and 5) share our results with the public and through professional publications.

Moss Garden Management and Protection

ELMA will conduct a mini Bioblitz to map and create photo points for moss gardens in up to 40 caves. The work will be conducted by ELMA Resources Management staff and volunteers from the Sandia and Pajarito Mesa Grattos. This is not a PMIS project but an ELMA Base-funded project and Centennial kickoff to be conducted in May 2016 and monitored throughout the year.

Table 5.16.2-1. Summary of overall cave ecology and species condition, indicators and measures, and rationale for assigning condition assessment at El Malpais National Monument.

Cave Ecology and Species			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Cave-dependent Species	Invertebrates		The condition of invertebrates in El Malpais caves is unknown because limited inventory information for arthropods only exists for 10 El Malpais caves. Invertebrates in El Malpais caves are not being monitored.
	Cave Entrance Floras		The condition of cave entrance flora in El Malpais caves is unknown. A full inventory of cave entrance flora has not been completed, and species composition of the flora is also unknown. Cave entrance flora in El Malpais caves are not being monitored.



Bobcat.

5.17. Mammals Resource Condition Brief

The contents of sub-chapter 5.17 were designed to be placed into a stand-alone mammals resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards and include the contact information of at least one NPS employee as a point contact for the public

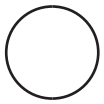
5.17.1. Noteworthy Highlights:

Approximately 55 mammal species have been recorded at El Malpais NM during 2003-2004 surveys by Bogan et al. (2007) and/or during the early 1990s surveys by Lightfoot et al. (1994). Additional species are believed to occur. During the 2003-2004 surveys, researchers recorded 21 rodent species, 12 bat species, eight carnivore species, three ungulate species, and two lagomorh species. Six of the species documented at the park are considered Species of Greatest Conservation Need, including one species that is federally and state-listed (Mexican gray wolf) and one species that is state-listed (spotted bat).

5.17.2. Condition Rationale:

The current condition of mammals at El Malpais NM, assessed using one indicator/measure, species occurrence (presence/absence), is unknown (Table 5.17.2-1). There is no current information on mammal species as a group, with the most recent surveys having been conducted in 2003-2004 by Bogan et al. (2007). However, note that this assessment focuses on mammals as a group; we conducted a separate assessment focusing on bats only, as bats are of particular interest in the park and a substantial amount of recent information is available on them. Approximately 55 species of mammals have been documented in the national monument, and additional species are thought to occur. Although condition and trends of mammals cannot be determined at this time, the 2003-2004 surveys (and earlier work) provide good baseline information for future monitoring and condition assessment.

Table 5.17.2-1. Summary of overall mammal condition, indicators and measures, and rationale for assigning condition at El Malpais National Monument.

Mammals			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Species Occurrence	Presence / Absence		There is no current information available on mammals (as a group) at the national monument. The most recent surveys were conducted in 2003-2004 (i.e., Bogan et al. 2007). Although condition can not be determined at this time, the 2003-2004 work, as well as earlier surveys by Lightfoot et al. (1994) and Valdez et al. (2002) provides baseline information for future monitoring and assessment. One of the species documented at the park is considered federally and state endangered, and another species is listed as threatened with the State. Six species, including these two endangered/threatened species, are listed as New Mexico Species of Greatest Conservation Need.



NPS / SHAWN THOMAS - TOWNSEND'S BIG-EARED BAT

Townsend's big-eared bat.

5.18. Bats Resource Condition Brief

The contents of sub-chapter 5.18 were designed to be placed into a stand-alone bats resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards and include the contact information of at least one NPS employee as a point contact for the public.

5.18.1. Noteworthy Highlights

Bats are an ecologically important and interesting group of mammals. Approximately 15 species of bats have been documented at El Malpais NM. Several species are known to use the national monument's caves. These include the Mexican (or Brazilian) free-tailed bat and Townsend's big-eared bat, which roost in relatively large numbers (the first in the summer, and the second in the winter). One of the species recorded in the national monument, the spotted bat, is listed as threatened with the State of New Mexico, as well as a Species of Greatest Conservation Need. Bats have been the subject of research and monitoring in the park in recent years because of the threat of white-nose syndrome (WNS), which was first discovered in eastern North America.

5.18.2. Condition Rationale

We used three indicators, each with one measure, to assess the condition of bats at El Malpais NM (Table 5.18.2-1). Under these three indicators, species occurrence, occurrence of *P. destructans* and/or WNS, and habitat availability and condition, current condition was judged to be good. Under the third indicator, we addressed primarily bat roosting (in winter and summer) in caves and trees. At least eight species have been observed using caves at the park, and managers are using various methods to protect bats from human disturbance (e.g., cave closures during sensitive times for bats). Even though condition under the second indicator is currently good, the threat from WNS remains with the closest confirmed presence of the disease in Arkansas (as of May 2015). Based on monitoring efforts at the park, neither *P. destructans* nor WNS have been detected in caves or bats within the national monument, but microclimate conditions are suitable for the fungus in some caves.

5.18.3. Management and Project Considerations

Project ideas for mitigating the threat of White-nose Syndrome (WNS) are summarized in the following abstract, which was submitted as a budget request in the NPS Project Management Information System.

Table 5.18.2-1. Summary of overall bat condition, indicators and measures, and rationale for assigning condition at El Malpais National Monument.

Bats			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Species Occurrence	Presence / Absence		Comparing the bat species observed in 1999-2000 by Valdez et al. (2002) and in 2003-2004 by Bogan et al. (2007; the lists were nearly the same) to that by Valdez (2012) in 2011, six species were not observed in 2011 that had been observed previously. However, some of the differences were probably due to differences in sampling locations between the efforts and the fact that some of the species are not common. Also, at least seven species have been documented by park staff and/or Northup et al. (2015) in 2014-2015. Based on the information available, we do not have any particular concerns for species occurrence at this time. There is insufficient data to judge trends. .
Occurrence of *P. destructans* and/or WNS	Presence / Absence		The monitoring work of Valdez (2012) captured >400 bats of eight species, and none of the captured bats showed evidence of the fungus or WNS. Valdez noted, however, that some subtle signs of the disease or fungus could have gone undetected. Samples collected and analyzed by Northup (2013) from 10 caves in the national monument were negative for the presence of *P. destructans* using the most accurate test available. Based on these results (and those of Northup et al. 2015), we consider the condition for this indicator/measure to be good at this time. However, awareness and concern for bats at the national monument remains high as this fungus and disease continues to be studied and monitored. Furthermore, only a small proportion of the lava tube caves at El Malpais NM have been/ are being monitored for *P. destructans*, and it is possible that other important (and as of yet undiscovered) winter hibernacula exist.
Habitat Availability & Condition	Free from / with Minimal Human Disturbance		We addressed primarily bat roosting (in winter and summer) in caves and/or trees. At least eight species have been observed using caves at the park, some for hibernating and some for maternity roosts. Based on the available information, including the continued, observed use of some of the caves by bats, we consider habitat availability and condition for bats with respect to caves to be good. Only a small number of caves are open to the public, and prior to cave entrance the public must obtain a permit and speak with a ranger about cave protection/visitation. Also, the park uses cave closures of some caves at especially sensitive times for bats. Additionally, more caves (fairly free from human disturbance) are probably used for roosting than are currently known. Although we have no specific information on bat use of piñon-juniper, ponderosa pine, or other vegetation at El Malpais NM, some of the species that occur at the park are known to roost in trees in these habitats. We consider condition good for this aspect of the assessment because of the availability and condition (judged to be good) of these areas at the park. Additionally, one relatively large and open pool of water on the northeast corner of the park is known to be a valuable resource for drinking and possibly foraging. Overall, condition is good for this indicator/measure.

Project title: Investigating Natural Defenses of Bats

Project Abstract: WNS is expected to reach New Mexico within the next five years, making the gathering of baseline information of New Mexico bats to be of paramount importance. Many western species of bats in ELMA are analogous to eastern species; therefore, our research is capable of having far-reaching impacts on the understanding of P. destructans and potential treatments of WNS. Identifying antimicrobial agents that inhibit the growth of P. destructans on bats and their habitat is in the early stages of development. Little is known about the natural defenses of bats and the role they play in combating P. destructans. Since 2013, six ELMA bat species were swabbed for DNA analysis of their microbiome and to culture Actinobacteria. Actinobacteria produce microbial agents, which are often abundant in caves. By culturing bacteria, our previous studies have determined that some naturally-occurring bacteria in ELMA caves inhibit P. destructans. By 2015, 900 isolates were cultured and more than 20, from five different genera of Actinobacteria, were shown to inhibit P. destructans. The next phase to determine the natural defenses of bats against P. destructans is to screen these isolates for the polyketide synthase type II (PKS II) gene group. Preliminary screening of 43 actinobacterial isolates from four ELMA sites found nine isolates positive for PKS II. We propose gene sequencing of positive isolates to determine PKS II gene diversity of NM bats and differences between these genes among different bat species.

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Scott's oriole

5.19. Landbirds Resource Condition Brief

The contents of sub-chapter 5.19 were designed to be placed into a stand-alone landbirds resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards and include the contact information of at least one NPS employee as a point contact for the public.

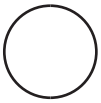
5.19.1. Noteworthy Highlights

At least 183 landbird species have been recorded in the national monument during surveys in the 1990s (Lightfoot et al. 1994) and 2002-2003 (Johnson et al. 2007) and observations by national monument staff/volunteers in 2011-early 2015. Forty-six of the species appear on one or more of the various lists of species of conservation concern. Three species (Bald Eagle, Gray Vireo, and Peregrine Falcon) are listed as threatened with the State of New Mexico. Although we judge the condition unknown due to a lack of recent comprehensive surveys, it seems clear that El Malpais NM is inhabited by a diverse array of birds, at least some of which breed in the park.

5.19.2. Condition Rationale

Using the species occurrence indicator to assess the condition of landbirds at El Malpais NM, we found current condition and trends to be unknown (Table 5.19.2-1). There are no current data representative of the entire park to assess current condition. The most recent standardized surveys were conducted in 2002-2003 during the breeding season. Recent observations (2011-early 2015) were made by park personnel throughout portions of the year along roads bordering the monument (Highway 53 and 117). Although condition cannot be determined at this time, the three efforts to survey/observe birds at the park have led to a substantial list of birds. At least 183 bird species have been recorded, including 46 species that appear on one or more lists of birds of conservation concern. This list includes three state-listed bird species but no federally-listed species. The 2002-2003 standardized surveys (and earlier work) provide baseline information for future monitoring and condition assessment.

Table 5.19.2-1. Summary of overall landbird condition, indicators and measures, and rationale for assigning condition at El Malpais National Monument.

Landbirds			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Species Occurrence	Presence / Absence		We used one indicator/measure, species occurrence, to assess the condition of landbirds at El Malpais NM. There are no current data representative of the entire park to assess current condition of birds. The most recent standardized surveys were conducted in 2002-2003 during the breeding season (i.e., Johnson et al. 2007). Recent observations (2011-early 2015) have been conducted by park personnel from January/February until May/June and throughout the remainder of the year along roads bordering the monument. Although condition and trend cannot be determined at this time, the three efforts to survey/observe birds at the park have led to a substantial list of birds-at least 183 bird species (and more if subspecies are included), including 46 species that appear on one or more lists of birds of conservation concern.



©ROBERT. SHANTZ - PLATEAU STRIPED WHIPTAIL

Plateau striped whiptail.

5.20. Herpetofauna Resource Condition Brief

The contents of sub-chapter 5.20 were designed to be placed into a stand-alone herpetofauna resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards and include the contact information of at least one NPS employee as a point contact for the public.

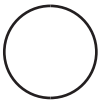
5.20.1. Noteworthy Highlights

A total of 21 species of amphibians and reptiles were recorded at El Malpais NM during 2002-2003 surveys by USGS (Nowak and Persons 2008) and/or during the early 1990s surveys by the University of New Mexico (Lightfoot et al. 1994). Several additional species were noted as "probably present" or "unconfirmed" by Nowak and Persons (2008). Of the 21 species, 18 were recorded during the 2002-2003 surveys (i.e., five amphibian and 13 reptile species). None of the species are federally or state-listed as endangered or threatened, but three are considered Species of Greatest Conservation Need (SGCN) in New Mexico.

5.20.2. Condition Rationale

The current condition of amphibians and reptiles at the national monument, assessed using one indicator/measure, species occurrence (presence/absence), is unknown (Table 5.20.2-1). There is no current information available on the herpetofauna of the park with which to assess condition. The most recent surveys were conducted by the USGS Southwest Biological Science Center in 2002-2003. Some earlier surveys by Lightfoot et al. (1994) were also reviewed for the assessment. Combined, the studies documented 21 species in the national monument. Although condition and trends cannot be determined, the 2002-2003 surveys (and earlier work) provide good baseline information for future monitoring and condition assessment.

Table 5.20.2-1. Summary of overall herpetofauna condition, indicators and measures, and rationale for assigning condition at El Malpais National Monument.

Herpetofauna			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Species Occurrence	Presence / Absence		There is no current information available on amphibians and reptiles at the national monument. The most recent surveys were conducted in 2002-2003 (i.e., Nowak and Persons 2008). Although condition can not be determined at this time,the 2002-2003 work, as well as earlier surveys by Lightfoot et al. (1994), provides baseline information for future monitoring and assessment.

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Appendix A: Team Members, Subject Matter Experts/Reviewers, and GIS Data Summary

Table A.1. El Malpais National Monument NRCA Project Team Members

El Malpais NM NRCA Project Team
Jeff Albright, NPS Water Resources Division's Coordinator of the NRCA Report Series
Lisa Baril, Utah State University Science Writer
Steve Baumann, NPS El Malpais and El Morro National Monuments' Resources Management Chief
Nina Chambers, Northern Rockies Conservation Cooperative Science Writer
Mitzi Frank, NPS El Malpais and El Morro National Monuments' Superintendent
Dave Hays, NPS El Malpais and El Morro National Monuments' Natural Resources Branch Chief (Former)
Allyson Mathis, Utah State University Science Writer
Donna Shorrock, NPS Intermountain Region Natural Resource Condition Assessment Regional Coordinator
Kim Struthers, Utah State University Science Writer/Editor
Lisa Thomas, NPS Southern Colorado Plateau Inventory and Monitoring Network Program Manager
Patty Valentine-Darby, University of West Florida Biologist and Writer/Editor
Eric Weaver, NPS El Malpais and El Morro National Monuments' Physical Science Technician and Acting Natural Resources Branch Chief

Table A.2. El Malpais National Monument NRCA Subject Matter Experts and/or Assessment Reviewers

Subject Matter Expert/Assessment Reviewer	Topic(s)	Project Deliverable(s)
Jeff Albright, National Park Service Water Resources Division, Natural Resource Condition Assessment Series Coordinator	Full report	Program Level Review
Steve Baumann, National Park Service El Malpais and El Malpais National Monuments Resources Management Chief	Full report	Park Expert Review
Eric Weaver, National Park Service El Malpais and El Malpais National Monuments Physical Science Technician and Acting Natural Resources Branch Chief	Full report	Park Expert Review
Stephen Monroe, National Park Service Southern Colorado Plateau I&M Network Program Hydrologist	Tinajas	Reviewed Tinajas section
Joel Wagner, National Park Service Water Resources Division Wetlands Program Lead	Tinajas	Reviewed Tinajas section
Ksienya Pugacheva, National Park Service Air Resources Division, Natural Resource Specialist	Air Quality	Reviewed air quality section and provided NRCA template
Tim Connors, National Park Service Geologic Resources Division, Geologist	Surface Geology	Reviewed Surface Geology sections
Vince Santucci, National Park Service Geologic Resources Division, Senior Paleontologist/GRD Liaison	Surface Geology: Paleontological Resources	Reviewed Paleontological Resources section
Lisa Thomas, National Park Service Southern Colorado Plateau I&M Network Program Manager	Vegetation topics	Reviewed Vegetation sections and participated in field assessment
Dale Pate, National Park Service Geologic Resources Division, National Cave and Karst Program Coordinator	Caves and Cave Ice, and Cave Ecology	Reviewed Caves and Cave Ice, Cave Ecology sections
Jim DeCoster, National Park Service Southern Colorado Plateau I&M Network Plant Ecologist	Vegetation	Participated in the field assessment
Chad Moore, National Park Service Natural Sounds and Night Skies Division Night Skies Program Manager	Night Sky	Provided information pertaining to night sky data collection methodology and interpretation of results.

Table A.2. El Malpais National Monument NRCA Subject Matter Experts and/or Assessment Reviewers (cont.)

Subject Matter Expert/Assessment Reviewers	Topic(s)	Project Deliverable(s)
Jeremy White, National Park Service Natural Sounds and Night Skies Division Physical Scientist	Night Sky	Reviewed Night Sky sections including Bortle Key Appendix C
Dr. Henri D. Grissino-Mayer, The University of Tennessee, Professor and Associate Department Head, Department of Geography	Distinct Vegetation Communities	Reviewed Distinct Vegetation Communities section
Myron Chase, National Park Service, Intermountain Regional Office, Regional IPM an d Invasive Species Coordinator	Exotic Plants	Reviewed Exotic Plants section
Mike Wrigley, National Park Service, Intermountain Regional Office, Wildlife Biologist	Wildlife	Reviewed Wildlife sections
Emma Brown National Park Service Natural Sounds and Night Skies Division Acoustical Resource Specialist	Soundscape	Reviewed Soundscape section provided NRCA template
Dr. William H. Romme, Professor emeritus of fire ecology and research scientist in the Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, CO.	Vegetation	Participated in the field assessment, co-authored the report upon which the vegetation section was based, and reviewed the draft of this section.
Brian Jacobs, Vegetation Ecologist who recently retired from the NPS at Bandelier NM	Vegetation	Participated in the field assessment and co-authored the report upon which the vegetation section was based

Table A.3. Summary of GIS Data Used in El Malpais National Monument's NRCA

Chapter or Natural Resource	GIS Data/Map	GIS Data Source
Chapter 2	Wilderness Map	Wilderness map provided by ELMA staff
	El Malpais National Monument Vicinity	ESRI online map
	Housing Density	NPS NRSS NPScape Program provided map.
	Southern Colorado Plateau Network Precipitation	Map obtained from NPS Southern Colorado Plateau Inventory and Monitoring website: http://science.nature.nps.gov/im/units/scpn/climate/climate.cfm/
	Watersheds	Data obtained from USGS National Map - Hydrography website: http://nhd.usgs.gov/ and base map from ESRI online
	Major Volcanic Features	Geology dataset originated from NPS Geologic Resources Division and provided by ELMA staff
Viewshed	Viewshed Vantage Points	Coordinates GPSd and provided on final DVD to park and IMR GIS
	Viewshed Analysis	Analysis files provided on final DVD to park and IMR GIS
	Housing Density	Data obtained from NPS NPScape website: http://science.nature.nps.gov/im/monitor/npscape/gis_data.cfm
	Road Density	Data obtained from NPS NPScape Website: http://science.nature.nps.gov/im/monitor/npscape/gis_data.cfm
Night Sky	ALR Map	NPS NRSS Natural Sounds and Night Skies Division provided map.
Soundscape and Appendix D	Acoustical Monitoring Locations	Coordinates taken from NPS NRSS Natural Sounds and Night Skies Division Acoustical monitoring snapshot report (2009).
	Areas Without Roads	Data obtained from NPS NPScape website: http://science.nature.nps.gov/im/monitor/npscape/gis_data.cfm
	L_{50} Impact, Natural, and Existing Maps	NPS NRSS Natural Sounds and Night Skies Division provided map.
Air Quality	Locations of Nitrogen sensitive vegetation	Data obtained from NPS IRMA website: https://irma.nps.gov/DataStore/

Table A.3. Summary of GIS Data Used in El Malpais National Monument's NRCA (cont.)

Surface Geology and Appendix E	El Malpais lava flows, vents, cinders cones and fields	Geology dataset originated from NPS Geologic Resources Division and provided by ELMA staff
	Lava Flow Surface	Image obtained from Google Earth
	Volcanic Vents and Floes	Image obtained from Google Earth
Caves and Cave Ice	Major volcanic units and lava tubes	Geology dataset originated from NPS Geologic Resources Division and provided by ELMA staff
	Junction Cave impact map	Map provided by ELMA staff
Tinajas	Drought map	Obtained from National Drought Mitigation Center
Vegetation: Piñon-Juniper	Vegetation Communities	Vegetation data layer was provided by ELMA staff.
Vegetation: Ponderosa Pine	Vegetation Communities	Vegetation data layer was provided by ELMA staff.
Vegetation: Grasslands and Shrublands	Vegetation Communities	Vegetation data layer was provided by ELMA staff.
	Fire Effects and Vegetation Map Plot Locations	Vegetation data layer was provided by ELMA staff and fire effects data were provided by Laura Trade, Bandelier New Mexico Fire Program
	Soil Types	Data obtained from Natural Resource Conservation Service
	Geology	Map obtained from Muldavin et al. 2013
Vegetation: Distinct and Appendix G	Geologic Substrates and Ancient Trees	Geology dataset originated from NPS Geologic Resources Division and provided by ELMA staff and papers or researchers cited in section
	Vegetation Map	Map obtained from Muldavin et al. 2013
Exotic Plants	Vegetation Map Plot Locations	Vegetation data layer was provided by ELMA staff
Bats	White-nose syndrome map	Obtained from www.whitenosesyndrome.org
Birds	Bird Conservation Regions In North America	Data obtained from North American Bird Conservation Initiative website: http://www.nabci-us.org

Appendix B: Viewshed Analysis Steps

The process used to complete El Malpais and El Morro National Monuments' viewshed analyses is listed below.

Downloaded 12 of the 1/3 arc second national elevation dataset (NED) grid (roughly equivalent to a 30 m digital elevation model [DEM]) from The National Map Seamless Server (http://seamless.usgs.gov/) (USGS 2015) and created a mosaic dataset. The x and y values for the NED are in arc seconds while the z data are in meters. The DEMs were reprojected into NAD83 Albers Meter to get all data in meters and into a geographic extent that covered the entire area.

Prepared observation point layers for viewshed analyses by importing GPSd points for all vantage point locations selected for viewshed analysis. Exported data a shapefile. Added field named "OFFSETA" (type = double) to shapefile and set value to an observer height of 1.68 m (~5'6").

Ran Viewshed Analysis using the Viewshed Tool in ESRI's ArcGIS 10.2, Spatial Analyst Toolbox, ran viewsheds using the following inputs.

- Input raster = 1/3 arc second NED
- Input point observer feature = obs_point.shp.

The rasters were reclassified into visible areas only, converted to polygons, and merged into one dataset for each park. The two datasets were reprojected into the Albers Equal Area Conic USGS projections to use NPS NPScape's housing and road density tools (NPS 2011a). Text attributes were added to both datasets for the area of analysis identifier (NPS 2011b).

Housing (CONUS, Density, SERGoM, 1970 - 2100, Metric Data (ESRI 9.3 File Geodatabase) (Theobald 2005) and road (United States and Canada, Density - All Roads, ESRI, 2005, Metric Data (ESRI 9.3 File Geodatabase) (ESRI 2010) GIS datasets were downloaded from NPScape's website at http://science.nature.nps.gov/im/monitor/npscape/gis_data.cfm?tab=1.

Standard Operating Procedures for both density tools (NPS 2014a,b) were followed based on NPScape instructions: https://irma.nps.gov/DataStore/Reference/Profile/2193329 and https://irma.nps.gov/DataStore/Reference/Profile/2193334.

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Appendix C: Bortle Dark-Sky Scale

Key for the Summer Sky— Latitudes 30° to 50° N

The Milky Way is not visible and sky glow extends above 35 degrees. Little to no dark adaptation is possible. Ground texture is easily seen, and artificial light dominates the landscape. Visible constellations are limited to the very brightest if any. The sky has a uniform washed out appearance.[1]

If this describes your nighttime environment, continue below

If the nighttime environment appears darker than this description, jump to the next section

Sky appears nearly completely washed out, and is luminous. Dark adaptation is not possible, ground is brightly illuminated and fewer than 200 stars are visible. Only the most major constellations are identifiable. For instance, the entire keystone of Hercules or the five stars of Delphinus are not completely visible.

this is accurate **Bortle Class 9** if darker—proceed below

Constellations are visible but may be missing key stars, sky background has a uniform washed out glow with light domes reaching 60 degrees above the horizon. Stars such as the tip of Sagitta or epsilon Lyrae are not visible. If clouds are present they are brilliantly lit.

this is accurate **Bortle Class 8** if darker—proceed below

Brighter constellations are easily seen in full, yet sky background has greyish or yellow background. Milky Way may be just barely seen near the zenith. The Scutum and Cygnus star clouds are not visible.If clouds are present they are brilliantly lit. Ground texture is still visible.

this is accurate **Bortle Class 7**

The Milky Way is visible but discontinuous, and lost to light domes near the horizon. Fine details and structure are not easily visible, if at all. Ground texture is still visible, and shadows are cast from light pollution. Light domes are clearly visible along the horizon and appear brighter than any portion of the visible Milky Way.[2]

If this describes your nighttime environment, continue below

If the nighttime environment appears darker than this description, jump to the next section

The Milky Way is just visible overhead, but is not continuous and is diminished to obvious skyglow. Cygnus ,Scutum, and Sagittarius star fields just visible. If clouds present they are illuminated and reflecting light. Ground texture is seen with difficulty.

this is accurate **Bortle Class 6** if darker—proceed below

Milky Way is faintly present, but may have occasional gaps and is lost to skyglow near the horizon. Great rift in Cygnus is just visible. Any clouds present are brighter than the background sky and reflect light back. Zodiacal light may be glimpsed, but is difficult to see amidst the light pollution. Ground texture is not visible but forms are easily seen.

this is accurate **Bortle Class 5** if darker—proceed below

Milky Way is evident from horizon to horizon, but fine details are lost. Clouds are just brighter than background sky, but appear dark at zenith. Light domes are much brighter than brightest part of Milky Way and extend to up to 15 degrees above the horizon. Zodiacal light is evident in west after sunset or in east before dawn. Deep sky objects such as the M13 globular cluster and Northern Coal Sac are visible.

this is accurate **Bortle Class 4**

The Milky Way has a defined outline with visible structure and detail. Very few light domes are visible just along the horizon and do not cast shadows. You may see color in the Zodical light when compared to bluish-white color of the Milky Way. Scattered clouds appear dark against the night sky except those clouds just above light domes.[3]

If this describes your nighttime environment, continue below

Milky Way appears complex with visible outline, however some light pollution is still evident along the horizon. Light domes only slightly brighter than brightest part of the Milky Way. Zodiacal light easily seen, but band and gegenschein difficult or absent. Many summer globular clusters and emission nebulae are visible with the naked eye despite distracting light domes along the horizon. Venus casts an obvious shadow.

this is accurate **Bortle Class 3** if darker—proceed below

Very few light domes are visible; with none extending above 5 degrees and fainter than the Milky Way. Airglow is often visible, and character in its brightness may be seen. Ground is mostly dark. The Zodiacal band (away from the Milky Way and at least 45 degrees above the horizon) and gegenschein are visible. The rift in the Cygnus star cloud is visible. The Prancing Horse in Sagittarius and Fingers of Ophiuchus dark nebulae are visible, extending to Antares. Jupiter and Milky Way cast barely visible shadows.

this is accurate **Bortle Class 2** if darker—proceed below

The Milky Way is intricate, marbled, and veined with Sagittarius region of the Milky Way casting obvious shadows. Milky Way appears 40 degrees wide in some parts with a convoluted outline. The horizon completely free of light domes, though some distant light domes may be visible from mountain tops. Transparency and seeing are excellent (among the best of the year) with very low airglow. Many objects such as M81 or the Helix nebula are visible with the naked eye. Zodical light is striking as a complete band. Any clouds are very difficult to see.

this is accurate **Bortle Class 1**

The Bortle Dark-Sky Scale is a qualitative scale developed by John Bortle and published in Sky & Telescope Magaine in 2001. It provides a useful complement to quantitative measures. The National Park Service is testing this dichotomous key for use by professional and citizen scientists. Some knowledge of the night sky and visual observational techniques are required to properly implement this assessment.

note 1) At least 5 minutes of dark adaptation is required to properly differentiate Class 7,8 & 9 skies.

note 2) At least 10 minutes of dark adaptation is required to properly differentiate Class 4, 5 & 6 skies.

note 3) 20 to 120 minutes of dark adaptation is required to properly differentiate Class 1, 2 & 3 skies.

Developed by Jeremy White, Dan Duriscoe, and Chad Moore of the NPS Natural Sounds & Night Skies Division, www.nature.nps.gov/night

August 2, 2012

Appendix D: Soundscape Models

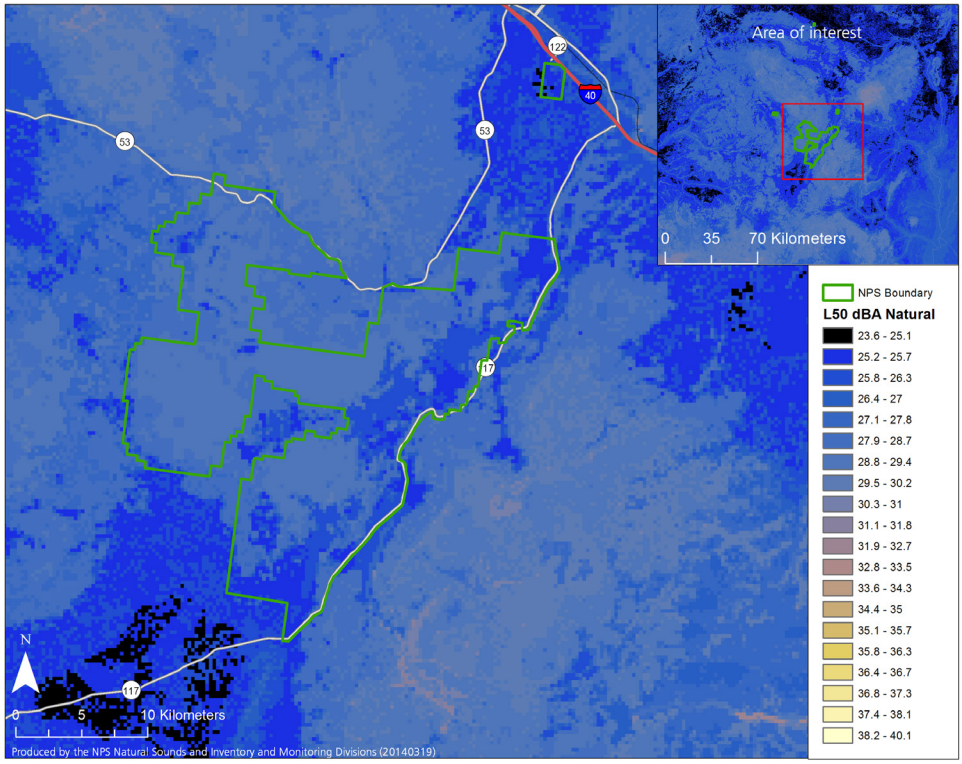


Figure D-1. Natural CONUS soundscape model zoomed to El Malpais NM.

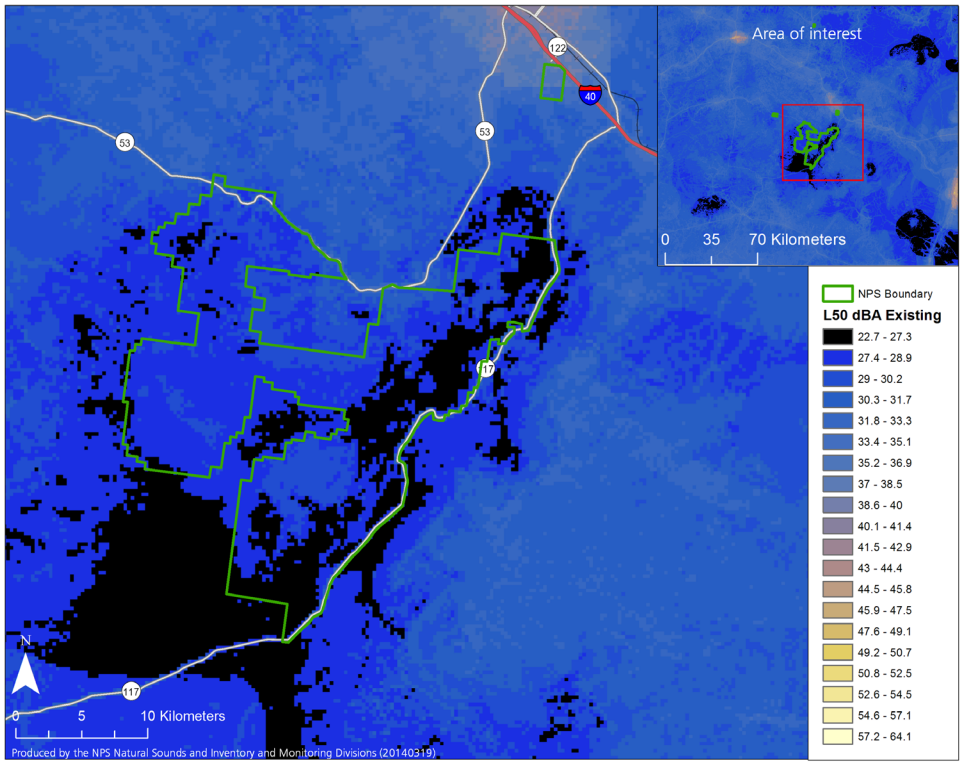


Figure D-2. Existing CONUS soundscape model zoomed to El Malpais NM..

Mennitt et al. (2013) developed a geospatial sound model by mapping sound pressure levels on a continental U.S. scale. The model included biological, climatic, geophysical, and anthropogenic factors to assess expected sound pressure levels for natural and existing conditions. The model suggested that the area within and surrounding El Malpais NM had a natural L_{50} dBA average of 27.8 (Figure D-1) and an existing L_{50} dBA average of 28.0 (Figure D-2) (Emma Lynch, Acoustical Resource Specialist, NPS Natural Sounds and Night Skies Division, provided Excel spreadsheet with values). The L_{50} represents the sound level reported that is exceeded 50 percent of the stated time period.

The impact of anthropogenic sound sources to the national monument's soundscape, which is the existing L_{50} dBA minus natural L_{50} dBA, was estimated to be an average of 0.38 dBA (map is included in the assessment). For further details refer to the soundscape assessment in section 4.3.

As NSNSD's predictive soundscape model continues to be developed and refined, it is intended to help park staff anticipate impacts by projecting future developments that have the potential to degrade soundscape condition.

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Appendix E: Geology Background

The landscape of El Malpais National Monument is dominated by basaltic volcanic rocks erupted in the El Malpais phase between 60,000 and 3,900 years before present in the Zuni-Bandera Volcanic Field. Five young basaltic lava flows (El Calderon, Twin Craters, Hoya de Cibola, Bandera and McCartys) make up most of the El Malpais landscape. These lava flows have a range of surface morphologies and were emplaced via a variety of processes. McCartys Flow is the youngest of these lava flows and provides important insight into lava flow inflation processes.

Two previous periods of basaltic volcanism occurred in the Zuni-Bandera field. The first phase of volcanism began 700,000 years ago and erupted a series of fluid lava flows (Laughlin et al. 1993), mapped as old basalt flows by Maxwell (1986). The second period of volcanism, at approximately 150,000 years before present, produced a series of cinder cones known as the Chain of Craters mostly to the west of current monument boundaries, along with associated lava flows (KellerLynn 2012). Cerro Bandera, the northernmost cinder cone in the Chain of Craters, is within monument boundaries (KellerLynn 2012).

Lava Flow Surface Features

Basaltic lava flows are typically fluid and able to spread out and travel great distances from their vents. Pahoehoe (ropy surface) flows (Figure E-1) are more fluid than aa (blocky) lavas, and travel at greater speeds. A pahoehoe flow surface may transition into aa downstream, and an eruption may change from one type of lava to another (Zimbelman et al. 2010). Both types of flows may be fed via channels and tubes (Kilburn 2000), but inflation processes only occur in pahoehoe flows (Larry Crumpler, personal communication, 2015).



Figure E-1. Pahoehoe surface on the McCartys Flow

The El Calderon Flows are the oldest of the major lava flows found in El Malpais NM, and are less than 60,000 years old (KellerLynn 2012). The eruption of the El Calderon Flows marked the initiation of the El Malpais phase of volcanism. Lava traveled from the vent approximately 35 km (22 miles) to the northeast, although much of the original extent of this lava flow has been buried by younger eruptions (KellerLynn 2012).

The Twin Craters Flows likely erupted from four main cinder cones that were active within a narrow time range approximately 18,000 years before present (KellerLynn 2012). These flows are exposed in the northern part of the monument and appear to be the shortest in length of the five major lava flows in El Malpais NM (Maxwell 1986). The Twin Craters Flows consist primarily of tube-fed pahoehoe, but also contain channelized aa lava (Dunbar 2010). They have lost much of their ropy pahoehoe structure and the original glassy surface rind given their age (Dunbar and Phillips 2004).

The Hoya de Cibola Flows are the only flows of the El Malpais phase of volcanism to be associated with a shield volcano. A shield volcano is a low, broad volcanic edifice made up of very fluid basalt lava flows (Jackson 1997). The other eruptions in the field either produced



Figure E-2. A lava channel in aa lava on the Bandera Flows.



Figure E-3. A tree mold on the Bandera Flows.

cinder cones such as El Calderon and Lost Woman Crater, or did not form a significant edifice, such as the McCartys Flow.

The Hoya de Cibola shield volcano is in the southwestern part of the monument (KellerLynn 2012). Pahoehoe lava flowed primarily east and southeast from the vent area, and probably also flowed to the northeast, but was buried by younger lava flows. Kipukas with volcanic substrates in the northeastern area of the monument are interpreted to consist of Hoya de Cibola flows on the basis of composition, flow similarity, vegetation and weathering (Maxwell 1986).

The second youngest lava flows in El Malpais, the Bandera Flows (Figure E-2), are the only ones that consists mostly of aa lava, versus pahoehoe. Blocky aa lavas have a rougher surface than pahoehoe lavas and have an extremely rugged, jagged, and rubbly surface (Jackson 1997). The Bandera Flows also have an extensive network of lava tubes, collapsed lava tubes, and contain tree mold fossils (Figure E-3) (KellerLynn 2012). These flows retain much of their surface structures, but have lost their original glassy surface (Dunbar and Phillips 2004).

The McCartys Flow is the most recent lava flow in the Zuni-Bandera Volcanic Field, and is approximately 3,900 years old (Dunbar and Phillips 2004). The flow is complex and was active over a period of many years (Larry Crumpler, personal communication, 2015). It was erupted from a vent area marked by an elevated platform of flow accumulations and a very small scoria cone less than 15 m (50 ft) tall (Crumpler et al. 2013).

As the youngest lava flow in the Zuni-Bandera Volcanic Field, and the product of one of the youngest eruptions in the southwest, surface features of the McCartys Flow are very well preserved. The surface of the flow consists of ropes, slabs, ridge-and-furrow lineations, and lava shatter zones (Crumpler et al. 2013). Other structures on the flow includes squeeze-ups, lava blisters, and lava driblets. The upper few millimeters of the surface consists of black volcanic glass called tachylite (Crumpler et al. 2013). The margins of flows are characterized by "toes," or lobes formed from breakouts, and may have several benches or levels. Lava Falls is a lava drip that formed during a breakout from one of the small lobes of the flow (Crumpler et al. 2013).

Inflation Structures - McCartys Flow

Important research into the mechanism of basaltic lava flow emplacement has occurred on the McCartys Flow since the 1930s and continues today with implications for understanding lava flows in planetary bodies. This research is applicable to basalts on Mars and the Moon (Crumpler et al. 2013; Zimbelman et al. 2013; 2012; 2010; Garry et al. 2011). The McCartys Flow (Figure E-4) is well-suited for study because it is one of the largest young lava flows on the planet, is well preserved with small scale features retained, and occurs in a simple setting of a broad sloping valley floor (Crumpler et al. 2013).

The surface of McCartys Flow is characterized by the presence of many large circular depressions, especially in the southern portion of the flow (Figure E-4). These depressions were previously thought to be collapsed lava tubes (Crumpler et al. 2013), but recent research has shown that they are lava rise pits formed via inflation (Crumpler et al. 2013; Zimbelman et al. 2013; 2012; and 2010; Garry et al. 2011).

Pahoehoe lava flows may either be emplaced via channels, tubes or as sheets (Garry et al. 2011). Much of the McCartys Flow was emplaced as sheets (Crumpler et al. 2013). Sheets are likely to form in large areas with very gentle slopes, and inflation is an important process for the emplacement of sheet flows (Garry et al. 2011). Flows inflate underneath cooled flow surfaces when lava supply is greater than the ability for a lava flow to spread laterally due to cooling at the flow margins. Inflation thickens the lava flow and produces a uniform uplift of the solidified surface.

Lava rise plateaus produced by inflation (Figure E-4) have been identified in the central and southern parts of the McCartys Flow, including in a large area near the vent and the region near Lava Falls (Zimbelman et al. 2013 and Crumpler et al. 2013). The plateau near Lava Falls was inflated more than 10 m (33 ft) (Crumpler et al. 2013). The surface of inflated plateaus can be relatively flat, with only minor relief across distances of 100 m (330 ft) (Crumpler et al. 2013).

Lava rise pits (also known as inflation pits) are uninflated zones of an inflated plateau where the solid upper crust and hardened bottom surface of a lava flow were not separated by further injection of liquid lava (Crumpler et al. 2013). Lava rise pits may form when topographic obstacles beneath a lava flow exist, and where the flow is thereby thinner. The thinner area will solidify more quickly and be unable to inflate (Garry et al. 2011; Crumpler et al. 2013). The floors of lava rise pits may consist of broken slabs of cooled lava or may have been flooded by molten material from the pit margins during inflation (Garry et al. 2011).

Because they form via an entirely different mechanism, lava rise pits are rarely connected to significant subsurface voids, unlike collapsed areas of lava tubes (Garry et al. 2013). On the McCartys Flow, lava rise pits are commonly 10 to 20 m (33 to 66 ft) in diameter with steep margins characterized by deep cracks or clefts (Figure E-5) (Crumpler et al. 2013). Lava "squeeze-outs" may occur on the slopes leading towards the depression where fluid lava escaped via clefts in the cooled surface of the flow.

Detailed work on the McCartys Flow, including mapping using differential GPS surveys, has been key in understanding the emplacement mechanism of the lava flow, providing new insight into the formation of basaltic lava flows. The work at McCartys Flow is part of a larger project to understand whether lava flows on Mars or the Moon may have undergone inflation (Zimbelman et al. 2012). By serving as an analog for lava flows on other planetary bodies, McCartys Flow is allowing researchers to identify and map specific surface features such as lava rise pits and flow margin terraces that may be found in inflated planetary lava flows (Zimbelman et al. 2013). This research, supported by NASA, to understand inflation processes



Figure E-4. Google Earth image showing the Lava Falls parking lot near the southern end of the McCartys Flow. The inflated rise plateau surface of the lava flow is relatively flat, and contains a number of circular depressions that are lava rise pits where the lava flow did not inflate. There was as much as 10 m (33 ft) of inflation or thickening of the lava flow in this area. Image by Google Earth (accessed June 3, 2015).

and their morphological characteristics at the McCartys Flow is continuing (Larry Crumpler, personal communication, 2015).

Volcanic Vents and Edifices

Basaltic lavas do not produce explosive eruptions because they have low viscosity. Eruptions consisting of bursts of volcanic blocks, bombs and tephra, fire fountains, and small ash and cinder columns yield cinder cones and associated cinder fields. Coarser grained material falls around vents to produce cinder cones or more widely during periods of higher explosivity.

The eruptions were mildly explosive (Strombolian type) to nonexplosive or effusive (Hawaiian type), as is typical for basaltic volcanoes.

Cinder cones are small volcanoes that are the most common type of volcano on land (Vespermann and Schmincke 2000). They have steep sides with either a conical, horseshoe, or elongated shape with craters filled by debris reworked from the rim of the cone. They are made up of layers of loose or welded cinders, volcanic bombs and blocks, and ash that accumulated around a vent.



Figure E-5. The steep margin of a lava rise pit on the surface of the McCartys Flow.

Cinder cones typically occur in fields. Each eruptive vent is monogenetic, meaning that it erupts only once (Vespermann and Schmincke 2000). The Chain of Craters produced prior to the El Malpais phase of volcanism is a good example of a field of monogenetic cinder cones.

Cinder cone eruptions usually produce only a small volume of erupted material. While the cinder cones of Zuni-Bandera field are of average size (less than 200 m [660 ft] tall), the lavas flows erupted from the cinder cones are of larger volume than typical (Theilig 1990).

Most of the volcanic edifices in El Malpais NM are cinder cones (Maxwell 1986 and KellerLynn 2012). The El Calderon and Bandera flows were erupted from single vents associated with cinder cones. The Twin Craters Flows were erupted from several cinder cones in a very short period of time.

El Calderon Crater (Figure E-6) is an approximately 60 m (200 ft) tall cinder cone that is breached to the northeast where rafted pieces of the cinder cone were carried away by the lava flow eruption. A cinder field covering 0.53 square km (0.20 square mi) was also produced during this eruption. This volcano is the most impacted of the cinder cones in El Malpais NM due to quarrying. An abandoned cinder quarry there has two vertical mine cuts that expose the stratification of the cinders (NPS 2015). An 8-km (5-mi) loop trail leads to the cinder cone and provides a view into the crater. The NPS recently constructed stairs on a former social trail leading to the rim of the crater (Eric Weaver, personal communication, 2015).



Figure E-6. El Calderon in the distance.

At least four vents were active during the eruption of the Twin Craters Flows: Lost Woman Crater, Twin Craters, Lava Crater and Cerro Candelaria (Figure E-7). Lost Woman Crater, Twin Craters, and Lava Crater are aligned on a northeastern trend, and Cerro Candelaria is east of Lava Crater (Cascadden et al. 1997). The four vents erupted within a short period of time. Field relationships

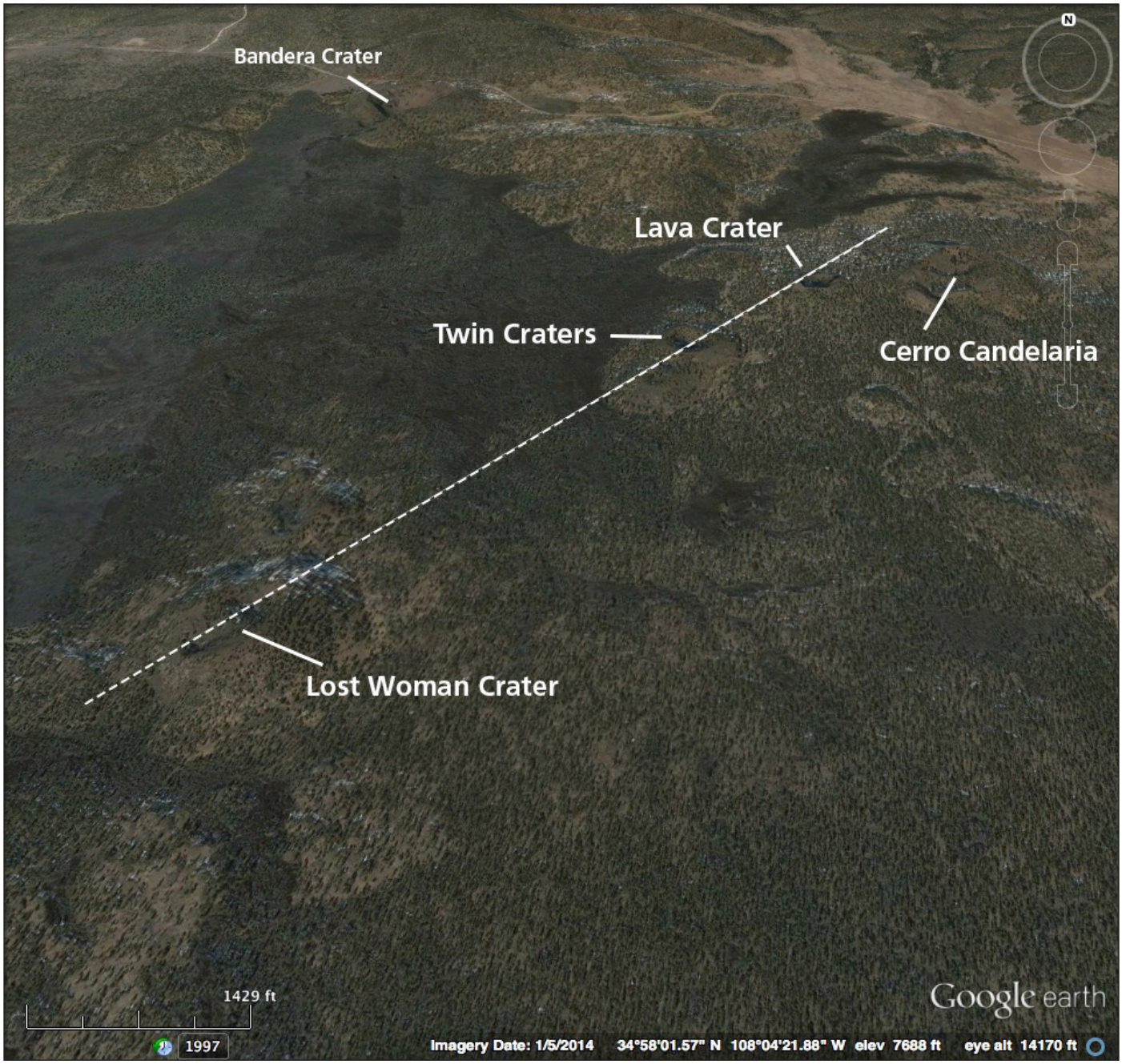


Figure E-7. Google Earth image showing the four vents (Lost Woman Crater, Twin Craters, Lava Crater and Cerro Candelaria) that produced the Twin Craters Flows, with Bandera Crater in the background. The dashed line shows the N38°E trend on which three of the cinder cones are aligned (Cascadden et al. 1997). Modified from a Google Earth image (accessed June 3, 2015).

demonstrate that the eruption of Twin Craters was followed by that of Lost Woman Crater and then by Lava Crater.

Cerro Candelaria and Lost Woman Crater are the largest of the cinder cones associated with the Twin Craters eruption, and are both approximately 110 m (360 ft) tall. Twin Craters actually consists of three small cinder cones aligned on a northeast trend of a probable fissure-type vent. A smaller unnamed cinder cone appears to be located north of Lost Woman Crater (Maxwell 1986). Lava Crater is a small spatter cone, which is a type of cinder cone that consists of cinders or pieces of lava that have been welded together as they were still molten when they landed, typically in low explosivity eruptions. This cone was breached to the northeast by

a small lava flow. In addition to these cinder cones, a larger area of mixed pyroclastics and lava flows were mapped for the Twin Craters eruptive events (Maxwell 1986). There may be additional small vents for the Twin Craters flows.

Bandera Crater is an ideal example of a breached cinder cone (Figure E-8) (Maxwell 1986). It was breached on the south side by the eruption of the Bandera Flows, with a collapsed lava tube also marking the direction of lava travel away from the vent. A large field of small cinders covering 3.9 square km (1.5 square mi) area surrounds the cinder cone on all but the south side with cinders covering sedimentary rocks and older basalt flows (Maxwell 1986). Four AML (Abandoned Mineral Lands) sites consisting of cinder quarries and related features are located in the Bandera cinder field (NPS 2015). Bandera Crater and much of the cinder field are in a private inholding within monument boundaries.


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Figure E-8. Bandera Crater is the largest cinder cone in El Malpais NM. It is breached on one side by the eruption of the lava flow. Welded cinders or spatter can be seen inside the rim of the crater.

Hoya de Cibola is the only shield volcano produced during the El Malpais phase of volcanism. It is a very small shield, being only approximately 2.4 km (1.5 mi) in diameter and 90 m (300 ft) high (KellerLynn 2012). The vent is located at the summit.

The McCartys vent area consists of a very small cinder cone on top of a broad platform of lava flow accumulations and cinders. This vent area is unusual in that it lacks a significant edifice per se, but is also not a fissure. The central McCartys scoria cone is very small, with a diameter of approximately 75 m (246 m), although the overall vent area is approximately 250 m (820 ft) wide. The vent platform has a broad convex surface with ramparts around the margins (Crumpler et al. 2013).

The area around the vent for the McCartys Flow has been substantially impacted by the use of McCartys Crater as a target area for a World War II bombing range.

At least three vent areas from older phases of volcanism in the Zuni-Bandera field have been documented in El Malpais. Cerro Bandera is a cinder cone that was active during the Chain of Craters phase of volcanism (Maxwell 1986). The crater of this cinder cone is less distinct than those of the El Malpais phase of volcanism due to its greater age.

Two vents for the first phase of volcanism in the Zuni-Bandera field are found within monument boundaries. One vent, Cerro Encierro, is in the northwest part of the Hole-in-the-Wall, a large kipuka with a volcanic substrate. Cerro Encierro is a small edifice approximately 43 m (140 ft) tall. Another vent on the west boundary apparently did not produce an edifice.

Paleontological Resources

Table E-1 summarizes information about El Malpais' known fossil resources. Most of the rock units exposed in El Malpais are volcanic (Maxwell 1986 and KellerLynn 2012), and fossils are generally rare in volcanic rocks. Tree molds (Figure E-2) are the most significant paleontological resources at El Malpais (KellerLynn 2012). Tree molds are only known from four other NPS

Table E-1. Known paleontological resources1 in El Malpais NM.

Rock Unit	Age	Fossils
McCartys Flow	3,900 years old	Tree molds
Bandera Flow	11,000 years old	Tree molds
El Calderon Flow	<60,000 years old	Tree molds
Tres Hermanos Sandstone	Upper Cretaceous	Unspecified "shell" fossils
Oak Canyon Member, Dakota Sandstone[2]	Upper Cretaceous	Unspecified fossils
San Andres Limestone	Upper Cretaceous	Unspecified fossils

Information is from Tweet et al. (2015), El Malpais tree mold geodatabase (Eric Weaver, personal communication, 2015) and Larry Crumpler (personal communication, 2015).

[1] Paleontological resources that may be found in lava tube caves, such as twigs, skeletal remains, and packrat middens, are not included in this table. Please see text for discussion of these resources.

[2] The Oak Canyon Member of the Dakota Sandstone is part of the Kdo unit (Clay Mesa Tongue of Mancos Shale and Lower Part of Dakota Sandstone) on the geologic map (KellerLynn 2012 and Maxwell 1986).

units (Craters of the Moon National Monument, Lava Beds National Monument, Puuhonua o Honaunau National Historical Park and Hawaii Volcanoes National Park) (KellerLynn 2012).

At El Malpais, tree molds have been reported in the El Calderon, Bandera and McCartys flows in El Malpais NM (Eric Weaver, personal communication 2015 and Larry Crumpler, personal communication, 2015). Ten tree mold locations are included in the park GIS database (Eric Weaver, personal communication, 2015), although additional tree molds are present in the monument. For example, the tree mold shown in Figure 4.5.2-3 is in the El Calderon flow (Larry Crumpler, personal communication, 2015). It is likely that many more tree molds may be found in the monument's young lava flows.

Because sedimentary rocks themselves are relatively rare within the monument and because not all sedimentary units contain fossils, the exposure of fossiliferous units within monument boundaries is also limited. Only three of the sedimentary rock units exposed in the monument are known to contain fossils: The Tres Hermanos Sandstone, the Oak Canyon Member of the Dakota Formation, and the San Andres Limestone (Tweet et al. 2015). However, specific information about what types of fossils are found in these units is lacking. Possible types of fossils include primarily marine invertebrates, with trace fossils, pollen and vertebrate fossils also potentially present.

While fossils have not been found in monument in the Abo Formation, Yeso Formation, Glorieta Sandstone, Entrada Sandstone, Zuni Sandstone, and the Cubero Tongue, Clay Mesa Tongue and Paguate Tongue Members of the Dakota Sandstone, they are known to occur in these units elsewhere (Tweet et al. 2015).

The lava tube caves in El Malpais contain a variety of undated vertebrate skeletal remains, packrat middens and other evidences of life (Tweet et al. 2015 and Eric Weaver, personal communication, 2015). Some of the bones are found deep in caves and may have mineral coatings as thick as 10-cm (3.9 in) (Eric Weaver, personal communication, 2015). Perennial cave ice deposits may contain Holocene twigs like those recovered from Candelaria Ice Cave (Dickfoss et al. 1997).

Bones of animals that are no longer living in the area or that have calcite or gypsum deposits on them are most likely prehistoric (Eric Weaver, personal communication, 2015). The vertebrate skeletal remains and packrat midden deposits are found on the rocky surfaces of the cave floors, and it is impossible to know whether the remains are modern or prehistoric without the

availability of absolute age determinations. But given the preservation capability of lava tubes caves, they likely contain significant Holocene fossils that have not yet been documented (Eric Weaver, personal communication, 2015).

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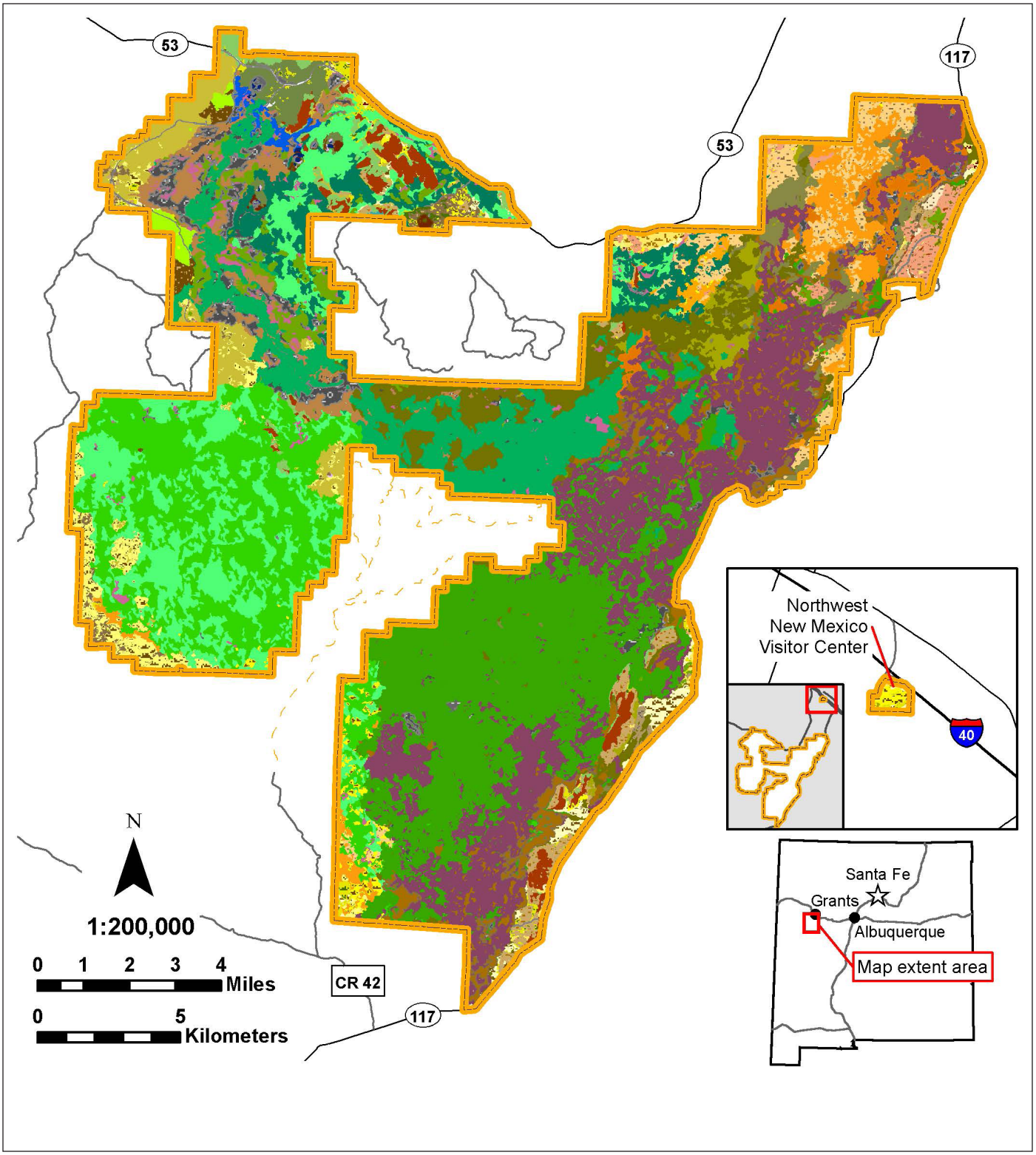
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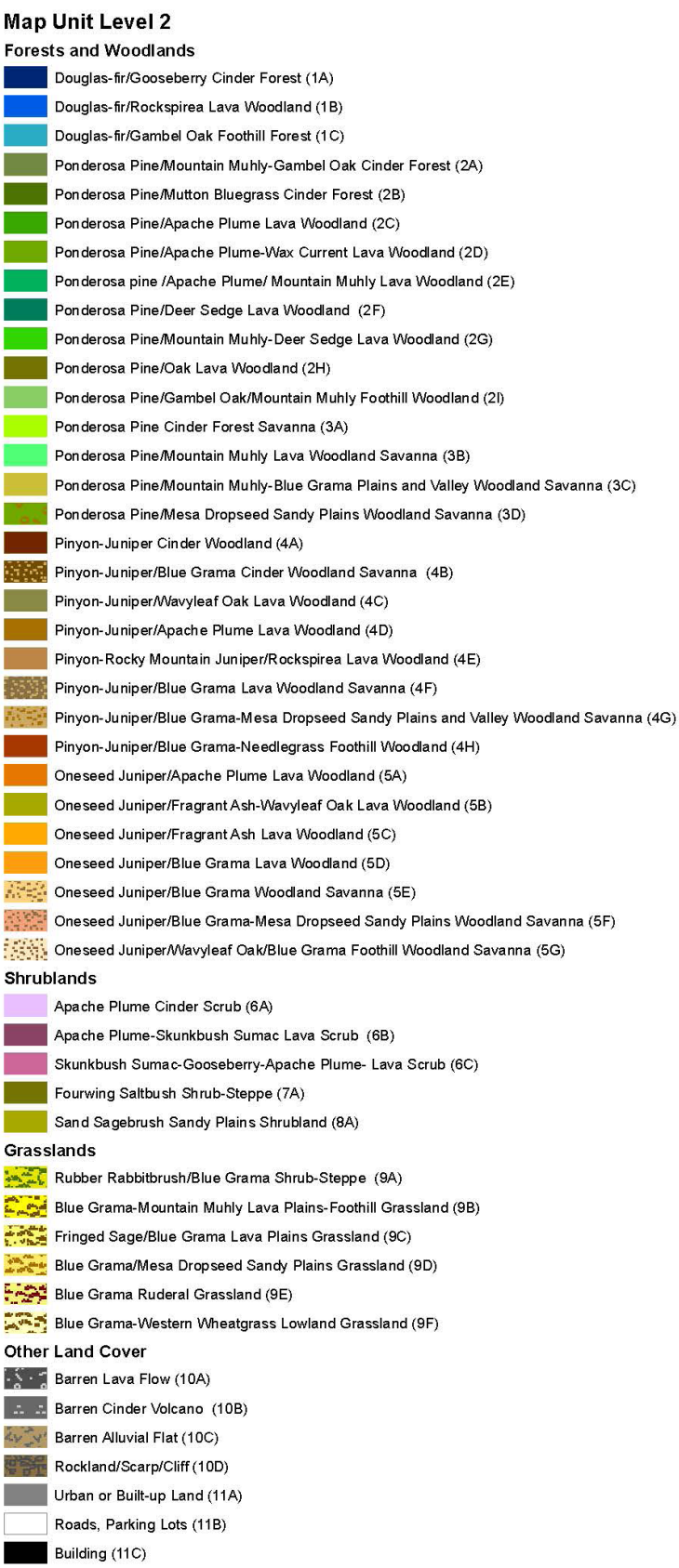
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Appendix F: El Malpais Vegetation Map

Vegetation map is from Muldavin, E., Y. Chauvin, T. Neville, P. Neville, A. Kennedy, H. Hulse, P. Arbetan, K. Schultz, M. Hall, and M. Reid. 2013. Vegetation Classification and Map: El Malpais National Monument. Natural Resource Technical Report NPS/SPCN/NRTR–2013/803. National Park Service, Fort Collins, Colorado. Available at https://irma.nps.gov/App/Reference/Profile/2203664 (accessed June 29, 2015).




Map Unit Level 2
Forests and Woodlands
Douglas-fir/Gooseberry Cinder Forest (1A)
Douglas-fir/Rockspirea Lava Woodland (1B)
Douglas-fir/Gambel Oak Foothill Forest (1C)
Ponderosa Pine/Mountain Muhly-Gambel Oak Cinder Forest (2A)
Ponderosa Pine/Mutton Bluegrass Cinder Forest (2B)
Ponderosa Pine/Apache Plume Lava Woodland (2C)
Ponderosa Pine/Apache Plume-Wax Current Lava Woodland (2D)
Ponderosa pine /Apache Plume/ Mountain Muhly Lava Woodland (2E)
Ponderosa Pine/Deer Sedge Lava Woodland (2F)
Ponderosa Pine/Mountain Muhly-Deer Sedge Lava Woodland (2G)
Ponderosa Pine/Oak Lava Woodland (2H)
Ponderosa Pine/Gambel Oak/Mountain Muhly Foothill Woodland (2I)
Ponderosa Pine Cinder Forest Savanna (3A)
Ponderosa Pine/Mountain Muhly Lava Woodland Savanna (3B)
Ponderosa Pine/Mountain Muhly-Blue Grama Plains and Valley Woodland Savanna (3C)
Ponderosa Pine/Mesa Dropseed Sandy Plains Woodland Savanna (3D)
Pinyon-Juniper Cinder Woodland (4A)
Pinyon-Juniper/Blue Grama Cinder Woodland Savanna (4B)
Pinyon-Juniper/Wavyleaf Oak Lava Woodland (4C)
Pinyon-Juniper/Apache Plume Lava Woodland (4D)
Pinyon-Rocky Mountain Juniper/Rockspirea Lava Woodland (4E)
Pinyon-Juniper/Blue Grama Lava Woodland Savanna (4F)
Pinyon-Juniper/Blue Grama-Mesa Dropseed Sandy Plains and Valley Woodland Savanna (4G)
Pinyon-Juniper/Blue Grama-Needlegrass Foothill Woodland (4H)
Oneseed Juniper/Apache Plume Lava Woodland (5A)
Oneseed Juniper/Fragrant Ash-Wavyleaf Oak Lava Woodland (5B)
Oneseed Juniper/Fragrant Ash Lava Woodland (5C)
Oneseed Juniper/Blue Grama Lava Woodland (5D)
Oneseed Juniper/Blue Grama Woodland Savanna (5E)
Oneseed Juniper/Blue Grama-Mesa Dropseed Sandy Plains Woodland Savanna (5F)
Oneseed Juniper/Wavyleaf Oak/Blue Grama Foothill Woodland Savanna (5G)
Shrublands
Apache Plume Cinder Scrub (6A)
Apache Plume-Skunkbush Sumac Lava Scrub (6B)
Skunkbush Sumac-Gooseberry-Apache Plume- Lava Scrub (6C)
Fourwing Saltbush Shrub-Steppe (7A)
Sand Sagebrush Sandy Plains Shrubland (8A)
Grasslands
Rubber Rabbitbrush/Blue Grama Shrub-Steppe (9A)
Blue Grama-Mountain Muhly Lava Plains-Foothill Grassland (9B)
Fringed Sage/Blue Grama Lava Plains Grassland (9C)
Blue Grama/Mesa Dropseed Sandy Plains Grassland (9D)
Blue Grama Ruderal Grassland (9E)
Blue Grama-Western Wheatgrass Lowland Grassland (9F)
Other Land Cover
Barren Lava Flow (10A)
Barren Cinder Volcano (10B)
Barren Alluvial Flat (10C)
Rockland/Scarp/Cliff (10D)
Urban or Built-up Land (11A)
Roads, Parking Lots (11B)
Building (11C)

Appendix G: Background on Bird Species of Conservation Concern Lists

This appendix provides background information on the organizations and efforts to determine species of birds that are in need of conservation. The information presented here supports Section 4.16.2, Data and Methods, of the landbirds chapter. This appendix contains some of the same, but additional, information as that section of the report.

One component of the landbird condition assessment was to examine species occurrence in a conservation context. We compared the list of species that occur at El Malpais National Monument (NM) (i.e., those detected during one or more of three surveys and/or observation efforts at the park) to lists of species of conservation concern developed by several organizations. There have been a number of such organizations that focus on the conservation of bird species. Such organizations may differ, however, in the criteria they use to identify and/or prioritize species of concern based on the mission and goals of their organization. They also range in geographic scale from global organizations such as the International Union for Conservation of Nature (IUCN), who maintains a "Red List of Threatened Species," to local organizations or chapters of larger organizations. This has been, and continues to be, a source of confusion, and perhaps frustration, for managers and others who need to make sense of and apply the applicable information. In recognition of this, the U.S. North American Bird Conservation Initiative (NABCI) was started in 1999; it represents a coalition of government agencies, private organizations, and bird initiatives in the U.S. working to ensure the conservation of North America's native bird populations. Although there remain a number of sources at multiple geographic and administrative scales for information on species of concern, the NABCI has made great progress in developing a common biological framework for conservation planning and design.

One of the developments from the NABCI was the delineation of Bird Conservation Regions (BCRs) (U.S. North American Bird Conservation Initiative 2014). Bird Conservation Regions are ecologically distinct regions in North America with similar bird communities, habitats, and resource management issues.

The purpose of delineating these BCRs was to:

- facilitate communication among the bird conservation initiatives;
- systematically and scientifically apportion the U.S. into conservation units;
- facilitate a regional approach to bird conservation;
- promote new, expanded, or restructured partnerships; and
- identify overlapping or conflicting conservation priorities.

G.1. Conservation Organizations Listing Species of Conservation Concern

Below we present a summary of some of the organizations that list species of conservation concern and briefly discuss the different purposes or goals of each organization.

U.S. Fish & Wildlife Service

The Endangered Species Act, passed in 1973, is intended to protect and recover imperiled species and the ecosystems upon which they depend. It is administered by the U.S. Fish and Wildlife Service (USFWS) and the Commerce Department's National Marine Fisheries Service (NMFS). USFWS has primary responsibility for terrestrial and freshwater organisms, while the responsibilities of NMFS are mainly marine wildlife, such as whales, and anadromous fish.

The USFWS also protects birds under the Migratory Bird Treaty Act (MBTA; USFWS 2016). This act "makes it illegal for anyone to

take, possess, import, export, transport, sell, purchase, barter, or offer for sale, purchase, or barter, any migratory bird, or the parts, nests, or eggs of such a bird except under the terms of a valid permit issued pursuant to Federal regulations" (USFWS 2016). An up-to-date list of the bird species protected by the Act (1,026 birds) can be found in (USFWS 2013). At least one of four criteria need to be met for a species to be listed under the Act: 1) it is covered by the Canadian Convention of 1916, as amended in 1996; 2) it is covered by the Mexican Convention of 1936, as amended in 1972; 3) it is listed in the annex to the Japanese Convention of 1972, as amended; and/or 4) it is listed in the appendix to the Russian Convention of 1976. Note that in the condition assessment, we did not compare the list of species recorded at El Malpais NM to the MBTA list. However, at least some of these species would be included in the other species of conservation concern lists we used.

State of New Mexico

In New Mexico, wildlife species are designated as threatened or endangered under the New Mexico Wildlife Conservation Act (NMDGF 2015a). For each endangered or threatened species, the New Mexico Department of Game and Fish (NMDGF) develops a recovery plan. A database of all vertebrate species in New Mexico, including threatened and endangered species, is maintained and can be searched online (NMDGF 2015b). The database is called the Biota Information System of New Mexico (BISON-M).

USFWS Birds of Conservation Concern

The USFWS has responsibilities for wildlife, including birds, in addition to endangered and threatened species. The Fish and Wildlife Conservation Act, as amended in 1988, further mandates that the USFWS "identify species, subspecies, and populations of all migratory nongame birds (i.e., Birds of Conservation Concern) that, without additional conservation actions, are likely to become candidates for listing under the Endangered Species Act" (USFWS 2008). The agency's 2008 effort, *Birds of Conservation Concern*, is one effort to fulfill the Act's requirements. The report includes both migratory and non-migratory bird species (beyond those federally-listed as threatened or endangered) that USFWS considers the highest conservation priorities. Three geographic scales are included--National, USFWS Regional, and the NABCI BCRs. The information used to compile the lists came primarily from the following three bird conservation plans: the Partners in Flight North American Landbird Conservation Plan, the U.S. Shorebird Conservation Plan, and the North American Waterbird Conservation Plan. The scores used to assess the species are based on factors such as population trends, distribution, threats, and abundance.

National Audubon Society/American Bird Conservancy

The National Audubon Society and American Bird Conservancy each formerly published their own lists of bird species of concern, but have recently combined efforts into a single "Watch List". This collaborative effort was based on a concern by these organizations that there were too many lists with similar purposes (Butcher et al. 2007). Their 2007 WatchList is based on, but not identical to, the Partners in Flight (PIF) approach to species assessment (described below).

The 2007 WatchList has two primary levels of concern: a "Red WatchList" and a "Yellow WatchList", although the latter is subdivided into two categories. The Red WatchList identifies what these organizations consider as species of highest national concern. This list overlaps considerably with the IUCNs "Red List" (not presented here), thus, can essentially be considered as a list of globally threatened birds that occur in the United States (Butcher et al. 2007). The Yellow WatchList is made up of species that are somewhat less critical, but serves as an early warning list of birds that have the potential of being elevated to the Red WatchList. Species on this list can be there either because their populations are declining or because they are considered rare.

Partners in Flight

Partners in Flight is a cooperative effort among federal, state, and local government agencies, as well as private organizations. One

of its primary goals, relative to listing species of conservation concern, is to develop a scientifically based process for identifying and finding solutions to risks and threats to landbird populations. Their approach to identifying and assessing species of conservation concern is based on biological criteria to evaluate different components of vulnerability (Panjabi et al. 2005). Each species is evaluated for six components of vulnerability: population size, breeding distribution, non-breeding distribution, threats to breeding, threats to non-breeding, and population trend. The specific process is presented in detail in the species assessment handbook (Panjabi et al. 2005).

The PIF assessments are conducted at multiple scales. At the broadest scale, the North American Landbird Conservation Plan (Rich et al. 2004) identifies what PIF considers "Continental Watch List Species" and "Continental Stewardship Species." Continental Watch List Species are those that are most vulnerable at the continental scale, due to a combination of small and declining populations, limited distributions, and high threats throughout their ranges (Panjabi et al. 2005). Continental Stewardship Species are defined as those species that have a disproportionately high percentage of their world population within a single Avifaunal Biome during either the breeding season or the non-migratory portion of the non-breeding season.

More recently, PIF has adopted BCRs, the common planning unit under the NABCI, as the geographic scale for updated regional bird conservation assessments. These assessments are available via an online database (http://www.rmbo.org/pif/pifdb.html) maintained by RMBO. At the scale of the individual BCRs, these same principles of concern (sensu Continental Watch List Species) or stewardship (sensu Continental Stewardship Species) are applied at the BCR scale. The intention of this approach is to emphasize conservation of species where it is most relevant, as well as the recognition that some species may be experiencing dramatic declines locally even if they are not of high concern nationally, etc. There are two categories (concern and stewardship) each for Continental and Regional levels. The details of the criteria for inclusion in each can be found in Panjabi et al. (2005), and a general summary is as follows. Note that in our Chapter 4 landbird analysis, we did not use the two stewardship categories.

Criteria for Species of Continental Importance

A. Continental Concern (CC)

- Species is listed on the Continental Watch List (Rich et al. 2004).
- Species occurs in significant numbers in the BCR.
- Future conditions are not enhanced by human activities.

B. Continental Stewardship (CS)

- Species is listed as Continental Stewardship Species (Rich et al. 2004).
- Relatively high density (compared to highest density regions) and/or a high proportion of the species occurs in the BCR.
- Future conditions are not enhanced by human activities.

Criteria for Species of Regional Importance

Regional scores are calculated for each species according to which season(s) they are present in the BCR. The formulae include a mix of global and regional scores pertinent to each season (see Panjabi et al. 2005 for details). The criteria for each category are:

A. Regional Concern (RC)

- Regional Combined Score > 13 (see Panjabi et al. 2005 for details).
- High regional threats or moderate regional threat combined with significant population decline.
- Occurs regularly in significant numbers in the BCR.

B. Regional Stewardship (RS)

- Regional Combined Score > 13 (see Panjabi et al. 2005 for details).
- High importance of the BCR to the species.

- Future conditions are not enhanced by human activities.

New Mexico Species of Greatest Conservation Need

Under the Comprehensive Wildlife Conservation Strategy (CWCS) for New Mexico, Species of Greatest Conservation Need (SGCN) have been designated in the state (NMDGF 2006). More than one-fourth (i.e., 26%) of the state's vertebrate, mollusc, and crustacean animals are considered SGCN. Of the 452 vertebrate, mollusc, and arthropod SGCN statewide, about 74 are birds. There are lists of SGCN for the entire state, as well as those for each of the individual ecoregions in New Mexico.

G.2. Literature Cited

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Appendix H: El Malpais NM Bird Lists

Listed below are the bird species recorded at El Malpais NM during 2002-2003 surveys during the breeding season (Johnson et al. 2007), bird observations in 1991-1993 by Lightfoot et al. (1994), and observations/sightings by El Malpais NM staff/volunteers from 2011-early 2015 along Highways 53 and 117 bordering the park. A total of 183 species are listed here; subspecies are not included.

Common Name	Scientific Name	Johnson et al. (2007) in 2002-2003	Lightfoot et al. (1994) in 1991-1993 [1]	eBird/Park Data 2011-early 2015 [2]
Acorn Woodpecker	Melanerpes formicivorus	X	X	X
American Crow	Corvus brachyrhynchos		X	X
American Goldfinch	Spinus tristis			X
American Kestrel	Falco sparverius	X	X	X
American Pipit	Anthus rubescens			X
American Robin	Turdus migratorius	X	X	X
American Tree Sparrow	Spizella arborea			X
Ash-throated Flycatcher	Myiarchus cinerascens	X	X	X
Baird's Sandpiper	Calidris bairdii			X
Bald Eagle	Haliaeetus leucocephalus			X
Band-tailed Pigeon	Patagioenas fasciata		X	X
Barn Owl	Tyto alba		X	
Barn Swallow	Hirundo rustica	X		X
Belted Kingfisher	Megaceryle alcyon			X
Bendire's Thrasher	Toxostoma bendirei			X
Bewick's Wren	Thryomanes bewickii	X	X	X
Black-capped Chickadee	Poecile atricapillus		X	
Black Phoebe	Sayornis nigricans			X
Black-chinned Hummingbird	Archilochus alexandri	X	X	X
Black-chinned Sparrow	Spizella atrogularis			X
Black-headed Grosbeak	Pheucticus melanocephalus	X	X	X
Black-throated Gray Warbler	Setophaga nigrescens	X	X	X
Black-throated Sparrow	Amphispiza bilineata	X		X
Blue Grosbeak	Passerina caerulea		X	X
Blue-gray Gnatcatcher	Polioptila caerulea	X		X
Blue-winged Teal	Anas discors			X
Brewer's Blackbird	Euphagus cyanocephalus		X	X
Brewer's Sparrow	Spizella breweri		X	X
Broad-tailed Hummingbird	Selasphorus platycercus	X	X	X
Brown Creeper	Certhia americana	X	X	X
Brown-headed Cowbird	Molothrus ater	X	X	X
Bullock's Oriole	Icterus bullockii	X	X	X
Burrowing Owl	Athene cunicularia		X	X
Bushtit	Psaltriparus minimus	X	X	X
Calliope Hummingbird	Selasphorus calliope			X

[1] Note that Lightfoot et al. (1994) included some species that were observed outside of national monument boundaries, but it is difficult to determine which species these are.

[2] The following species appear in the eBird database from observers other than national monument staff/volunteers: American White Pelican, Cactus Wren, Common Grackle, House Sparrow, Phainopepla, and Western Screech-Owl.

Common Name	Scientific Name	Johnson et al. (2007) in 2002-2003	Lightfoot et al. (1994) in 1991-1993 [1]	eBird/Park Data 2011-early 2015 [2]
Canyon Towhee	Melozone fusca	X	X	X
Canyon Wren	Catherpes mexicanus		X	X
Cassin's Finch	Haemorhous cassinii		X	X
Cassin's Kingbird	Tyrannus vociferans	X	X	X
Cassin's Sparrow	Peucaea cassinii		X	
Cedar Waxwing	Bombycilla cedrorum		X	X
Chestnut-collared Longspur	Calcarius ornatus			X
Chipping Sparrow	Spizella passerina	X	X	X
Cinnamon Teal	Anas cyanoptera			X
Clark's Nutcracker	Nucifraga columbiana		X	X
Clay-colored Sparrow	Spizella pallida			X
Cliff Swallow	Petrochelidon pyrrhonota	X	X	X
Common Nighthawk	Chordeiles minor	X	X	X
Common Poorwill	Phalaenoptilus nuttallii		X	X
Common Raven	Corvus corax	X	X	X
Cooper's Hawk	Accipiter cooperii		X	X
Cordilleran Flycatcher	Empidonax occidentalis	X	X	X
Crissal Thrasher	Toxostoma crissale			X
Curve-billed Thrasher	Toxostoma curvirostre	X		X
Dark-eyed Junco	Junco hyemalis	X	X	X
Downy Woodpecker	Picoides pubescens		X	X
Dusky Flycatcher	Empidonax oberholseri	X	X	X
Eared Grebe	Podiceps nigricollis			X
Eastern Meadowlark	Sturnella magna	X		X
Eurasian Collared-Dove	Streptopelia decaocto			X
European Starling	Sturnus vulgaris			X
Evening Grosbeak	Coccothraustes vespertinus			X
Ferruginous Hawk	Buteo regalis			X
Flammulated Owl	Psiloscops flammeolus			X
Gadwall	Anas strepera			X
Gambel's Quail	Callipepla gambelii	X		
Golden Eagle	Aquila chrysaetos		X	X
Golden-crowned Kinglet	Regulus satrapa			X
Grace's Warbler	Setophaga graciae	X	X	X
Gray Flycatcher	Empidonax wrightii	X		X
Gray Vireo	Vireo vicinior	X		X
Great Blue Heron	Ardea herodias		X	X
Great Horned Owl	Bubo virginianus		X	X
Greater Roadrunner	Geococcyx californianus	X	X	X
Great-tailed Grackle	Quiscalus mexicanus			X
Green Heron	Butorides virescens		X	
Green-tailed Towhee	Pipilo chlorurus	X		X

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Common Name	Scientific Name	Johnson et al. (2007) in 2002-2003	Lightfoot et al. (1994) in 1991-1993 [1]	eBird/Park Data 2011-early 2015 [2]
Green-winged Teal	Anas crecca		X	X
Hairy Woodpecker	Picoides villosus	X	X	X
Hammond's/Dusky Flycatcher	Empidonax hammondii/ oberholseri			X
Hepatic Tanager	Piranga flava	X	X	X
Hermit Thrush	Catharus guttatus			X
Horned Lark	Eremophila alpestris	X	X	X
House Finch	Haemorhous mexicanus	X	X	X
House Wren	Troglodytes aedon	X		X
Indigo Bunting	Passerina cyanea			X
Juniper Titmouse	Baeolophus ridgwayi	X	X	X
Killdeer	Charadrius vociferus		X	X
Ladder-backed Woodpecker	Picoides scalaris	X		X
Lapland Longspur	Calcarius lapponicus			X
Lark Bunting	Calamospiza melanocorys			X
Lark Sparrow	Chondestes grammacus	X	X	X
Lazuli Bunting	Passerina amoena			X
Lesser Goldfinch	Spinus psaltria	X	X	X
Lewis's Woodpecker	Melanerpes lewis		X	X
Lincoln's Sparrow	Melospiza lincolnii	X		X
Loggerhead Shrike	Lanius ludovicianus		X	X
Long-billed Curlew	Numenius americanus			X
Long-billed Dowitcher	Limnodromus scolopaceus			X
Long-eared Owl	Asio otus		X	
MacGillivray's Warbler	Geothlypis tolmiei			X
Mallard	Anas platyrhynchos			X
Merlin	Falco columbarius			X
Mountain Bluebird	Sialia currucoides	X	X	X
Mountain Chickadee	Poecile gambeli	X	X	X
Mountain Plover	Charadrius montanus		X	X
Mourning Dove	Zenaida macroura	X	X	X
Nashville Warbler	Oreothlypis ruficapilla			X
Northern Flicker	Colaptes auratus	X	X	X
Northern Goshawk	Accipiter gentilis		X	X
Northern Harrier	Circus cyaneus		X	X
Northern Mockingbird	Mimus polyglottos	X	X	X
Northern Pintail	Anas acuta		X	
Northern Pygmy-Owl	Glaucidium gnoma			X
Northern Rough-winged Swallow	Stelgidopteryx serripennis		X	
Olive-sided Flycatcher	Contopus cooperi			X
Orange-crowned Warbler	Oreothlypis celata			X

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Common Name	Scientific Name	Johnson et al. (2007) in 2002-2003	Lightfoot et al. (1994) in 1991-1993 [1]	eBird/Park Data 2011-early 2015 [2]
Peregrine Falcon	Falco peregrinus			X
Pine Siskin	Spinus pinus		X	X
Pinyon Jay	Gymnorhinus cyanocephalus	X	X	X
Plumbeous Vireo	Vireo plumbeus	X	X	X
Prairie Falcon	Falco mexicanus			X
Purple Martin	Progne subis		X	X
Pygmy Nuthatch	Sitta pygmaea	X	X	X
Red Crossbill	Loxia curvirostra	X	X	X
Red-breasted Nuthatch	Sitta canadensis	X	X	X
Red-eyed Vireo	Vireo olivaceus			X
Red-naped Sapsucker	Sphyrapicus nuchalis			X
Red-tailed Hawk	Buteo jamaicensis	X	X	X
Red-winged Blackbird	Agelaius phoeniceus			X
Rock Pigeon	Columba livia		X	
Rock Wren	Salpinctes obsoletus	X	X	X
Rose-breasted Grosbeak	Pheucticus ludovicianus			X
Rough-legged Hawk	Buteo lagopus			X
Ruby-crowned Kinglet	Regulus calendula		X	X
Rufous Hummingbird	Selasphorus rufus		X	X
Rufous-crowned Sparrow	Aimophila ruficeps	X		X
Sage Sparrow	Amphispiza belli		X	
Sage Thrasher	Oreoscoptes montanus		X	X
Sagebrush Sparrow	Artemisiospiza nevadensis			X
Savannah Sparrow	Passerculus sandwichensis		X	X
Say's Phoebe	Sayornis saya	X	X	X
Scaled Quail	Callipepla squamata		X	
Scott's Oriole	Icterus parisorum	X	X	X
Sharp-shinned Hawk	Accipiter striatus		X	X
Solitary Sandpiper	Tringa solitaria			X
Song Sparrow	Melospiza melodia			X
Spotted Sandpiper	Actitis macularius			X
Spotted Towhee	Pipilo maculatus	X	X	X
Steller's Jay	Cyanocitta stelleri	X	X	X
Swainson's Hawk	Buteo swainsoni		X	
Swainson's Thrush	Catharus ustulatus			X
Townsend's Solitaire	Myadestes townsendi	X	X	X
Townsend's Warbler	Setophaga townsendi			X
Tree Swallow	Tachycineta bicolor		X	
Turkey Vulture	Cathartes aura	X	X	X
Vesper Sparrow	Pooecetes gramineus	X	X	X
Violet-green Swallow	Tachycineta thalassina	X	X	X

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Common Name	Scientific Name	Johnson et al. (2007) in 2002-2003	Lightfoot et al. (1994) in 1991-1993 [1]	eBird/Park Data 2011-early 2015 [2]
Virginia's Warbler	Oreothlypis virginiae	X	X	X
Warbling Vireo	Vireo gilvus	X		X
Western Bluebird	Sialia mexicana	X	X	X
Western Kingbird	Tyrannus verticalis	X	X	X
Western Meadowlark	Sturnella neglecta	X	X	X
Western Sandpiper	Calidris mauri			X
Western Scrub-Jay	Aphelocoma californica	X	X	X
Western Tanager	Piranga ludoviciana	X	X	X
Western Wood-Pewee	Contopus sordidulus	X	X	X
White-breasted Nuthatch	Sitta carolinensis	X	X	X
White-crowned Sparrow	Zonotrichia leucophrys		X	X
White-faced Ibis	Plegadis chihi		X	
White-throated Sparrow	Zonotrichia albicollis			X
White-throated Swift	Aeronautes saxatalis	X	X	X
White-winged Dove	Zenaida asiatica			X
Wild Turkey	Meleagris gallopavo		X	X
Williamson's Sapsucker	Sphyrapicus thyroideus			X
Wilson's Phalarope	Phalaropus tricolor			X
Wilson's Warbler	Cardellina pusilla		X	X
Wood Duck	Aix sponsa			X
Yellow Warbler	Setophaga petechia		X	X
Yellow-bellied Sapsucker	Sphyrapicus varius		X	
Yellow-headed Blackbird	Xanthocephalus xanthocephalus			X
Yellow-rumped Warbler	Setophaga coronata	X	X	X
Zone-tailed Hawk	Buteo albonotatus			X
Total number of bird species		75	109	168

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

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National Park Service
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