



Integrated Upland Protocol of the Mojave Desert Network

Volume 1, Protocol Narrative

Natural Resource Report NPS/MOJN/NRR—2015/1010





ON THIS PAGE

Yucca brevifolia var. *jaegeriana* wooded scrubland community, Mojave National Preserve

Photograph by: Jean J. Pan, NPS

ON THE COVER

Larrea tridentata shrubland community, Death Valley National Park

Photograph by: Jean J. Pan, NPS

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Contents

	Page
Figures.....	ix
Tables.....	xiii
Appendices.....	xv
Standard Operating Procedures (SOPs)	xvii
Supplementary Materials	xix
Executive Summary	xxi
Acknowledgments.....	xxiii
Abbreviations	xxv
1. Background and Objectives	1
1.1. Rationale for Monitoring Upland Communities in MOJN.....	1
1.1.1. Rationale for Vegetation Monitoring	2
1.1.2. Rationale for Soils Monitoring.....	5
1.1.3. Rationale for Invasive Plants Status and Trends Monitoring.....	7
1.2. Objectives	10
1.2.1. Monitoring Questions	10
1.2.2. Measureable Objectives.....	11
1.3. Overview of the MOJN Parks	11
1.3.1. Death Valley National Park (DEVA)	15
1.3.2. Great Basin National Park (GRBA)	17
1.3.3. Joshua Tree National Park (JOTR).....	19
1.3.4. Lake Mead National Recreation Area (LAKE).....	21
1.3.5. Manzanar National Historic Site (MANZ).....	23
1.3.6. Mojave National Preserve (MOJA).....	25
1.3.7. Grand Canyon-Parashant National Monument (PARA)	27
1.4. Overview of Selected Upland Communities in MOJN Parks	29

Contents (continued)

	Page
1.4.1. DEVA – Creosote Bush Mixed Desert Shrubland Community	29
1.4.2. GRBA – Sagebrush Shrub Steppe Community	31
1.4.3. JOTR – Joshua Tree Wooded Alliance Community	34
1.4.4. LAKE – Creosote bush-White bursage Shrub Community	36
1.4.5. MANZ – Rabbitbrush Shrubland Community	39
1.4.6. MOJA – Joshua Tree Wooded Scrubland Community	41
1.4.7. PARA – Sagebrush Shrub Steppe Community	45
1.5. Potential Integration with Other Protocols	47
2. Sampling Design	49
2.1. Population of Inference	49
2.2. Response Design	58
2.2.1. Vegetation	60
2.2.2. Soil	60
2.2.3. Invasive Plant Species	63
2.3. Sample Size and Spatial Design	64
2.3.1. Power Analysis for Sample Size	64
2.3.2. Spatial Design	67
2.4. Sampling Frequency and Timing	67
2.5. Benefits of the Selected Design	68
3. Field Methods	71
3.1. Standard Operating Procedures	71
3.2. Logistics	72
3.2.1. Permitting	72
3.2.2. Hiring the Field Crew	72
3.2.3. Arranging for Training	72

Contents (continued)

	Page
3.2.4. Field Season Preparations.....	73
3.3. Field Methods.....	73
3.3.1. Daily Field Activities	73
3.3.2. Site Characterization, Macroplot Set-up and Revisit	74
3.3.3. Vegetation Monitoring	74
3.3.4. Soils Monitoring.....	75
3.3.5. Invasive Plant Species - Status and Trends Monitoring.....	75
3.3.6. End of Field Tour and Season Activities.....	76
4. Data Management	79
4.1. Project Information Management Overview	79
4.2. Overview of Database Design	80
4.2.1. Tabular Databases	80
4.2.2. Spatial Databases.....	81
4.3. Preparation.....	81
4.4. Data Acquisition.....	82
4.5. Data Entry and Processing.....	82
4.6. Quality Review	83
4.7. Metadata	83
4.7.1. Sensitive Information	84
4.8. Data Certification	84
4.9. Data Delivery.....	85
4.10. Data Analyses and Product Development and Delivery	85
4.11. Posting and Distribution	85
4.12. Archiving and Records Management	85
4.13. Season Closeout.....	85

Contents (continued)

	Page
5. Data Analysis and Reporting	87
5.1. Data Analysis.....	87
5.1.1. Status	87
5.1.2. Trend.....	88
5.2. Reporting	90
5.2.1. Annual Reports.....	91
5.2.2. Annual Briefs.....	91
5.2.3. Comprehensive Reports.....	91
5.2.4. Protocol Review	96
6. Personnel Requirements and Training	97
6.1. Personnel Requirements	97
6.2. Roles and Responsibilities.....	97
6.3. Qualifications, Training, and Calibration.....	99
7. Operational Requirements	101
7.1. Annual Workload and Schedule.....	101
7.2. Facilities and Equipment Needs	103
7.3. Budget	104
Literature Cited	105

Figures

	Page
Figure 1.1. Mojave Desert Network conceptual model for dry systems.....	4
Figure 1.2. Conceptual model indicating the phases of invasion in relation to the logistic population growth curve.	9
Figure 1.3. The seven parks of the Mojave Desert Network (MOJN).	13
Figure 1.4. Map of Death Valley National Park showing wilderness areas.....	16
Figure 1.5. Map of Great Basin National Park.....	18
Figure 1.6. Map of Joshua Tree National Park showing wilderness areas.....	20
Figure 1.7. Map of Lake Mead National Recreation Area showing wilderness areas.....	22
Figure 1.8. Map of Manzanar National Historic Site.....	24
Figure 1.9. Map of Mojave National Preserve showing wilderness areas.	26
Figure 1.10. Map of Grand Canyon-Parashant National Monument showing wilderness areas.	28
Figure 1.11. Distribution and example of the creosote bush (<i>Larrea tridentata</i>) mixed desert shrubland community between ~900 – 1,500 m (3,000-5,000 ft) and ½ to 3 mi of paved/unpaved roads at Death Valley National Park.....	30
Figure 1.12. Distribution and example of the sagebrush (<i>Artemisia</i> spp.) shrub steppe community at Great Basin National Park.	32
Figure 1.13. Distribution and example of the Joshua tree (<i>Yucca brevifolia</i> var. <i>brevifolia</i>) wooded alliance community at Joshua Tree National Park.	35
Figure 1.14. Distribution and example of the creosote bush (<i>Larrea tridentata</i>) - white bursage (<i>Ambrosia dumosa</i>) shrub community between 450 to 1,500 m (1,500 to 5,000 ft) elevation at Lake Mead National Recreation Area.	38
Figure 1.15. Distribution and example of the rabbitbrush (<i>Ericameria nauseosa</i>) shrubland community at Manzanar National Historic Site.....	40
Figure 1.16. Photos of Jaeger’s Joshua tree (<i>Yucca brevifolia</i> var. <i>jaegeriana</i>), the “dwarf” variety found at Mojave National Preserve and Joshua tree (<i>Yucca brevifolia</i> var. <i>brevifolia</i>), the variety found at Joshua Tree National Park.	42
Figure 1.17. a) Distribution and b) example of the Joshua tree (<i>Yucca brevifolia</i> var. <i>jaegeriana</i>) wooded scrubland community at Mojave National Preserve.....	44

Figures (continued)

	Page
Figure 1.18. Distribution and example of the sagebrush (<i>Artemisia</i> spp.) shrub steppe community at Grand Canyon-Parashant National Monument.	46
Figure 2.1. Generalized Random Tessellation Stratified (GRTS) draw for Death Valley National Park.	51
Figure 2.2. Generalized Random Tessellation Stratified (GRTS) draw for Great Basin National Park.	52
Figure 2.3. Generalized Random Tessellation Stratified (GRTS) draw for Joshua Tree National Park.	53
Figure 2.4. Generalized Random Tessellation Stratified (GRTS) draw for Lake Mead National Recreation Area.	54
Figure 2.5. Generalized Random Tessellation Stratified (GRTS) draw for Manzanar National Historic Site.	55
Figure 2.6. Generalized Random Tessellation Stratified (GRTS) draw for Mojave National Preserve.	56
Figure 2.7. Generalized Random Tessellation Stratified (GRTS) draw for Grand Canyon-Parashant National Monument.	57
Figure 2.8. Standard macroplot and transect layout for upland monitoring.	59
Figure 2.9. Simulation of power for trend testing at LAKE to detect annual change of 1% and 4% in log(% shrub cover) metrics for a 1-2 revisit design (parks sampled every 3 years) over 20 years and 30 years.	65
Figure 2.10. Simulation of power for trend testing at DEVA to detect annual change of 1% and 4% in log(total cover) metrics for a 1-2 revisit design (parks sampled every 3 years) over 20 years and 30 years.	66
Figure 4.1. Idealized flow schematic of the stages of project information management, from pre-season preparation to season close-out.	79
Figure 5.1. Example table of contents from an annual report from the MOJN integrated upland protocol.	92
Figure 5.2. Example figure for vegetation status.	93
Figure 5.3. Example figure for invasive plant status.	93
Figure 5.4. Example trend figure for % total cover (vegetation parameter) ($\pm$ SE) after the first three sampling periods for hypothetical Park A.	94

Figures (continued)

	Page
Figure 5.5. Example trend figure for soil erosion (soil parameter) ($\pm$ SE) after the first three monitoring intervals for hypothetical Park A.	95
Figure 5.6. Example trend figure for invasive plant status.	95

Appendix Figures

Figure B1. Boxplots of percent shrub and total cover in the pilot data for each park.	B-3
Figure B2. Boxplots of percent shrub and total cover for the 2008-2010 GRBA pilot data.	B-4
Figure B3. Simulation power for trend testing of cover in DEVA for annual declines of 1% and 4% in log transformed percent shrub cover over 20 years, percent shrub cover over 30 years, percent total cover metrics over 20 years, and percent total cover metrics over 30 years for a [1-2] revisit design.	B-8
Figure B4. Simulation power for trend testing of cover in GRBA for annual declines of 1% and 4% in log transformed percent shrub cover over 20 years, percent shrub cover over 30 years, percent total cover metrics over 20 years, and percent total cover metrics over 30 years for a [1-2] revisit design (based on pilot data from 2008-09 only).	B-9
Figure B5. Simulation power for trend testing of cover in JOTR for annual declines of 1% and 4% in log transformed percent shrub cover over 20 years, percent shrub cover over 30 years, percent total cover metrics over 20 years, and percent total cover metrics over 30 years for a [1-2] revisit design.	B-10
Figure B6. Simulation power for trend testing of cover in LAKE for annual declines of 1% and 4% in log transformed percent shrub cover over 20 years, percent shrub cover over 30 years, percent total cover metrics over 20 years, and percent total cover metrics over 30 years for a [1-2] revisit design.	B-11
Figure B7. Simulation power for trend testing of cover in MOJA for annual declines of 1% and 4% in log transformed percent shrub cover over 20 years, percent shrub cover over 30 years, percent total cover metrics over 20 years, and percent total cover metrics over 30 years for a [1-2] revisit design.	B-12
Figure B8. Simulation power for trend testing of cover in PARA for annual declines of 1% and 4% in log transformed percent shrub cover over 20 years, percent shrub cover over 30 years, percent total cover metrics over 20 years, and percent total cover metrics over 30 years for a [1-2] revisit design.	B-13

Tables

	Page
Table 1.1. Area and elevation of Mojave Desert Network parks.	14
Table 1.2. Mission Statements for Mojave Desert Network parks.....	14
Table 2.1. Elevation, area, and spatial dataset used to determine the distribution of communities selected for each park.	50
Table 2.2. Proposed park monitoring schedule by year and season.	68
Table 3.1. Standard Operating Procedures (SOPs) for the IU protocol.	71
Table 4.1. Data Management Quality review process for data entry.	83
Table 5.1. Examples of response variables from the IU protocol used to assess vital signs.	88
Table 5.2. Possible interpretations of changes in soil parameters through time.	90
Table 5.3. Example table for status of soil parameters at hypothetical Park A.....	94
Table 6.1. Roles and responsibilities for implementing the IU protocol.....	98
Table 7.1. Annual implementation schedule for IU monitoring.	101
Table 7.2. Estimated annual IU protocol budget.....	104

Appendix Tables

Table A1. Invasive plant species for status and trends monitoring at Death Valley National Park.	A-1
Table A2. Invasive species for status and trends monitoring at Great Basin National Park.	A-1
Table A3. Invasive species for status and trends monitoring at Joshua Tree National Park.	A-1
Table A4. Invasive species for status and trends monitoring at Lake Mead National Recreation Area.	A-2
Table A5. Invasive species for status and trends monitoring at Manzanar National Historic Site.	A-2
Table A6. Invasive species for status and trends monitoring at Mojave National Preserve.	A-3
Table A7. Invasive species for status and trends monitoring at Grand Canyon-Parashant National Monument.	A-3

Tables (continued)

Page

Appendix Tables (continued)

Table B1. Pilot data details. B-2

Table B2. Transformations, fixed effects estimates, and variance components estimates
by park for percent shrub cover. B-6

Table B3. Transformations, fixed effects estimates, trend test results, and variance
components estimates by park for total percent cover. B-7

Appendices

	Page
Appendix A: Status and Trend Invasive Species for the MOJN Parks.....	A-1
Appendix B: Power to Detect Trend in Cover Metrics in Mojave Desert Network Parks	B-1

Standard Operating Procedures (SOPs)

Standard operating procedures (SOPs) and Appendices are bound in a separate accompanying document *Integrated Upland Protocol of the Mojave Desert Network, Volume 2, Standard Operating Procedures*.

SOP 1: Preparations and Equipment Setup Prior to the Field Season

SOP 2: Training Observers

SOP 3: Daily Field Activities

SOP 4: Spatial Data Naming Conventions

SOP 5: Crust-Friendly Field Procedures

SOP 6: Site Characterization

SOP 7: Macroplot Establishment and Revisit Set-Up

SOP 8: Measuring Cover of Vegetation and Soil Surface Features Using Point-Intercept Sampling

SOP 9: Measuring Basal and Canopy Gaps Using Line-Intercept Sampling

SOP 10: Assessing Invasive Plant and Disturbance Frequency Using Quadrats

SOP 11: Soil Measurements

SOP 12: Site Assessment for Invasive Plant and Target Tree Species

SOP 13: Repeat Photos

SOP 14: Unknown Shrub Species

SOP 15: End of Field Tour and Season Activities

SOP 16: Information Management Workflow and Tasks

SOP 17: Data Management

SOP 18: Database Design

SOP 19: Data Analysis and Reporting

SOP 20: Protocol Revision and Review

Supplementary Materials

The following MOJN I&M network wide standard operating procedures (SOPs) are available on the MOJN I&M SharePoint site (document is hyperlinked) or available upon request from the MOJN I&M Data Manager:

MOJN SOP M1: [Incidental Observations of Incipient Invasive Species](#)

MOJN SOP M2: [Prioritizing Invasive Species for Status and Trends Monitoring](#)

MOJN SOP M3: [Global Position System](#)

MOJN SOP M4: [Field Safety Plan](#)

MOJN SOP M5: [Archiving](#)

MOJN SOP M6: [Biological Data Profile](#)

MOJN SOP M7: [Data Quality](#)

MOJN SOP M8: [Database Naming Conventions](#)

MOJN SOP M9: [Documentation Non-spatial](#)

MOJN SOP M10: [Documentation Spatial](#)

MOJN SOP M11: [Image Management](#)

MOJN SOP M12: [NPS Metadata Tools and Editor](#)

MOJN SOP M13: [Project Deliverables](#)

MOJN SOP M14: [Sensitive Data](#)

MOJN SOP M15: [Season Closeout](#)

MOJN SOP M16: [Directory Structure Non-Spatial](#)

MOJN SOP M17: [File Naming Conventions](#)

MOJN SOP M18: [Digitizing Information and Photographs](#)

Executive Summary

The mission of the National Park Service is “to conserve unimpaired the natural and cultural resources and values of the National Park System for the enjoyment of this and future generations” (NPS 1999a). To uphold this goal, the Director of the NPS approved the Natural Resource Challenge to encourage national parks to focus on the preservation of the nation’s natural heritage through science, natural resource inventories, and expanded resource monitoring (NPS 1999a). Through the Natural Resources Challenge, NPS implemented the “Vital Signs Monitoring Program,” a long-term ecological monitoring program that will provide rigorous, scientifically-based information on the status and trends of park ecosystems. With data from this program, park managers will be better able to evaluate complex and challenging resource issues and make sound decisions that result in long-term protection of park ecosystems. Information on park resource conditions will also be useful for park planning, research, education, and public awareness.

In 2000, 270 NPS units with substantial natural resources were organized into 32 inventory and monitoring (I&M) networks based on ecological similarity and geographic proximity as part of the Natural Resources Challenge. The Mojave Desert Network (MOJN) I&M was one of the networks created and includes seven NPS units in California, Nevada, and Arizona. MOJN is comprised of: Death Valley National Park (DEVA), Great Basin National Park (GRBA), Joshua Tree National Park (JOTR), Lake Mead National Recreation Area (LAKE), Manzanar National Historic Site (MANZ), Mojave National Preserve (MOJA), and Grand Canyon-Parashant National Monument (PARA). Collectively, these units encompass over 3.3 million hectares (8.3 million acres), or 9.7% of the total land area managed by NPS, making MOJN the largest network in terms of area in the lower 48 states.

After a series of vital signs scoping workshops, 20 priority park vital signs - indicators of ecosystem health - that represent a broad suite of ecological phenomena operating across multiple temporal and spatial scales were identified for MOJN I&M (see Chung-MacCoubrey et al. (2008) for details on the vital signs selection process). MOJN I&M vital signs fall into five broad categories: Air & Climate, Geology & Soils, Water, Biological Integrity, and Landscapes. With the integration of the status and trends of invasive species into the Integrated Upland Protocol, this protocol addresses seven of the 20 vital signs (vegetation change, invasive plants, soil erosion & deposition, soil disturbance, soil chemistry & nutrient cycling, soil hydrologic function, and biological soil crusts) that fall into two of the five categories, Geology & Soils and Biological Integrity. Monitoring of vegetation in riparian areas and the early detection of invasive species will be addressed in a separate set of protocols. We anticipate that as protocols addressing other vital signs are developed, data from these other vital signs will be incorporated with data from this protocol to provide a more comprehensive view of the monitored upland communities.

MOJN I&M and network parks decided that Integrated Upland monitoring will be conducted on select upland shrub communities. Shrub communities were chosen because this physiognomic class collectively represents a large proportion of each park and captures several focal communities of interest (e.g., Joshua tree, creosote bush, and sagebrush), thus, providing a common theme among

parks. In collaboration with park units, representative upland communities were selected for monitoring and will be assessed for changes in vegetation, soils, and target invasive species. All macroplots in each park will be monitored on a 3-year revisit schedule with trend analyses planned after three visits. Parameters examined in long-term monitoring macroplots include change in shrub species community composition, life form composition, key soil parameters (e.g., pH, soil surface disturbance, biological soil crusts), and frequency of occurrence of target “status and trends invasive species.”

This protocol details the why, where, how, and when of the monitoring program. As recommended by Oakley et al. (2003), the protocol consists of a narrative and an accompanying set of standard operating procedures (SOPs; both specific to IU and network wide) that detail the steps required to collect, manage, and disseminate the data representing the status and trend of upland communities in the MOJN parks. For all references to the IU protocol SOPs, see the *Integrated Upland Protocol of the Mojave Desert Network, Volume 2, Standard Operating Procedures* (Pan et al. 2015). Collected data, in combination with other vital signs monitoring data, will provide a context for the interpretation of status and trends of upland communities within the network.

The protocol is intended to be a “living” document that evolves as new information emerges and methodologies continue to be refined. Changes to the protocol are carefully documented in a revision history log. The first few cycles of monitoring will address the logistics of field monitoring (e.g., travel time between sites, time needed for on the ground monitoring) and status of upland communities (e.g., site variability, inter-annual variability). From there, the focus will shift toward trend analysis to detect ecologically meaningful declines or increases, from which appropriate management strategies can be developed.

Acknowledgments

Funding for this project was provided through the National Park Service Natural Resource Challenge and the Servicewide Inventory and Monitoring Program. This protocol is the result of collaborative efforts between MOJN I&M and park resources staff, particularly past and current members of the Vegetation Working Group (J. Bradybaugh [PARA], J. Cipra [DEVA], N. Darby [MOJA], J. Fox [PARA], J. Hoines [JOTR], D. Hughson [MOJA], L. Inafuku [MANZ], A. Miller [JOTR], A. Newton [LAKE], B. Roberts [GRBA], M. Slaton [DEVA], K. Turner [LAKE], K. Yanksey [PARA]). K. Heister and A. Chung-MacCoubrey's contributions as the previous MOJN I&M Coordinators laid the groundwork for the vegetation related protocols. S. Newbold (previous MOJN I&M network ecologist) and B. Pendleton (USFS cooperator) were critical to the early stages of protocol development. We thank P. Latham (Pacific West I&M coordinator) for her assistance in her role as interim MOJN I&M Program Manager in 2010. J. Brackin provided significant help preparing this document. B. Seward and D. Gundlach created additional maps for the protocol. Tony Ross (LAKE creative services) created some of the illustrations. We thank Lise Grace, technical editor at the North Coast and Cascades Network Inventory and Monitoring Program, for formatting the report and guiding us through the publication process. Some sections of the protocol narrative were inspired by or adapted from the MOJN I&M *Selected Large Springs of the Mojave Desert Network: Protocol Narrative* (Moret et al. Unpublished Report).

Abbreviations

B: Boron	NCPN: Northern Colorado Plateau Inventory and Monitoring Network
BLM: Bureau of Land Management	NPS: National Park Service
BoD: MOJN I&M Board of Directors	NRCS: Natural Resources Conservation Service
BSC: Biological Soil Crust	PARA: Grand Canyon-Parashant National Monument
Ca: Calcium	P: Phosphorus
Co: Cobalt	QA/QC: Quality Assurance/Quality Control
Cu: Copper	S: Sulfur
DEVA: Death Valley National Park	S&T: Status and trends
dS: deci-Siemens	SOP: Standard Operating Procedure
DM: Data Management	TC: Technical Committee
DMP: Data Management Plan	UTM: Universal Transverse Mercator
EC: Electrical Conductivity	VWG: Vegetation Working Group
EMAP: Environmental Monitoring and Assessment Program	WASO: NPS Washington Office
EPMT: Exotic Plant Management Team	Zn: Zinc
Fe: Iron	
GMP: General Management Plan	
GPS: Global Positioning System	
GRBA: Great Basin National Park	
GRTS: Generalized Random Tessellation Stratified	
I&M: Inventory and Monitoring	
IAR: Investigator Annual Report	
IRMA: Integrated Resource Management Applications	
IU: Integrated Upland	
JHA: Job Hazard Analysis	
JOTR: Joshua Tree National Park	
K: Potassium	
LADWP: Los Angeles Department of Water and Power	
LAKE: Lake Mead National Recreation Area	
MANZ: Manzanar National Historic Site	
Mg: Magnesium	
Mn: Manganese	
Mo: Molybdenum	
MOJA: Mojave National Preserve	
MOJN: Mojave Desert Inventory and Monitoring Network	
N: Nitrogen	

1. Background and Objectives

This document presents a protocol for monitoring the status and trends of upland communities for the seven parks (hereafter, “park” is used in a general sense to refer to all of the different types of units in the National Park Service, or NPS) in the Mojave Desert Network (MOJN), Inventory and Monitoring (I&M) program. The MOJN parks include: Death Valley National Park (DEVA), Great Basin National Park (GRBA), Joshua Tree National Park (JOTR), Lake Mead National Recreation Area (LAKE), Manzanar National Historic Site (MANZ), Mojave National Preserve (MOJA), and Grand Canyon-Parashant National Monument (PARA). This protocol details the approach that MOJN I&M will undertake, including descriptions of the sampling design, field methods, data analysis and reporting, data management requirements, and operational requirements, for monitoring upland communities to meet the goals and objectives of the network. In this section, we outline the rationale for monitoring upland communities, objectives of the protocol, and provide a brief description of each of the MOJN parks and selected communities.

1.1. Rationale for Monitoring Upland Communities in MOJN

In order to fulfill the NPS mission (NPS 1916) of leaving resources “unimpaired for the enjoyment of future generations”, NPS managers are directed by federal law and NPS policies to know the conditions of natural resources under their stewardship. More recently, the National Parks Omnibus Management Act of 1998 (NPS 1998) established the framework for fully integrating natural resource monitoring and other science activities into the management processes of the National Park System. Section 5934 of the Act requires the Secretary of the Interior to develop a program of “inventory and monitoring of National Park System resources to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources.” In 2001, NPS Management Policies (NPS 2001a) specifically directed that “natural systems in the National Park System, and the human influences upon them, will be monitored to detect change. NPS will use the results of monitoring and research to understand the detected change and to develop appropriate management actions.” For example, if monitoring shows that there is a correlation between air quality and a decrease in the Joshua tree (*Yucca brevifolia*) population at JOTR, then JOTR can investigate air quality management actions.

Monitoring is a central component of natural resource stewardship in the NPS and provides information needed for effective, science-based managerial decision-making and resource protection. The intent of the NPS I&M program is to monitor a set of “vital signs”, which 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, the known or hypothesized effects of stressors, or elements that have important human values or resource significance. Data from vital signs monitoring will help define the typical limits of variation in park resources by augmenting historic data, determining what constitutes resource impairment, and identifying the need to initiate or change management practices.

This protocol directly addresses seven highly ranked vital signs out of 20 (Chung-MacCoubrey et al. 2008; discussed below), which we broadly categorize as vegetation (change), soils, and invasive

plants. The grouping and co-monitoring of these vital signs makes ecological sense as there are strong interactions and feedbacks between plants and the soils that they live in (Gurevitch et al. 2006). For example, changes in soil chemistry have been linked to greater invasions by non-native plants, leading to losses of native plant species (Brooks 2003, Daehler 2003).

MOJN I&M parks are faced with the increasing pressures of air pollution, habitat loss, fragmentation, and altered disturbance regimes (e.g., fire, land development; Chung-MacCoubrey et al. 2008). Climate models also predict significant climatic changes, increasing temperatures but decreasing precipitation, for the southwestern United States (Seager et al. 2007, Archer and Predick 2008). The presence and composition of vegetation depends on a multitude of abiotic and biotic factors, including climate, resource availability, and soil microbial community, thus, making vegetation, and the soils associated with it, good general indicators of environmental change across parks (Vasek and Lund 1980, Janssens et al. 1998, Klironomos 2002, Hereford et al. 2006; Figure 1.1).

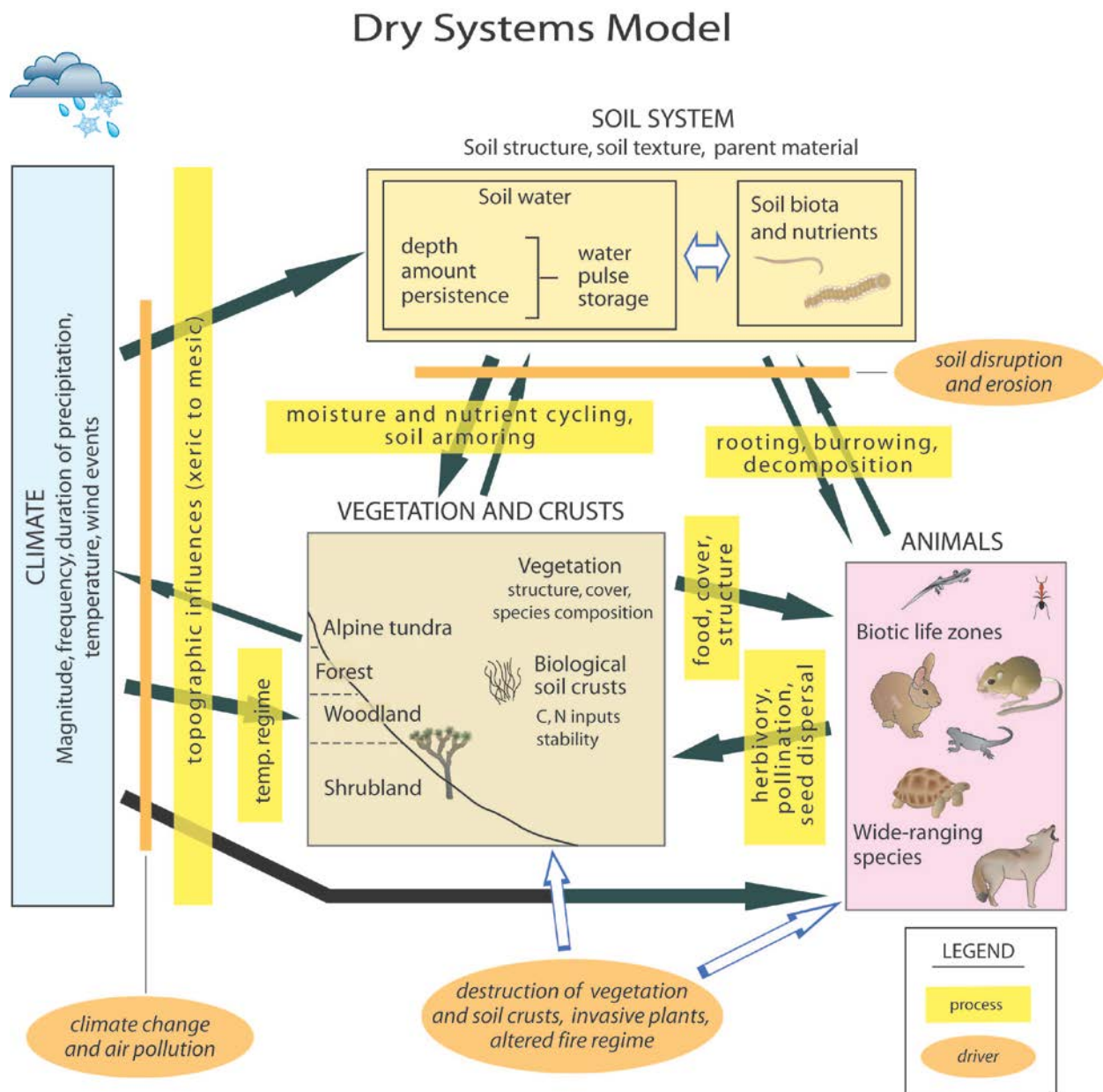
1.1.1. Rationale for Vegetation Monitoring

Terrestrial ecosystems cover ~29% of the earth's surface and vegetation is the dominant biological macrofeature of terrestrial ecosystems (Groombridge and Jenkins 2002). Vegetation has significant, if not the primary, influence in shaping terrestrial ecosystems (Figure 1.1). Plants are primary producers, are the 3-dimensional structure of communities, provide critical habitat (food, shelter, and substrate) for animals and microbes, and, as standing biomass, sequester resources and influence geochemical cycles (Chapin et al. 2002, Gurevitch et al. 2006). Recognizing the important role of vegetation in the ecosystem as well as its sensitivity to a variety of environmental factors, the MOJN parks ranked vegetation change as the second most important vital sign, behind only meteorology.

The presence and type of vegetation found in a particular area is influenced primarily by abiotic factors associated with climate (Merriam 1898, Woodward 1987, Kelly and Goulden 2008). The effects of temperature can vary with season and life history stage (Smith et al. 2009, Collins et al. 2010, Kreyling 2010). For example, in the Mojave Desert, Beatley (1974a) found that creosote bush (*Larrea tridentata*) was not found in sites where the winter extreme minimum is below -17°C or the mean minimum is below -2°C. With the predicted changes for the Mojave Desert under global climate change scenarios, warmer temperatures and fewer frost free days (Archer and Predick 2008), we may see an expansion of creosote bush into areas where it was previously excluded by minimum temperatures (Chambers and Pellant 2008). In general, it is predicted that many species in the southwestern deserts will have range shifts, primarily moving up in elevation to escape warmer temperatures (Archer and Predick 2008), leading to changes in species associations and community composition.

While temperature has important effects on vegetation, water availability may play an even larger role on vegetation in desert ecosystems (Smith et al. 1997). Changes in plant community composition occur during drought events, as some species are more negatively affected than others (Noy-Meir 1973, Hereford et al. 2006, Miriti et al. 2007, DeFalco et al. 2010, McAuliffe and Hamerlynck 2010). For instance, McAuliffe and Hamerlynck (2010) found that *Ambrosia* spp. were less drought tolerant and suffered greater mortality under drought conditions than creosote bush. Moreover, creosote bush

was able to take advantage of wet periods through greater growth (Hereford et al. 2006). In desert environments, water availability and the timing of precipitation events have significant effects on annuals (Archer and Predick 2008, Ott et al. 2011), particularly annual invasives that are a larger proportion of the annual community during low rainfall years compared to high rainfall years (Brooks and Berry 2006). More often than not, temperature and precipitation interact to affect species distributions (Adams et al. 2009, Munson et al. 2011). For example, regional sagebrush (*Artemisia* spp.) distributions are best predicted by summer precipitation and temperature (Bradley 2010).



DMM July 2006

Figure 1.1. Mojave Desert Network conceptual model for dry systems. This model illustrates the interconnectedness of vegetation and soils and how vegetation and soil interact and are affected by other components of the ecosystem. Figure from Chung-MacCoubrey et al. (2008).

Biotic interactions, such as competition and parasitism, can also influence vegetation (Woodward 1987), particularly community composition and diversity. One well-known example of a biotic interaction in desert communities is nurse plants, an example of facilitation, where there are positive interactions among species (McAuliffe 1988, Flores and Jurado 2003, Gurevitch et al. 2006). Nurse plants provide a protected environment (e.g., higher water and fertility) for seedlings to establish and may play a critical role in shaping plant communities. White bursage (*Ambrosia dumosa*) has been found to “nurse” creosote bush. While creosote bush seedlings are primarily found under the canopy

of white bursage adults, white bursage seedlings are primarily found in the interspaces, away from other plants (McAuliffe 1988, Walker et al. 2001). Thus, the distribution and spread of creosote bush may be heavily dependent on the distribution of white bursage.

Because of the many factors that influence vegetation, monitoring vegetation change will provide us with information not only on how vegetation in the MOJN parks changes through time, but also on factors that are not directly monitored through a vital sign, such as biotic interactions. Since vegetation change is such an encompassing vital sign and with the important role of water in the MOJN parks, MOJN I&M decided to monitor vegetation found in two areas to address the vegetation change vital sign, upland and riparian. In this protocol, we describe the monitoring of upland communities only. We define uplands as all areas that are not riparian. Therefore, upland plant communities are defined as communities that are not associated with riparian areas. Vegetation associated with riparian areas is also of high management priority because of its association with rare water supplies, biodiversity, productivity, and high potential for disturbance; vegetation associated with water will be monitored as part of the Riparian Vegetation protocol (in development).

The MOJN parks encompass a wide range of upland plant communities, from saltbush (*Atriplex* spp.) and creosote bush communities at low elevations to bristlecone pine (*Pinus longaeva*) communities at the highest elevations. Given the large size of most of the MOJN parks and limitations of existing inventories (e.g., soils, vegetation) at most of the MOJN parks, financial and logistical constraints required that we focus on one plant community per park in order to have a reasonable sample size for each park. Moreover, representatives from the MOJN parks were interested in addressing questions and monitoring change within specific communities rather than vegetation as a whole (i.e., at a particular location or without a specific context). For this protocol, we focused on shrub communities because this physiognomic class is a major component of deserts (Gurevitch et al. 2006), represents a large proportion of the area of each park, and captures several focal communities (characterized by Joshua tree, creosote bush, and sagebrush) that are representative of and of interest to the parks.

1.1.2. Rationale for Soils Monitoring

One of the definitions for soil from the Soil Science Society of America is “The unconsolidated mineral or organic matter on the surface of the earth that has been subjected to and shows effects of genetic and environmental factors of: climate (including water and temperature effects), and macro- and microorganisms, conditioned by relief, acting on parent material over a period of time. A product-soil differs from the material from which it is derived in many physical, chemical, biological, and morphological properties and characteristics.” (<https://www.soils.org/publications/soils-glossary/>). This definition illustrates that many factors influence soils and how soils respond to changes in these factors are an important indicator of environmental change.

Vegetation and soils are tightly linked, as soils support vegetation and vegetation shapes soils from the parent materials. The plant species and types of vegetation in a particular area are heavily influenced by the soils of that area (Gurevitch et al. 2006), possibly leading to endemic communities (e.g., plant communities on serpentine outcrops). In arid areas, like the Mojave Desert, endemic species and unique assemblages of plants can be found on gypsum soils (Meyer 1986). The soils in the different MOJN parks are under a variety of stressors, including nitrogen deposition, trampling

(e.g., human, exotic large animals), and climate change (e.g., changes in the amount and timing of precipitation), the effects of which may vary by park but can have widespread effects on plant communities. Monitoring soil changes in upland communities will provide important data that will contribute to our understanding of changes that are observed in upland plant communities.

Biota, including living organisms and vegetation, is one of the five important factors for soil formation and plays a critical role in building soil (Jenny 1941, Dubbin 2001). Vegetation protects the soil surface from disturbance and facilitates the input of organic materials to the soil. Clays form from the weathering of primary minerals. Once organic matter begins to accumulate, biological activity by decomposers increases, leading to the decay and incorporation of organic matter into the upper few centimeters of soil and some soluble ions, such as Ca^{2+} , are moved downward. With more time, additional organic matter accumulates and moves deeper into the soil. When weathering products are removed, more weathering occurs and the soil profile becomes increasingly acidic. Eventually, the soil is depleted of the basic cations, Ca^{2+} , Mg^{2+} , K^{+} , and Na^{+} .

The type of vegetation found on soil has a huge effect on the properties of the soil associated with it. For example, the physical and chemical characteristics of forest and adjacent prairie soils in the midcontinent of the United States have been compared and found to differ in a predictable and consistent manner (Ugolini and Edmonds 1983). Although prairie and forest soils contain comparable amounts of organic matter, prairie soils have thinner organic horizons at the surface, higher clay contents at the surface, organic matter distributed to greater depths, and are less acidic. Nitrogen concentrations in forest and prairie soils follow the same trend as the organic matter; nitrogen is mostly concentrated at the surface in forest soils, but reaches greater depths in the prairie, owing to the differing distribution of biomass in forests (mostly aboveground) and prairies (extensive root systems belowground; Caldwell and Richards 2005).

In desert systems, vegetation effects can include biological soil crusts (BSC), which occur in the top 1 to 4 mm of the soil, can comprise over 70% of the living ground cover, and are an important source of organic matter for soils. The main components of soil crusts are cyanobacteria, bryophytes, and lichens. BSC cover most soil spaces in deserts not occupied by vascular plants (Belnap 2001). Large scale disturbance of BSC threatens ecosystem integrity by increasing soil loss (erosion/dust), increasing the rate of water loss, and reducing soil fertility, all of which may alter vegetation and soil properties.

In terrestrial ecosystems, soils are responsible for performing five important functions (Dubbin 2001, Brady and Weil 2004). Namely, soils:

- 1) act as a medium for plant growth, providing physical support and an anchor for root systems, resources for growth, and facilitates the exchange of gases between roots and the above-ground atmosphere.
- 2) are a habitat for a multitude of organisms and harbors much of the earth's genetic diversity (i.e., microbes and insects).

- 3) play a vital role in the breakdown and recycling of nutrients, plant and animal wastes, and in the major geochemical cycles. For example, soils have the capacity to assimilate large quantities of organic waste, converting the waste into nutrient forms that may be used by plants and animals or act as a nutrient sink and sequester recalcitrant materials (e.g., carbon-rich biomass).
- 4) regulate water quality since nearly all of the water that ends up in streams, rivers, and lakes is modified as it passes over or through soil. Contaminated water that percolates through the upper layers of soil may be cleansed by a variety of soil processes that remove impurities and destroy disease bearing organisms. Conversely, clean water passing through contaminated soil may become contaminated.
- 5) are important as an engineering material since most structures rest on soil.

Given especially the first four functions, it is not surprising that five of the MOJN I&M vital signs pertain to soils: soil erosion and deposition, soil chemistry and nutrient functioning, soil hydrologic function, soil surface disturbance, and biological soil crusts.

1.1.3. Rationale for Invasive Plants Status and Trends Monitoring

National Parks are constantly deluged by new non-native plants arriving through a variety of pathways. Non-native plants invade an estimated 1,862 ha (4,600 ac) of public lands each day in the United States (Asher and Harmon 1995) and significantly alter local flora. Nearly one-third of NPS lands in the lower 48 states plus Hawaii have been invaded (Westbrooks 1998). For the NPS, non-native plant invasions present a significant challenge to the agency's ability to maintain natural resources "unimpaired for the enjoyment of future generations." The invasive plant species vital sign was ranked third out of 20 vital signs, reflecting the magnitude and extensive effects of non-native invasive species on park communities.

We use the definition of invasive plant species proposed by Cronk and Fuller (1995), "An alien plant spreading naturally (without direct assistance of people) in natural or semi-natural habitats, to produce a significant change in terms of composition, structure or ecosystem processes." For a species to be considered as non-native (i.e., alien), large-scale geographic barriers (e.g., oceans, mountain ranges) must generally be overcome, usually with the help of humans (Invasive Species Advisory Committee 2006). We use the USDA Plants database (<http://plants.usda.gov/java/>) to establish whether a species is native or non-native to North America. With temporal changes in climate, species experience natural range expansions or contractions in response to changing environmental conditions (Graham and Grimm 1990, Davis and Shaw 2001), and species from neighboring ecoregions may move into MOJN parks. We do not consider species with this "natural" range expansion or contraction to be non-native and, thus, they are not considered invasive species.

For this protocol, we focus on the **status and trends** (S&T) of well-established invasive plant species rather than species that are incipient, or establishing, in the MOJN parks (see *MOJN I&M SOP M2 - Prioritizing Invasive Species for Status and Trends Monitoring* for more details). Invasive

species population growth can be described by four phases of invasion (Williamson 2006, Theigardues and Dukes 2007, Brooks and Klinger 2009; Figure 1.2), specifically:

1. *Colonization phase*: When a plant species is very rare, isolated, or does not currently inhabit parks. If a species has been found in parks, it is extremely isolated (one or two occurrences) and has been actively treated or eradicated.
2. *Establishment phase*: When a plant species is isolated, but has had multiple (three or more) occurrences within parks and typically has had repeated escapes and treatments (i.e., populations are small but persistent).
3. *Spread phase*: When a plant species is becoming widespread (growing exponentially) within park boundaries.
4. *Equilibrium phase*: When a plant species has reached an equilibrium point and has widespread stable populations.

Species in the first two phases are considered incipient invasive species and will be monitored under a separate protocol, Invasive Species – Early Detection (in development). Invasive species that are in the spread and equilibrium phases, and generally no longer managed for eradication, will be considered for S&T monitoring as part of this protocol and/or the Riparian Vegetation protocol, depending on which community they occur in (Appendix A).

Although incipient invasive species receive most of the management attention due to the potential for successful control, it is also important to understand the current status of established invasive species, even if little direct management action can be taken. In 2002, the National Research Council thoroughly reviewed the state of knowledge on invasions, including predicting introductions and establishment. One of their key recommendations for furthering knowledge and preventing invasions was that “...careful recording of the circumstances of arrival, persistence, and invasion of non-indigenous species in the United States would substantially improve prediction and risk assessment.” (National Research Council 2002). Understanding the trajectory of established invasive species can help us to prevent other species from taking similar trajectories to widespread establishment.

Established invasive species negatively affect park resources and visitor enjoyment by altering landscapes and fire regimes, reducing native plant and animal habitat, and diminishing park aesthetics. Invasive species are second only to habitat loss as threats to global biodiversity (Wilcove et al. 1998) and are recognized as a major component of human-induced global change (Vitousek et al. 1997). Annual invasives, such as red brome (*Bromus rubens*) and cheatgrass (*Bromus tectorum*), are not only displacing native plants (see DeFalco et al. 2003, Salo et al. 2005), but also altering ecological processes associated with fire, which was previously uncommon in desert regions, by creating larger and more frequent wildfires (D’Antonio and Vitousek 1992, Brooks and Matchett 2006). Slow growing and long-lived native desert plants, such as blackbrush (*Coleogyne*

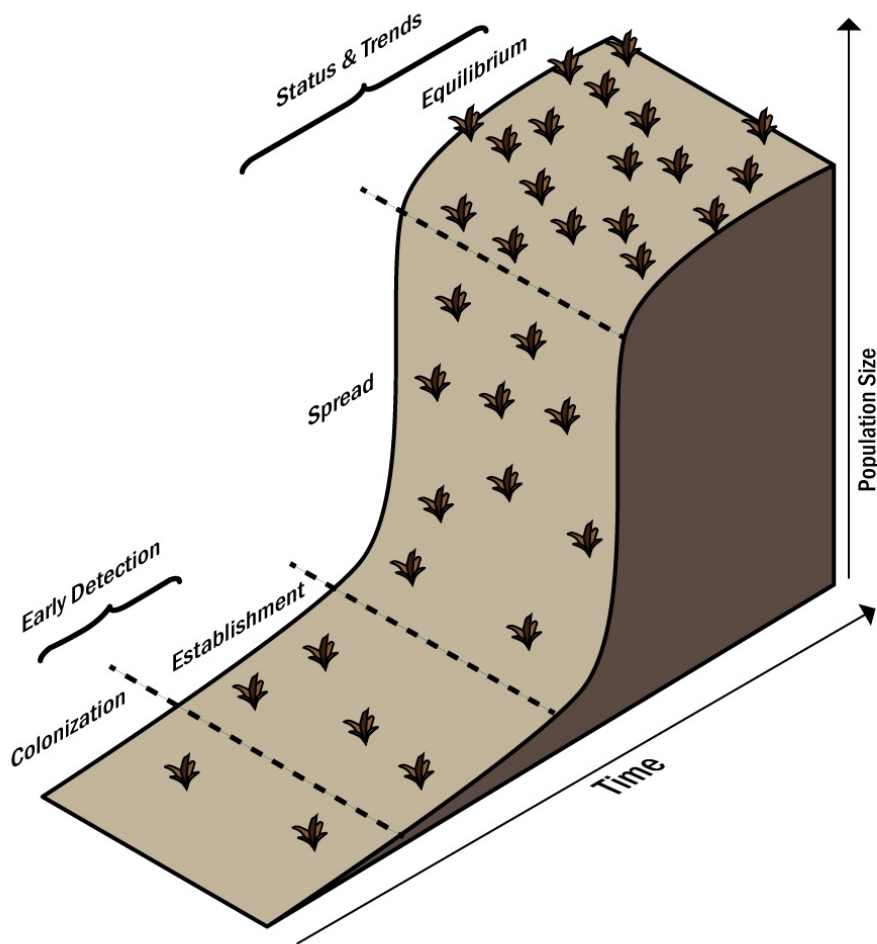


Figure 1.2. Conceptual model indicating the phases of invasion in relation to the logistic population growth curve. Invasive species in colonization and establishment phases are candidates for Early Detection monitoring while species in the spread and equilibrium phases are candidates for S&T monitoring. Adapted from Klinger and Brooks (2008).

ramosissima), are generally not adapted to wildfires and, thus, may be incapable of persisting in areas susceptible to a grass-fire cycle (Callison et al. 1985, Minnich 1995, Lei 1999). Other plant species commonly found in the Mojave Desert, i.e., Joshua trees (*Yucca brevifolia*) and creosote bush (*Larrea tridentata*), may also be similarly negatively affected by changing fire cycles (Brown and Minnich 1986, Minnich 1995). A disturbing finding is that many annual invasive species, such as red brome, Mediterranean grass (*Schismus* spp.), and redstem filaree (*Erodium cicutarium*), are found in areas considered relatively undisturbed by humans (Burgess et al. 1991, Brooks 1998, Craig et al. 2010), suggesting that upland communities in arid lands are not as immune to invasion as previously thought (Loope et al. 1988).

1.2. Objectives

The overarching programmatic goals of the MOJN I&M program are to obtain and provide data on selected vital signs that will (Chung-MacCoubrey et al. 2008):

- 1) allow managers to make better-informed decisions and work more effectively with other agencies and individuals for the benefit of park resources.
- 2) provide early warning of abnormal conditions of park resources and contribute to the development of effective mitigation measures that will reduce costs of management.
- 3) provide data to better understand the dynamic nature of park ecosystems and for comparisons with other, altered environments.
- 4) furnish data to meet certain legal and congressional mandates related to natural resource protection and visitor enjoyment.
- 5) offer a means of measuring progress toward performance goals.

Monitoring data are intended to detect long-term environmental change, provide insights into the ecological consequences of change, and help decision-makers determine if observed changes necessitate a change in management practices. In order to achieve this goal, protocols and data collected on the different vital signs need to be integrated to provide a more comprehensive understanding of park ecosystems (see section 1.5 *Potential Integration with Other Protocols*).

Specific monitoring objectives for vital signs and protocols were developed as *monitoring questions* that identify conceptual and management issues. *Measurable objectives* link the monitoring questions to data collection. The monitoring questions and measurable objectives for the Integrated Upland protocol are presented below.

1.2.1. Monitoring Questions

The Integrated Upland (IU) protocol was designed to address seven of MOJN I&M's 20 vital signs. These vital signs are addressed by considering the following questions (vital sign):

- 1) How is structure and composition of vegetation changing over time in network parks? (*vegetation change*)
- 2) How are soil surface properties, chemistry, and hydrologic function changing over time? (*soil surface disturbance, soil erosion and deposition, soil chemistry and nutrient functioning, soil hydrologic function*)
- 3) How are the abundance, structure, and composition of biological soil crusts (BSC) changing over time? (*biological soil crusts*)
- 4) What relationships are observed between soil properties, invasive species, and plant community characteristics? (*invasive plants*)

1.2.2. Measureable Objectives

In light of the monitoring questions and broader goals outlined above, this protocol will address the following corresponding measurable objectives in upland shrub communities (example of measures):

- 1) Determine trends in shrub species and life form composition, structure, and relative abundance. (*% cover by shrub species and life form, species composition, life form composition*)
- 2) Determine status and trends in soil chemistry, the magnitude and extent of soil erosion and surface disturbance, and soil hydrologic function. (*soil pH, compaction, basal gaps*)
- 3) Determine status and trends in abundance and composition of biological soil crust (BSC). (*presence, % cover, and types of BSCs*)
- 4) Determine status and trends in distribution, phenology, and abundance of targeted invasive plant species. (*% cover, frequency, and distribution of targeted invasive species*)

1.3. Overview of the MOJN Parks

Seventeen percent of all terrestrial lands are classified as arid, with the four arid deserts of North America (Chihuahuan, Great Basin, Mojave, and Sonoran) making up 10% of the arid lands (Smith et al. 1997). Arid regions receive from 0 to 150 mm/year of precipitation and any precipitation that is gained is generally lost through evaporation. The North American deserts can be described as either “cold” deserts (i.e., Great Basin), where average temperatures are below freezing during the winter and a significant portion of the precipitation is in the form of snow, or “warm” deserts (i.e., Chihuahuan, Mojave, Sonoran) that are above freezing in the winter and receive precipitation mostly as rain. The MOJN parks fall within three contiguous semi-arid desert ecosystems, from the Great Basin Desert in the north, to the Mojave Desert, and then to the Sonoran Desert in the south.

The dry desert environment of most of the MOJN area is formed as a consequence of the winter rain shadow effect from the Sierra Nevada and the Transverse mountain ranges. This rain shadow is formed because the moist air masses travel eastward from the Pacific Ocean, rise, cool, and drop the bulk of their moisture load as rain or snow once they encounter mountain ranges, resulting in very little moisture falling on the far, or east, side of the mountain ranges. The precipitation pattern of the western side of the Mojave Desert is dominated by this cool season precipitation (i.e., most precipitation falls during winter precipitation events), while the eastern side of the Mojave Desert has a bimodal distribution, being affected by both winter and summer precipitation (Hereford et al. 2004). In contrast to winter precipitation events, summer precipitation (monsoon) events originate from the south and generally take the form of thunderstorms that drop a large amount of rain in a very short period of time. Even though summer precipitation can be substantial (averaging 29% for the eastern Mojave), the less intense winter precipitation events play a more critical role in the Mojave Desert ecosystem in terms of water availability, as rainfall events are widespread and longer in duration.

The seven MOJN park units are spread across three states, Arizona, California, and Nevada (Figure 1.3), and encompass over 3.3 million ha (>8.3 million ac) of land (Table 1.1). From north to south,

there is a gradient of increasing temperature and decreasing elevation across these deserts. GRBA and the northern part of DEVA are located within the high-elevation cold desert environment of the Great Basin, while the other parks are located southward, in the warm desert environments. MANZ sits at the intersection of the Great Basin Desert, Mojave Desert, and eastern Sierra Nevada Mountains, and is an interesting mix of all three of ecosystems. JOTR includes part of the transition between the Mojave and Sonoran deserts, with the western part of the park (>915 m or 3000 ft) part of the Mojave Desert and the eastern part of the park (<915 m or 3000 ft) the Sonoran Desert (the California extension of the Sonoran desert is referred to as the Colorado Desert). LAKE is primarily Mojave Desert, but sections of the eastern part of the park are part of the Colorado Plateau. PARA sits on the eastern part of the Mojave Desert and transitions from the basin and range country to the Colorado Plateau; the central and eastern parts of PARA are Great Basin Desert and, thus, have plant communities that are representative of cold desert environments.

The uniqueness of each of the MOJN parks is reflected in their individual mission statements (Table 1.2). Park histories and specific park descriptions are provided in the next sections.



Figure 1.3. The seven parks of the Mojave Desert Network (MOJN).

Table 1.1. Area and elevation of Mojave Desert Network parks.

Park Name	Abbreviation	Area	Elevation Range
Death Valley National Park	DEVA	1,374,420 ha (3,396,266 ac)	-86 to 3,368 m (-282 to 11,050 ft)
Great Basin National Park	GRBA	31,194 ha (77,082 ac)	1,615 to 3,981 m (5,299 to 13,061 ft)
Joshua Tree National Park	JOTR	321,327 ha (794,016 ac)	153 to 1,772 m (502 to 5,814 ft)
Lake Mead National Recreation Area	LAKE	607,028 ^b ha (1,500,000 ac)	152 to 1,719 m (499 to 5,640 ft)
Manzanar National Historic Site	MANZ	329 ha (813 ac)	1,158 m (3,799 ft)
Mojave National Preserve	MOJA	619,923 ha (1,531,863 ac)	274 to 2,438 m (899 to 7,999 ft)
Grand Canyon-Parashant National Monument	PARA	424,242 ^a ha (1,048,321 ac)	366 to 2,447 m (1,201 to 8,028 ft)
Total		3,378,463 ha (8,348,365 ac)	-86 to 3,981 m (-282 to 13,061 ft)

^a Total size of PARA includes 84,358 hectares (208,453 ac) of NPS-owned land, 327,288 hectares (808,746 ac) of BLM-managed lands, and 12,595 hectares (31,123 ac) of non-federal lands.

^b Area of administrative boundary.

Table 1.2. Mission Statements for Mojave Desert Network parks.

Park Name	Park Mission Statement ^a
Death Valley National Park (DEVA)	Death Valley National Park dedicates itself to protecting significant desert features that provide world class scenic, scientific, and educational opportunities for visitors and academics to explore and study.
Great Basin National Park (GRBA)	The mission of Great Basin National Park is to preserve for the benefit, inspiration, and enjoyment of present and future generations a representative segment of the Great Basin of the western United States and to promote an understanding of the natural and cultural heritage of the entire physiographic region.
Joshua Tree National Park (JOTR)	The National Park Service at Joshua Tree National Park preserves and protects a representative area of the Colorado and Mojave deserts and the natural and cultural resources for the benefit and enjoyment of present and future generations. The park includes rich biological and geological diversity, cultural history, recreational resources, and outstanding opportunities for scientific study.
Lake Mead National Recreation Area (LAKE)	We provide diverse inland water recreational opportunities in a spectacular desert setting for present and future generations.
Manzanar National Historic Site (MANZ)	Manzanar National Historic Site dedicates itself to protecting the physical remnants of the internment camp and telling the story of the internment of over 110,000 individuals of Japanese ancestry during World War II in an accurate and balanced way that represents diverse viewpoints and beliefs.
Mojave National Preserve (MOJA)	Mojave National Preserve was established to preserve outstanding natural, cultural, and scenic resources while providing for scientific, educational, and recreational interests.
Grand Canyon-Parashant National Monument (PARA)	Grand Canyon-Parashant is a model of land management for the BLM and NPS that conserves its natural, scientific, and historic resources and includes ecological restoration and protection in a broad ecosystem context, while honoring the history and living traditions of the people who came before us: "the place where the west stays wild."

^a Mission statements obtained from park General Management Plans (NPS 1992, 1995, 1996, 1999b, 2002a, 2002b, 2008b).

1.3.1. Death Valley National Park (DEVA)

Death Valley National Monument was established in 1933 by Presidential Proclamation from President Herbert Hoover, “Whereas it appears that the public interest would be promoted by including certain lands known as Death Valley, in California, within a national monument of the preservation of the unusual features of scenic, scientific, and educational interest therein contained” (No. 2028-Feb. 11, 1933-47 Stat. 2554). Death Valley National Monument was enlarged in 1937, when President Franklin Roosevelt signed a supplementary Presidential Proclamation (No. 2228-50 Stat.1823) increasing its size from 648,226 ha (1,601,800 ac) to 836,806 ha (2,067,793 ac). In 1952, President Harry S. Truman further enlarged the monument by adding Devil’s Hole (16 ha or 40 ac), which is home to the endangered Devil’s Hole pupfish (*Cyprinodon diabolis*), through an additional Presidential Proclamation (No. 2961). Devil’s Hole is located in Nye County, Nevada, and is disjunct from the rest of the monument (Unrau 1997, NPS 2002a; not shown on Figure 1.4). In 1984, Death Valley National Monument became part of the UNESCO Man and Biosphere Program as the main feature of the Mojave and Colorado Desert Biosphere Reserve.

Death Valley National Monument became Death Valley National Park in 1994 as part of the California Desert Protection Act (PL 103-433); it was one of the three NPS units established as part of the Act. As part of its establishment, ~510,000 ha (1.27 million ac) were added to DEVA, bringing it to almost 1.37 million ha (3.4 million ac), most of which is designated wilderness (Figure 1.4), making it the largest park in the lower 48 states (Figure 1.3). Today, DEVA includes all of Death Valley, which is 156-mile-long and formed between two major mountain ranges, the Amargosa Range on the east and the Panamint Range on the west, and the Saline, Eureka, northern Panamint, and Greenwater valleys (Figure 1.4). Death Valley is located in the transition zones between the Mojave Desert, the Great Basin, and the Whites and Inyo portion of the Sierra Nevada Range. The lowest point in North America is found in DEVA (Badwater, -86 m below sea level), which is also the base for the greatest elevation gradient in the contiguous United States. DEVA’s wide diversity of habitats, including sand dunes, desert scrub, pinyon-juniper forests, bristlecone pine forests, sagebrush shrubland, springs, riparian corridors, marshes and subterranean pools, are home to over 1,200 native plant species, including fifty locally and regionally endemic species that have adapted to DEVA’s unique and varied environment (NPS 2002a).

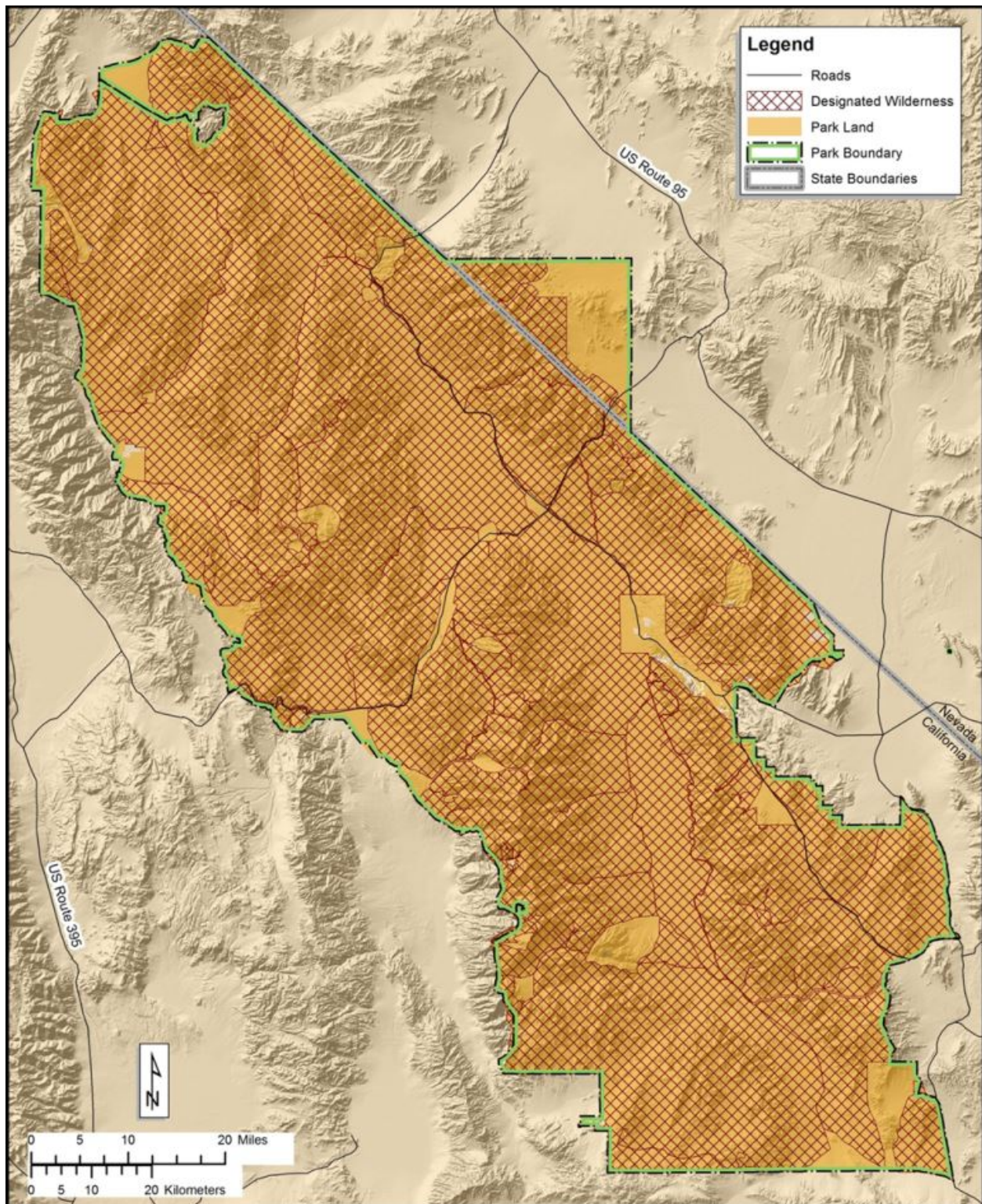


Figure 1.4. Map of Death Valley National Park showing wilderness areas. Devil's Hole is not shown.

1.3.2. Great Basin National Park (GRBA)

In 1922, Lehman Caves National Monument was established by Presidential Proclamation (No. 1618; 42 Stat. 2260) signed by President Warren G. Harding. Lehman Caves is one of the largest limestone solution caverns in the western United States and the national monument was a 240 ha (593 ac) parcel surrounding the entrance to Lehman Caves, carved out from the then Nevada National Forest. Lehman Caves National Monument was initially administered by the Forest Service (Department of Agriculture) and transferred to the NPS in 1933, during a major federal government reorganization. Lehman Caves National Monument and much of the surrounding South Snake Range were designated as Great Basin National Park in 1986, the nation's 49th national park, when President Ronald W. Reagan signed Public Law 99-565 (100 Stat. 3181), or the "Great Basin National Park Act of 1986" (Unrau 1990). The purpose of the park was "to preserve for the benefit and inspiration of the people a representative segment of the Great Basin of the Western United States possessing outstanding resources and significant geological and scenic values."

Unlike the rest of the MOJN parks, GRBA lies wholly in the Great Basin Desert region. It is a mountainous park as its 31,161 ha (77,000 ac) encompasses the rugged South Snake Range (Figure 1.5), an elongated north-south trending range bounded on the west by Spring Valley and on the east by Snake Valley, located in central eastern Nevada (Figure 1.3). The boundaries of GRBA are contiguous with BLM lands managed by the Ely, NV, district office. Besides Lehman Caves, another major feature of GRBA is Wheeler Peak (3,982 m; 13,063 ft), the highest point in the Snake Range and second highest peak in Nevada, where the only glacier in Nevada is found. The extreme elevational changes in GRBA lead to a variety of different habitats, ranging from sagebrush communities at lower elevations to alpine/subalpine communities at high elevations. GRBA also contains some of the largest known groves of bristlecone pines, one of the oldest known living organisms, reaching more than 4,900 years old.

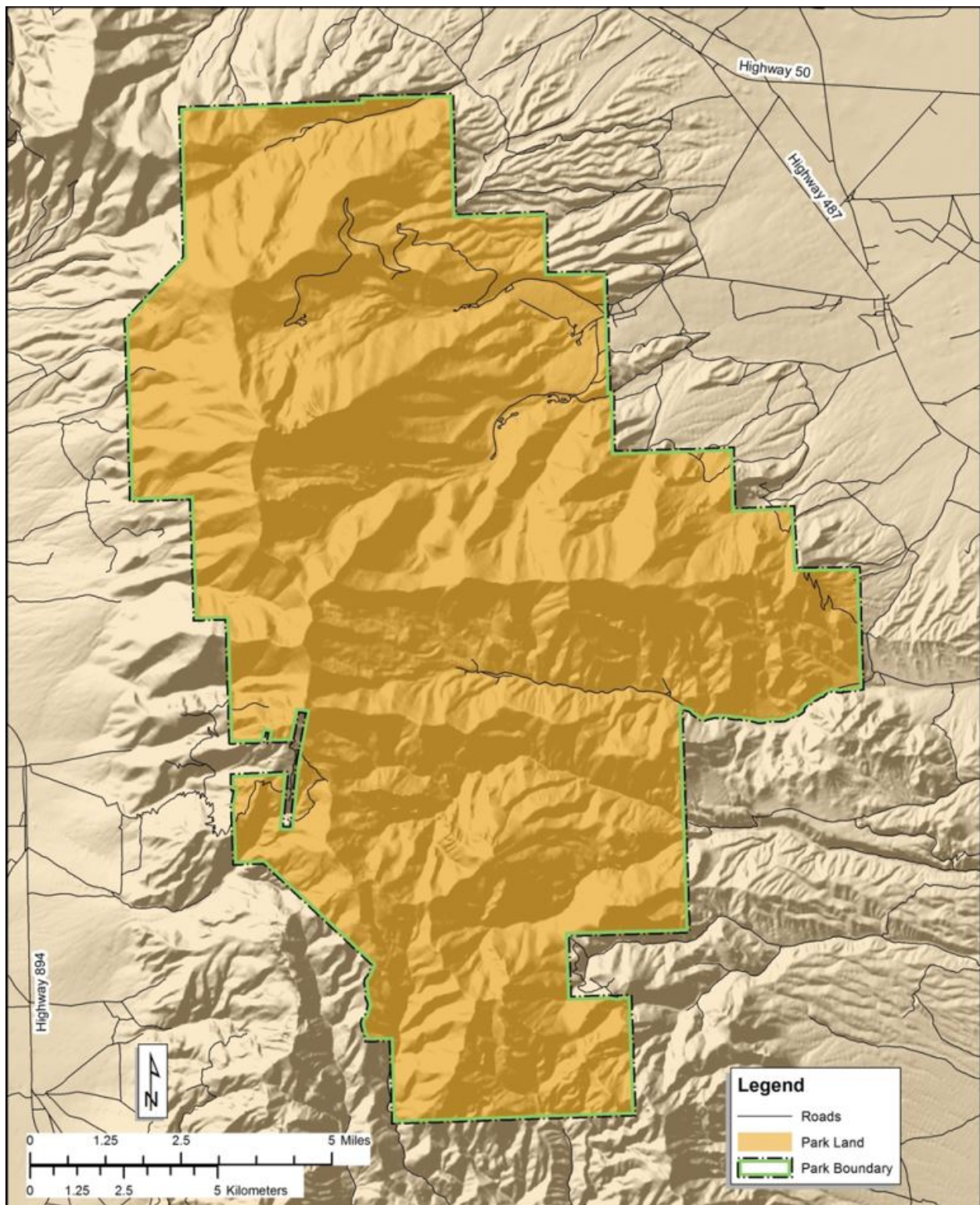


Figure 1.5. Map of Great Basin National Park.

1.3.3. Joshua Tree National Park (JOTR)

Joshua Tree National Monument was established in 1936 through a Presidential Proclamation (No. 2193 50 Stat. 1760) by President Franklin D. Roosevelt because its "lands contain historic and prehistoric structures and have situated thereon various objects of historic and scientific interest". Originally, 334,003 ha (825,340 ac) was set aside as Joshua Tree National Monument to preserve an ecologically dynamic region of the California Desert, a transition zone between the Colorado and Mojave deserts (NPS 1999c). However, the size of the monument was reduced by 117,156 ha (289,500 ac) (PL 837, 64 Stat. 1033) by Congress in 1950 in order to allow for mining on former monument lands (i.e., Eagle and Pinto Mountains). In 1950, the Twentynine Palms Corporation donated the Oasis of Mara (~24 ha or 58 ac) to the monument, which was authorized by Congress in 1961, as a detached unit for the purpose of administrative and visitor center facilities. In 1984, Joshua Tree National Monument, along with Death Valley National Monument, became part of the UNESCO Mojave and Colorado Desert Biosphere Reserve.

Joshua Tree National Monument became Joshua Tree National Park in 1994, as one of three NPS units established as part of the California Desert Protection Act (PL 103-433). As part of JOTR's establishment, 94,696 ha (234,000 ac) were added, bringing the park to over 319,702 ha (790,000 ac), of which almost 75% is designated wilderness (Figure 1.6). Currently, the western boundary of the park lies along the Little San Bernardino Mountains, part of the Transverse ranges, the southern edge along the base of the mountains that form the north perimeter of the Coachella Valley, the eastern edge includes the Coxcomb Mountains, and the Morongo Basin defines the north boundary (NPS 1995). The major valleys in JOTR include the Pinto Basin, Juniper Flats, Covington Flats, Pleasant, Queen, and Lost Horse. With the compressed transition zone between the Mojave Desert (on the western side of the park) and the Colorado Desert (on the eastern side of the park) at JOTR, it is possible to cross from one desert to the next in less than 65 miles. Creosote bush (*Larrea tridentata*), ocotillo (*Fouquieria splendens*), and palo verde (*Cercidium floridum*) dominate the Colorado desert portion of JOTR, while the famous Joshua tree stands (*Yucca brevifolia* var. *brevifolia*) occupies the Mojave Desert part of the park. The western part of the park is higher than the eastern part of the park, averaging 1,219 m (4,000 ft) to 610 m (2,000 ft) above sea level, respectively, and is slightly cooler and wetter. JOTR is well known for its five fan palm oases, an unusual feature in desert systems (NPS 1999c).

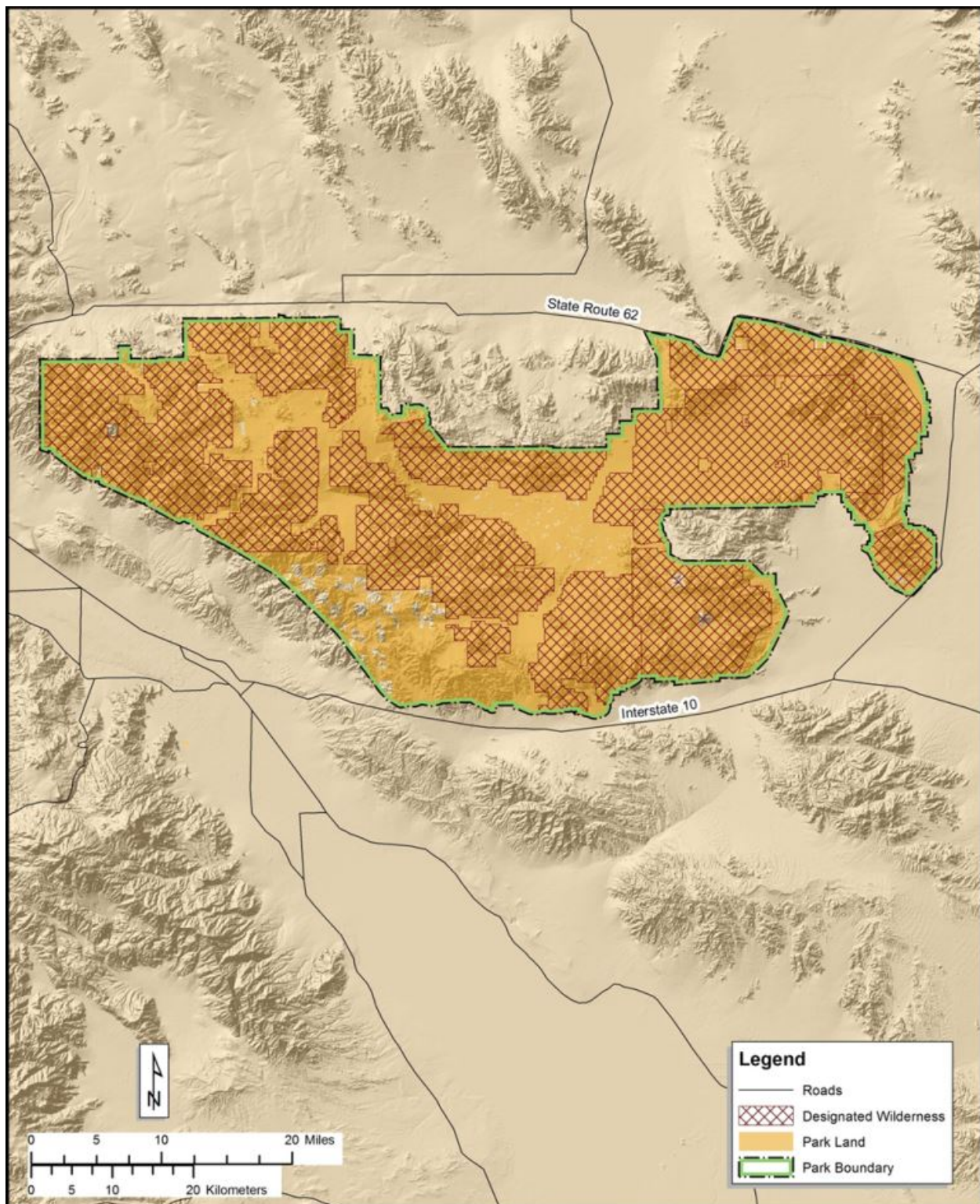


Figure 1.6. Map of Joshua Tree National Park showing wilderness areas.

1.3.4. Lake Mead National Recreation Area (LAKE)

Lake Mead formed as a consequence of the damming of the Colorado River by Hoover Dam in 1935 (U.S. Bureau of Reclamation 2004). While the Bureau of Reclamation maintained control of the dam, power plant, and reservoir, NPS was brought in to administer and develop recreational facilities along the lake and surrounding land that was part of the Reclamation withdrawal through a memorandum of agreement in 1936. This unit along the lake was named the “Boulder Dam Recreation Area”. In 1947, the recreation area was enlarged through the addition of the proposed Lake Mohave, which was to be formed after the completion of Davis Dam (in 1951), near Laughlin, NV. In 1964, Boulder Dam Recreation Area officially became a unit of the NPS when President Lyndon Johnson signed an act (Public Law 88-639; 78 Stat. 1039) establishing the area as the Lake Mead National Recreation Area for “the general purpose of public recreation, benefit and use, and in a manner that will preserve, develop, and enhance ... the recreation potential, and in a manner that will preserve the scenic, historic, scientific, and other important features of the area ...” (NPS 1994). LAKE supports a diversity of water based recreation for over eight million visitors per year and is among the premier inland water recreation areas in the West.

The boundaries of LAKE have changed since its establishment in 1964, with the Grand Canyon part of the recreation area transferred to Grand Canyon National Park and the Shivwits Plateau portion becoming part of the Grand Canyon-Parashant National Monument. Today, LAKE is the 4th largest NPS unit in the continental US with an administrative boundary of nearly 607,000 ha (1.5 million ac), 60% of which is in AZ and 40% in NV, with almost 27,316 ha (67,500 ac) of designated wilderness (Figure 1.7; NPS 2010b). It is bounded on the north by the town of Overton, NV, the Virgin Mountains, and PARA, on the east by Grand Canyon National Park, PARA, and the Black Mountains, on the south by Bullhead City, AZ, and Laughlin, NV, and on the west by Boulder City, NV, the Eldorado Mountains, and Newberry Mountains. In addition to Lakes Mead and Mohave, major features of LAKE include the Black Canyon, Boulder Canyon, Fortification Hill, Newberry Mountains, Black Mountains, Pinto Valley, and Redstone.

A majority of LAKE is part of the Mojave Desert, but sections of the eastern part of the park are part of the Colorado Plateau, with the Grand Wash Cliffs delimiting the Mojave Desert section from the Colorado Plateau. Moreover, the northern range of a number of Sonoran Desert plant species are along the southern tip of LAKE, making areas like the Newberry Mountains particularly diverse. The Colorado River’s former channel and associated lake shoreline, in combination with the park’s desert springs, form some of the most expansive areas of desert riparian community, one of the Southwest’s most threatened habitats. The park supports significant populations of approximately 100 species of special concern and species at the limits of their distributional range, due in large part to these rare, riparian communities (Chung-MacCoubrey et al. 2008). As water levels in Lake Mead drop due to increased water demand and numerous drought years, more land is exposed. Consequently, the dry-land acreage of LAKE is increasing. While some areas of the newly exposed lands become riparian habitats and areas of emergent vegetation, the great majority of the newly exposed areas tend to be colonized by invasive plants. This results in a major management threat across the park (NPS 2010b).

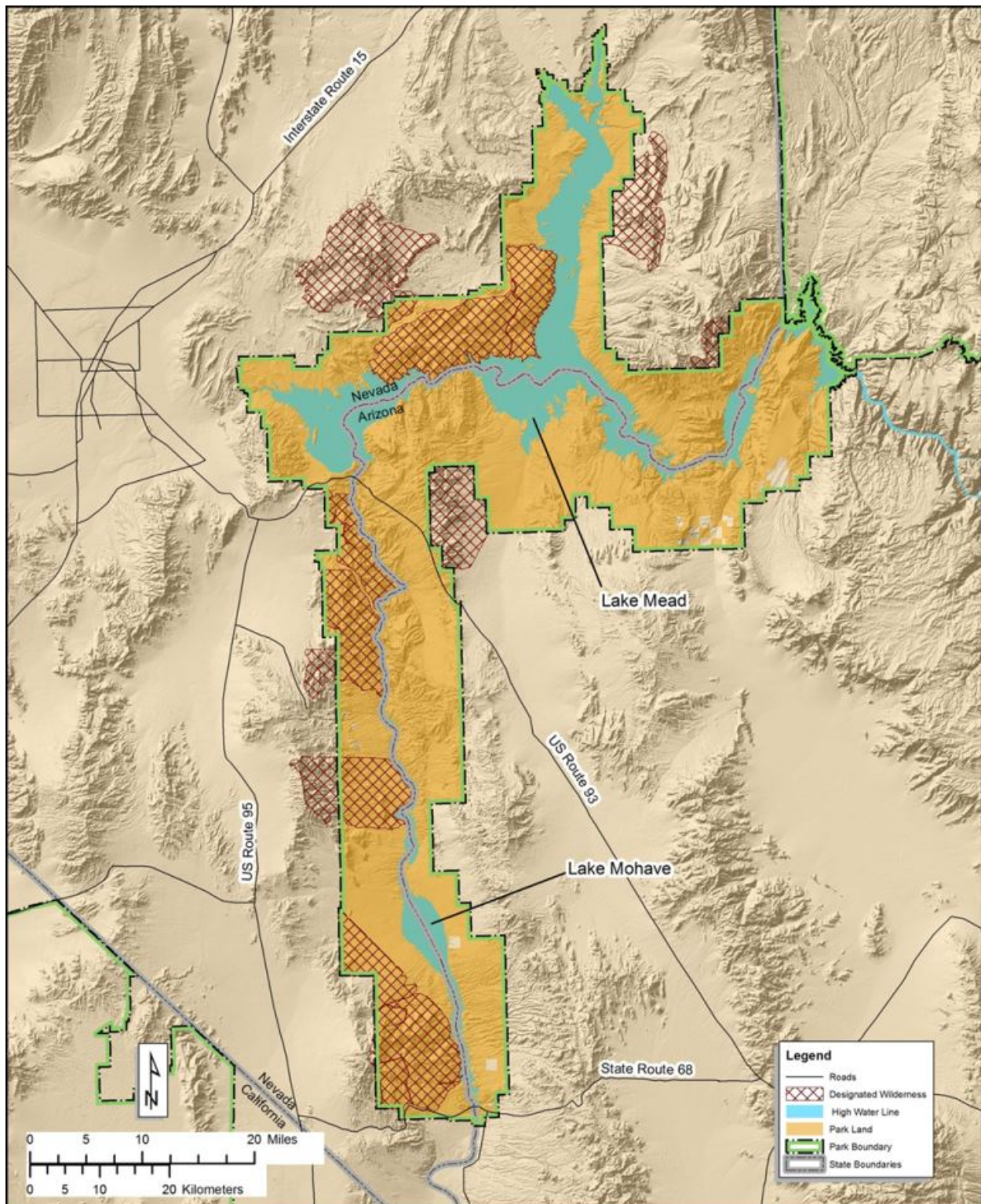


Figure 1.7. Map of Lake Mead National Recreation Area showing wilderness areas.

1.3.5. Manzanar National Historic Site (MANZ)

Manzanar National Historic Site was established in 1992 when President George H. W. Bush signed Public Law 102-248 (106 Stat. 40). The park was established to “provide for the protection and interpretation of the historical, cultural, and natural resources associated with the relocation of Japanese- Americans during World War II...” Manzanar was one of 10 War Relocation Centers established during WWII to confine persons of Japanese descent residing on the west coast as a security measure against sabotage and espionage. Manzanar was selected as the first representative of the War Relocation Centers because it was determined to be the best preserved, as it still had two small rock sentry posts located at the historic entrance near Highway 395, a large wood-frame auditorium built by the internees, the foundations of many buildings, the remaining gridwork of the center's road system, numerous landscape plantings, and the remains of many of the rock gardens built by the internees. In addition to representing the Japanese internment period, MANZ would also interpret the earlier historic eras of the area, such as Native American use and pioneer ranching and farming in the area, including the early twentieth century agricultural village of Manzanar (NPS 1996).

The original Manzanar War Relocation center consisted of 2,509 ha (6,200 ac) leased from the Los Angeles Department of Water and Power (LADWP), which included outlying acreage for agricultural production, a reservoir, and water and sewage treatment plant facilities. Today, MANZ consists of 329 ha (814 ac) that were acquired from LADWP when the National Historic Site was established (Figure 1.8). It includes the administrative area, camp cemetery, camouflage net factory, and experimental plantation for producing natural rubber from the guayule plant. MANZ is located near the valley floor of the Owens Valley (~1,158 m or 3,800 ft), at the eastern base of the Sierra Nevada in eastern California, and the northwestern edge of the Mojave Desert (Figure 1.3; NPS 1996). In the rain shadow of the Sierra Nevada mountains, MANZ predominantly experiences a high-desert type climate, with extreme temperatures, high winds, and severe dust storms. Accordingly, the predominant plant community of the area is Great Basin sagebrush scrub, characterized by sagebrush, saltbush, and rabbitbrush (*Ericameria* spp.).

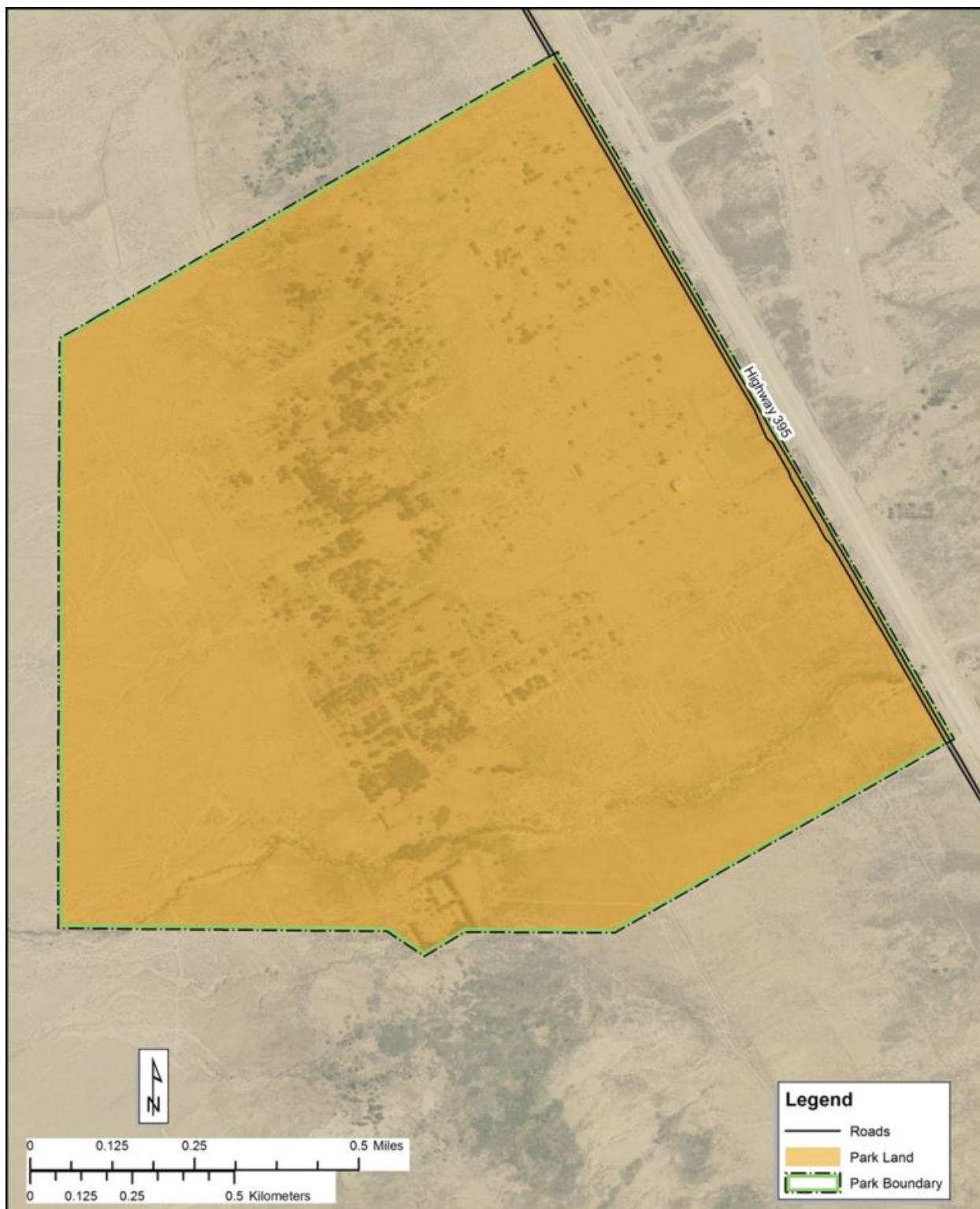


Figure 1.8. Map of Manzanar National Historic Site.

1.3.6. Mojave National Preserve (MOJA)

Mojave National Preserve was the third park unit established by the 1994 California Desert Protection Act (PL 103-433), at which time the former “East Mojave National Scenic Area”, administered by the BLM, was transferred to the NPS and renamed. Although DEVA and JOTR were representatives of the Mojave Desert region, MOJA was established because the previous two parks “do not embrace the particular ecosystems and transitional desert type found in the Mojave Desert area lying between them on public lands now afforded only impermanent administrative designation as a national scenic area”; MOJA protects a significant portion of the eastern Mojave Desert (Nystrom 2003).

MOJA is the third largest national park unit in the continental United States, at nearly 647,000 ha (1.6 million ac; Figure 1.3), ~44% of which is designated wilderness (Figure 1.9). The boundaries of MOJA on the north and south are major interstate highways, I-15 and I-40, respectively, the Nevada–California state line on the east, and parts of the Union Pacific Railroad on the west. Major features of the preserve include Kelso Dunes, dry lakebeds and evidence of volcanic activity (domes, lava flows, cinder cones), a number of mountain ranges (e.g., Providence Mountains, New York Mountains, and parts of the disjunct Clark Mountains), and Cima Dome and Lanfair Valley, which have Joshua tree (*Yucca brevifolia* var. *jaegeriana*) woodlands that have the greatest known abundance of Joshua trees. While most of MOJA is part of the Mojave Desert, elements of the Great Basin and Sonoran deserts can also be found in the preserve at high elevations and along the southern border of the park, respectively. One of the most well-known species on the preserve is the desert tortoise (*Gopherus agassizii*), a species federally listed as threatened (NPS 2002b). The preserve contains prime habitat for the desert tortoise and approximately half of its lands have been designated Critical Habitat (NPS 2002b).

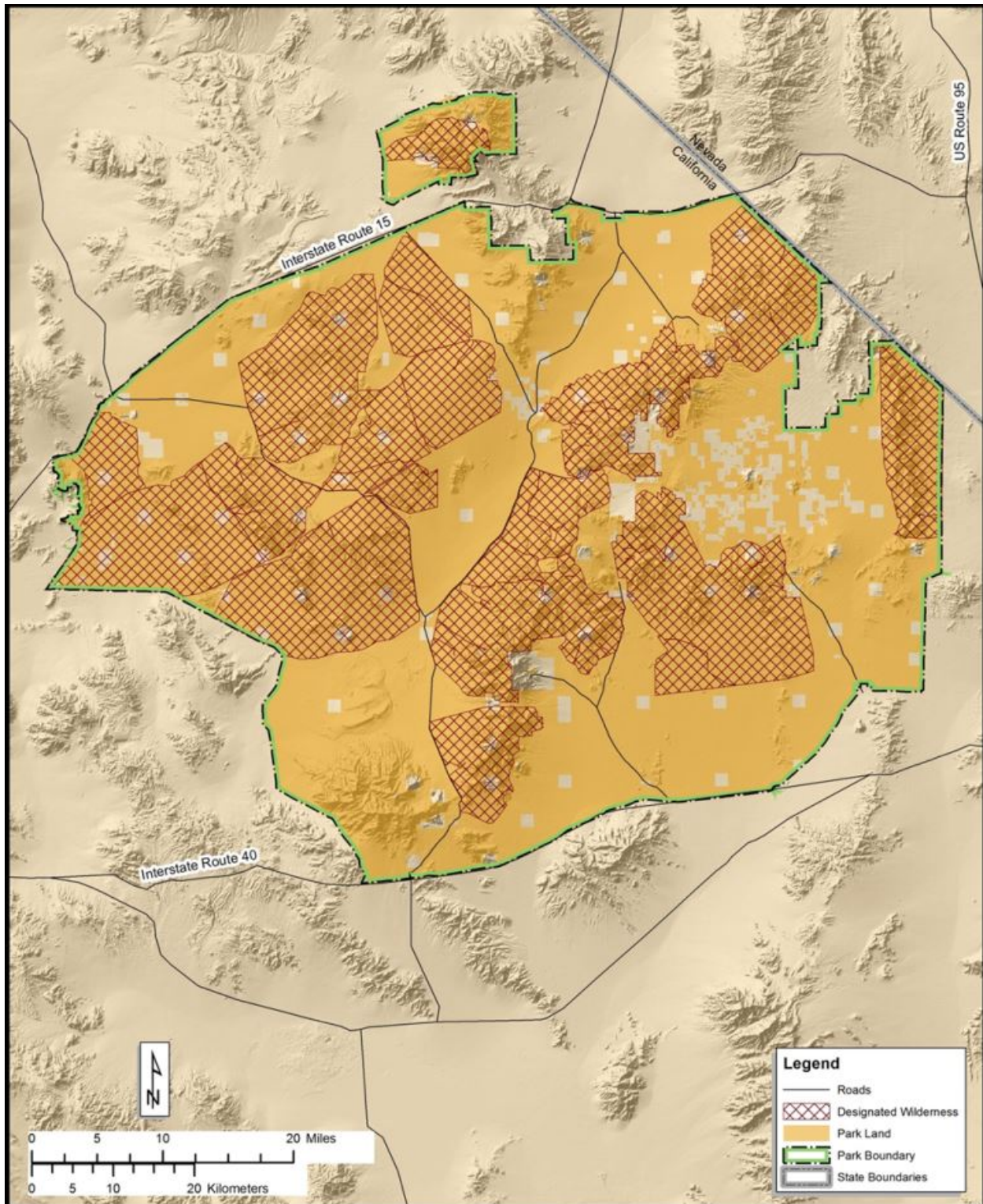


Figure 1.9. Map of Mojave National Preserve showing wilderness areas.

1.3.7. Grand Canyon-Parashant National Monument (PARA)

Grand Canyon-Parashant National Monument, the most recently established park unit of MOJN, was established in 2000 through Presidential Proclamation 7265 by President William J. Clinton. It was established to protect “a vast, biologically diverse, impressive landscape encompassing an array of scientific and historic objects.” Approximately 424,240 ha (1.048 million ac) of land were set aside for PARA to be cooperatively managed by the BLM and NPS (Figure 1.10). A majority of the lands for PARA came from land that was managed by BLM (327,287 ha or 808,744 ac that were part of the Arizona Strip) and NPS (84,175 ha or 208,000 ac, generally referred to as the Shivwits Plateau, that were part of LAKE). Each agency still retains the primary management authority over their respective sections. There are also a number of Arizona state (9,391 ha; 23,205 acres) and private lands (3,205 ha; 7,920 acres) that are within the park boundary. The entire designated wilderness in PARA, 76,130 ha (188,121 ac), is located on the BLM portion of the park (NPS 2008b).

PARA is located in northwestern Arizona in the drainage of the Colorado River (Figure 1.3). It is bordered by Grand Canyon National Park to the south and east, LAKE and the state of Nevada to the west, and surrounded by the southern portion of the Colorado Plateau called the Arizona Strip on the north (Figure 1.10). PARA is isolated from the rest of the Colorado Plateau by the Grand Canyon and even though it borders Grand Canyon National Park, there is no direct access to the canyon from PARA. However, PARA does provide spectacular overviews of the Grand Canyon and major features such as the Shivwits Plateau, Grand Wash Cliffs, and the volcanic Uinkaret Mountains, which include Mount Logan and Mount Trumbull and are known as “sky islands” because their high elevation provides distinctive habitats from the surrounding areas. The monument spans three ecoregions, the Mojave Desert, the Great Basin, and the Colorado Plateau, and plants typical of specific regions can be found together along the transition zones. PARA lies at the northeast edge of the Mojave Desert and this region is found at the lower elevations on the west side of the park, where Joshua tree woodlands occur. The Great Basin region is the largest region of the monument, covering most of the central and eastern parts of the monuments, and is characterized by sagebrush shrublands and pinyon-juniper (*Pinus* spp. – *Juniperus* spp.) woodlands. The smallest region is the Colorado Plateau, which tends to be found at the highest elevation areas in the park; tree communities, like Ponderosa pine (*Pinus ponderosa*) forests, are representative of the Colorado Plateau region (NPS 2011).

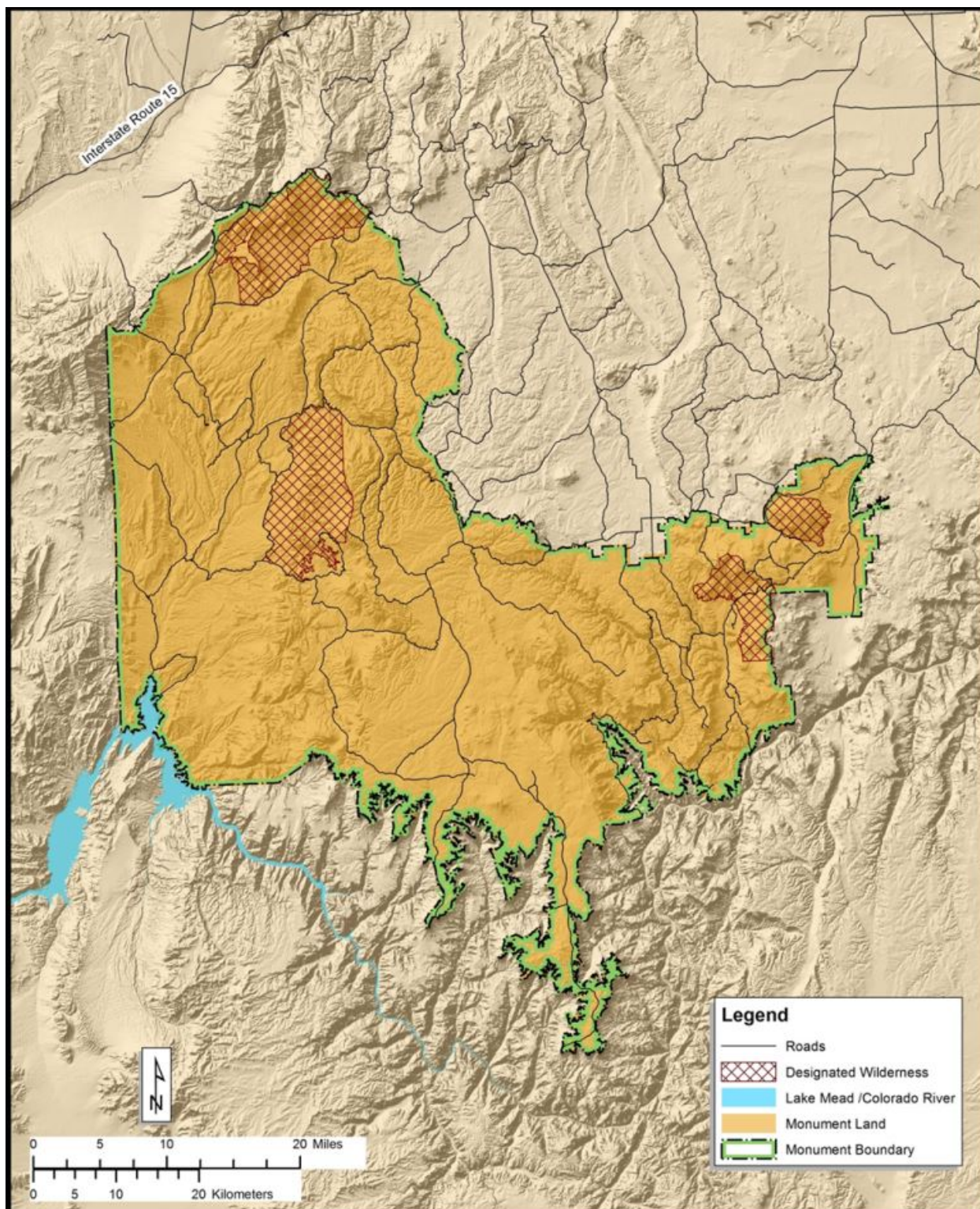


Figure 1.10. Map of Grand Canyon-Parashant National Monument showing wilderness areas.

1.4. Overview of Selected Upland Communities in MOJN Parks

In collaboration with the parks, one shrub community per park was selected for IU monitoring. Communities were generally selected because they were spatially dominant, of special management concern to a park (i.e., parks have a specific interest in a particular community), or sensitive to environmental change. The upland communities selected by each park are described below.

1.4.1. DEVA – Creosote Bush Mixed Desert Shrubland Community

At DEVA, the creosote bush (*Larrea tridentata*) mixed desert shrubland community was selected for monitoring because of its spatial dominance. To achieve a more reasonable area to monitor, we limited the creosote mixed desert shrubland community to an elevation of ~900 – 1,500 m (3,000–5,000 ft) and from ½ mi to up to 3 mi away from the nearest paved or unpaved road (Figure 1.11).

The most prevalent physiognomic community found in DEVA is desert scrub (major species found in “scrub” communities are shrubs that are generally less than 2 m tall; Ornduff 1974), which covers over 75% of the park (NPS 2002a). Shrubs typically associated with the desert scrub community at DEVA include creosote bush, Joshua tree, saltbush (*Atriplex* spp.), and sagebrush (*Artemisia* spp.). While Joshua trees are characteristic of the Mojave Desert, creosote bush is much more widespread across the landscape and found in all three warm deserts. Interestingly, each of the warm deserts has its own chromosomal race of creosote bush, with higher chromosome numbers (hexaploids) tied to greater aridity (i.e., Mojave Desert; Duran et al. 2005). Moreover, creosote bush is known to be drought tolerant, with many plants surviving through severe drought events (Bainbridge 2007), and its northern distribution is limited by freeze stress (Beatley 1974a, Smith et al. 2009). With the modeled climate change scenarios for the desert regions of higher temperatures, increased aridity, and fewer freeze events (Archer and Predick 2008), spatial distributions of creosote bush may shift northward (Smith et al. 2009). Given the dominance of the desert scrub community across DEVA, the spatially extensive creosote bush-mixed desert shrubland upland community would reflect changing conditions along a large area of the park.

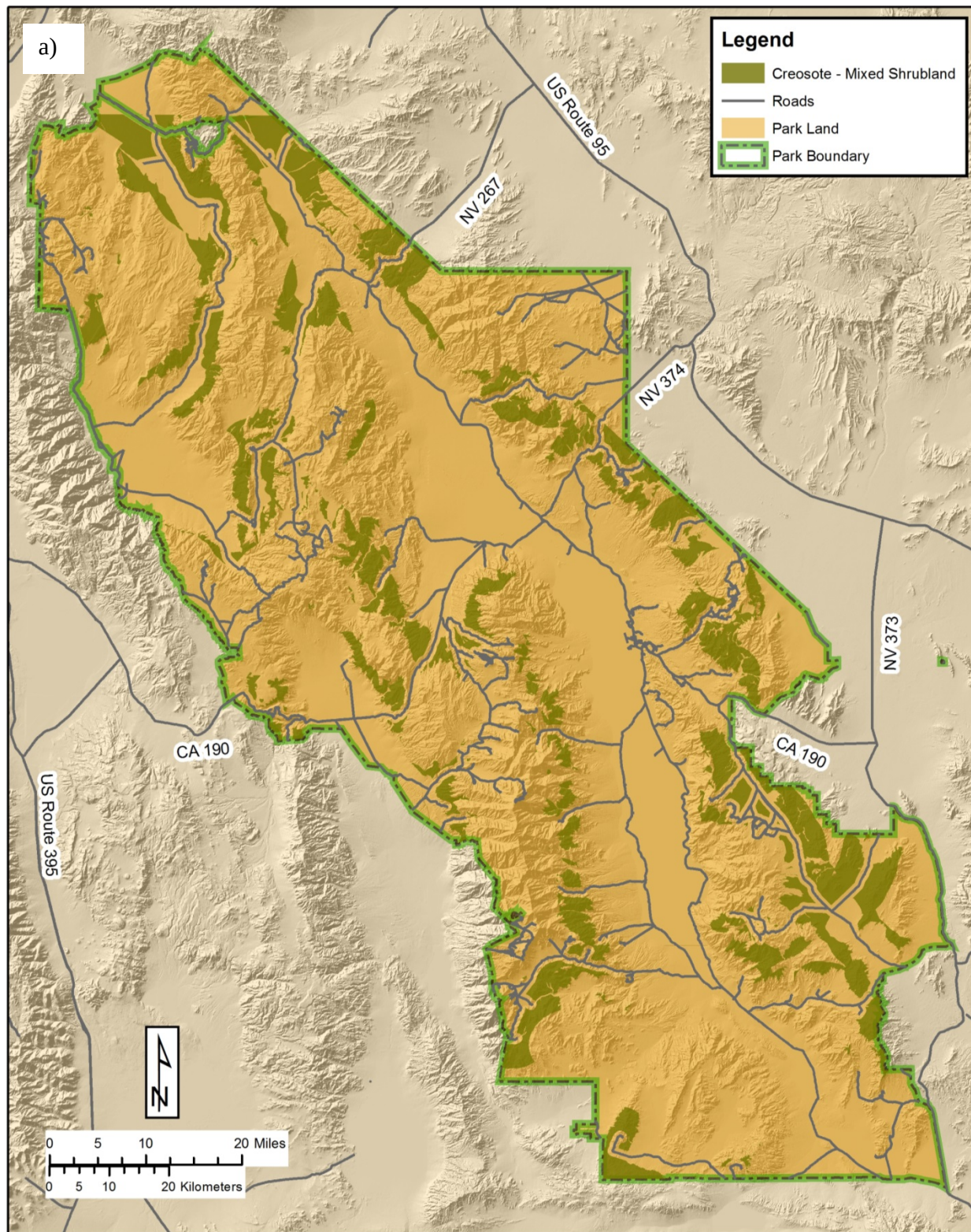


Figure 1.11. a) Distribution and b) example of the creosote bush (*Larrea tridentata*) mixed desert shrubland community between ~900 – 1,500 m (3,000-5,000 ft) and ½ to 3 mi of paved/unpaved roads at Death Valley National Park.



Figure 1.11. a) Distribution and b) example of the creosote bush (*Larrea tridentata*) mixed desert shrubland community between ~900 – 1,500 m (3,000-5,000 ft) and ½ to 3 mi of paved/unpaved roads at Death Valley National Park (continued).

1.4.2. GRBA – Sagebrush Shrub Steppe Community

The sagebrush (*Artemisia* spp.) shrub steppe community was selected for GRBA because it is a community of special management concern (Figure 1.12). The multiple species of sagebrush are indicator species for the Great Basin Desert, the most common of which is *A. tridentata*, or big sagebrush. The sagebrush shrub steppe communities that we will monitor for IU at GRBA are characterized by multiple species of *Artemisia*, namely *A. tridentata*, *A. arbuscula* (dwarf sagebrush), and *A. nova* (black sagebrush).

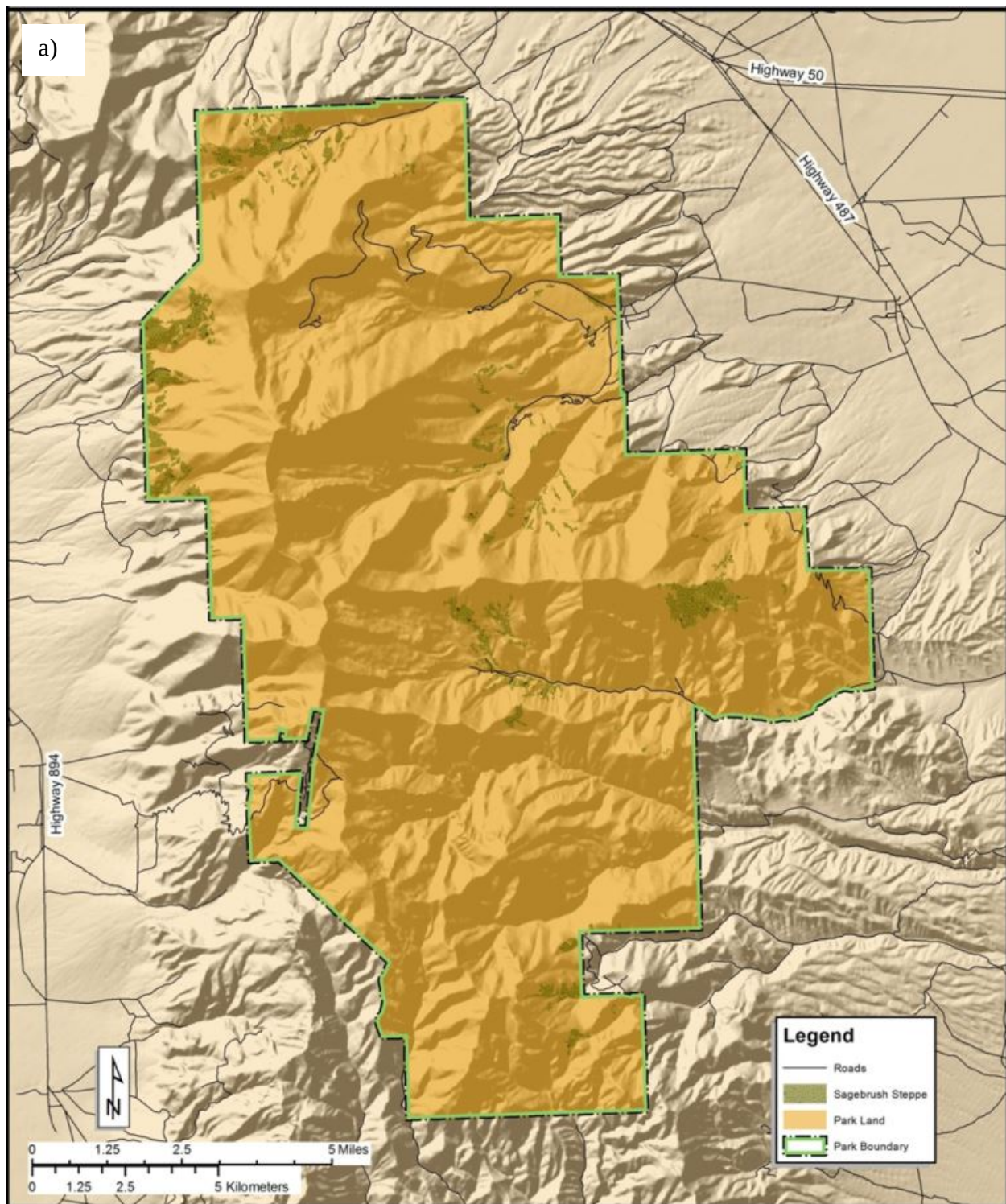


Figure 1.12. a) Distribution and b) example of the sagebrush (*Artemisia* spp.) shrub steppe community at Great Basin National Park.



Figure 1.12. a) Distribution and b) example of the sagebrush (*Artemisia* spp.) shrub steppe community at Great Basin National Park (continued).

Sagebrush shrub steppe and pinyon pine-juniper (primarily, *Pinus monophylla* and *Juniperus oerosperma* in GRBA) woodlands are the dominant communities in the Great Basin region, covering about 60% of the land area (Miller et al. 2010). However, the relative abundance of each of these communities has shifted recently, with pinyon-juniper woodlands increasing and sagebrush shrub steppe communities decreasing. Pinyon-juniper woodlands have increased 10-fold in the last 130 years (Miller and Tausch 2001). Within GRBA, over 80% of the sagebrush shrub steppe community has been lost in the last 100 years, down from 6,637 ha (16,400 ac) to only 1,234 ha (3,050 ac) of pristine sagebrush shrub steppe currently remaining (GRBA unpublished data 2005). Factors that may have contributed to the decline of sagebrush shrub steppe communities include excessive grazing by domestic livestock, fire-suppression, and climate change (Miller et al. 2010). A more recent threat to the sagebrush shrub steppe communities is invasion by cheatgrass (*Bromus tectorum*), which has changed these communities from perennial shrub dominated to annual grass dominated. Managing for the maintenance of the sagebrush shrub steppe community at GRBA is crucial, not only from a biodiversity perspective, but also for wildlife management, as sagebrush shrub steppe provides valuable habitat for a number of sensitive small mammal species (Hamilton

and Horner 2010), such as the sagebrush vole (*Lagurus curtatus*) and yellow-bellied marmot (*Marmota flaviventris*).

1.4.3. JOTR – Joshua Tree Wooded Alliance Community

The iconic Joshua tree (*Yucca brevifolia* var. *brevifolia*) wooded alliance community was selected for monitoring at JOTR because it is of special management concern and its sensitivity to environmental change. Joshua tree woodlands are a significant community on the western side of the park (Figure 1.13), which is the part of the park most heavily affected by air quality issues (Tonnesen et al. 2003). Because of its proximity to Los Angeles, JOTR suffers from some of the nation's worst air pollution. There is a gradient of air pollution across the park as air pollution is blown from the west (Los Angeles basin) to the east, such that the west side of the park experiences greater pollution than the east side. One of the park's major concerns is nitrogen deposition, which can act as a fertilizer and favor plants that rapidly respond to nitrogen availability, such as invasive annual grasses (Rao and Allen 2010). Increases in annual invasive grasses have also been linked to increased fire frequency (D'Antonio and Vitousek 1992, Brooks and Matchett 2006), which can negatively affect Joshua tree woodlands as Joshua trees experience high mortality after being burned (DeFalco et al. 2010).

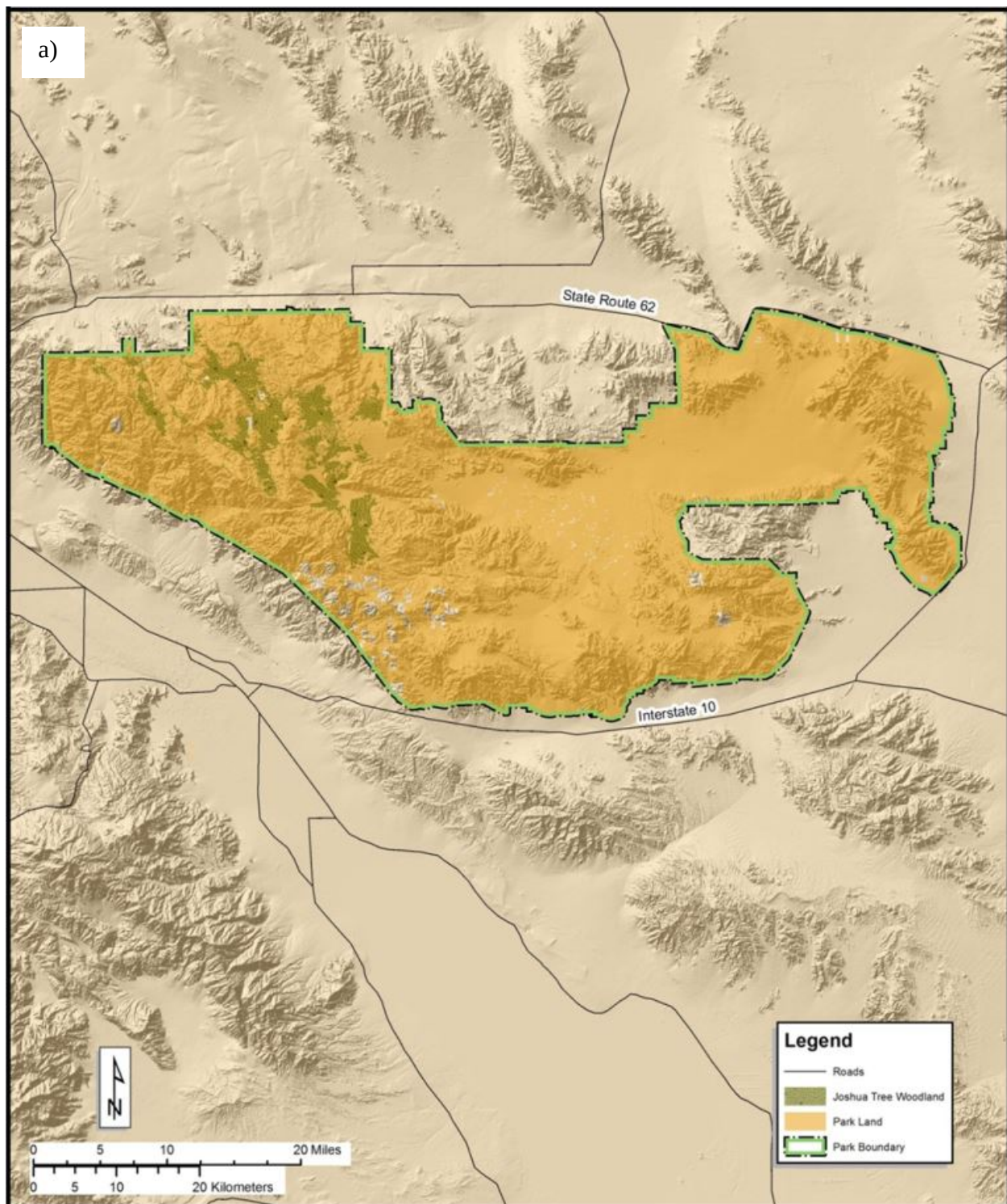


Figure 1.13. a) Distribution and b) example of the Joshua tree (*Yucca brevifolia* var. *brevifolia*) wooded alliance community at Joshua Tree National Park. Photo provided by JOTR.



Figure 1.13. a) Distribution and b) example of the Joshua tree (*Yucca brevifolia* var. *brevifolia*) wooded alliance community at Joshua Tree National Park. Photo provided by JOTR (continued).

Historic data indicates that Joshua trees had a much more extensive distribution during the Pleistocene and its distribution shrank as climates warmed during the Holocene. Under future climate change models, Joshua tree wooded alliance communities are predicted to undergo dramatic community shifts, as the Joshua tree range contracts, particularly in the southern parts of its range (Cole et al. 2011). Cole et al. (2011) predict that Joshua tree populations in JOTR will go extinct and, similarly, most populations in MOJA. However, smaller-scale models indicate that local refugia for Joshua trees may exist (Barrow and Murphy-Mariscal 2012). Given their location in the park and previous response to climate change, Joshua tree wooded alliance communities are an ideal community for detecting change within the park and responses of this community to air quality and climate change may provide an early indication of how other plant communities in the park will react.

1.4.4. LAKE – Creosote bush-White bursage Shrub Community

The creosote bush and white bursage (*Ambrosia dumosa*) shrub community between ~450 to 1,500 m (1,500 to 5,000 ft) elevation was selected for monitoring at LAKE because of its spatial dominance. This community is the most widespread of all plant communities, occupying ~85% of LAKE (NPS 2010a), and spans both the Nevada and Arizona sides of the park (Figure 1.14). Although the creosote-bursage community ranges from 150 (500 ft) to over 1,500 m (5,000 ft), we chose to focus

on areas higher than 450 m (1,500 ft) because areas within LAKE above that elevation were not submerged due to the filling of Lakes Mead and Mohave.

The creosote-white bursage alliance is found over 70% of the Mojave Desert (Schwinning and Hooten 2009). While both creosote bush and white bursage are considered to be relatively widespread species, a number of factors have been found to affect their distribution. For example, at LAKE, it has been found that white bursage has been disappearing from some creosote-bursage communities due to feral burros, while creosote bush has been expanding into grasslands (NPS 2010b). With its wide spatial distribution across the park, this community would reflect changes in natural resources over wide expanses of the park.

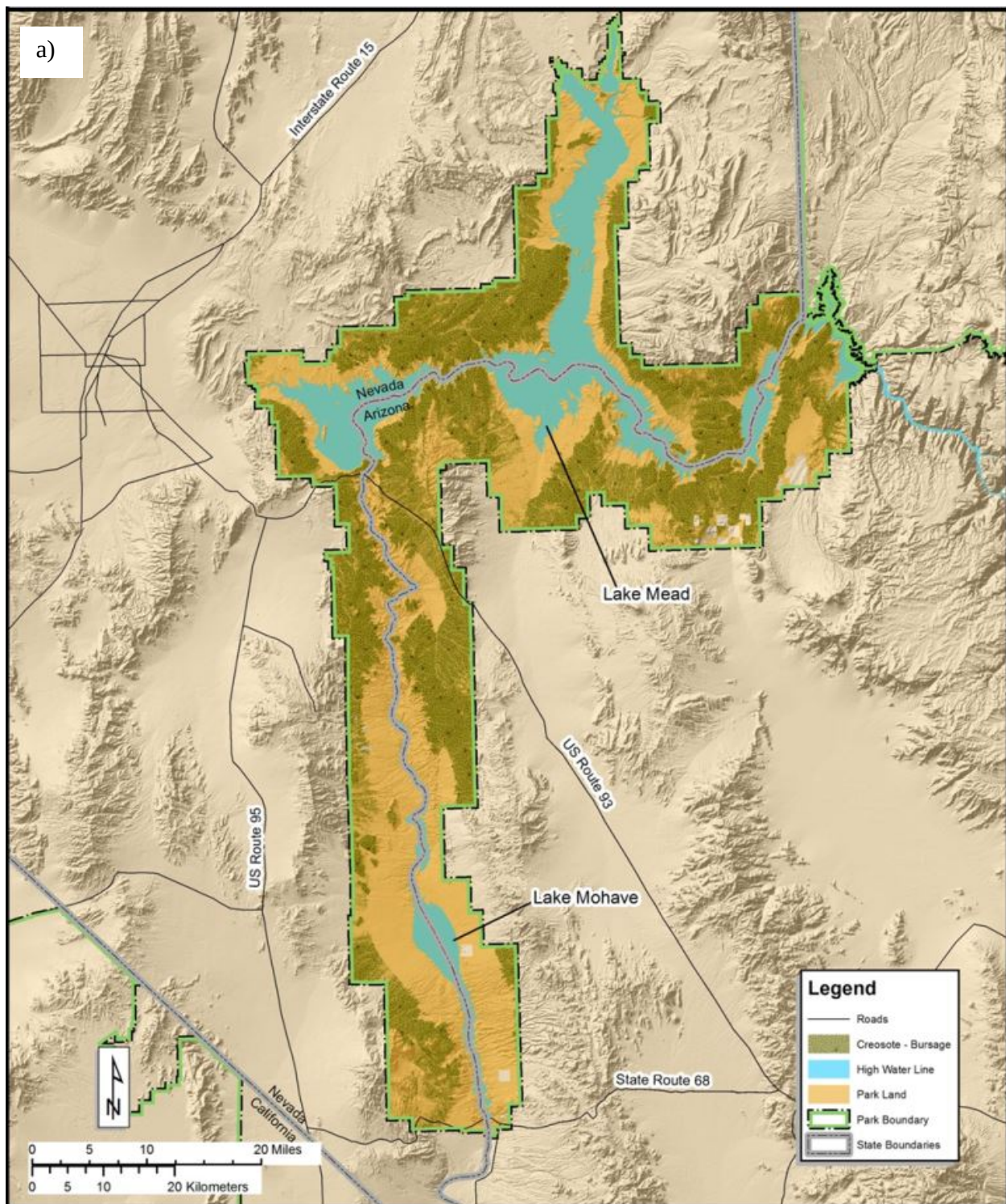


Figure 1.14. a) Distribution and b) example of the creosote bush (*Larrea tridentata*) - white bursage (*Ambrosia dumosa*) shrub community between 450 to 1,500 m (1,500 to 5,000 ft) elevation at Lake Mead National Recreation Area.

b)



Figure 1.14. a) Distribution and b) example of the creosote bush (*Larrea tridentata*) - white bursage (*Ambrosia dumosa*) shrub community between 450 to 1,500 m (1,500 to 5,000 ft) elevation at Lake Mead National Recreation Area (continued).

1.4.5. MANZ – Rabbitbrush Shrubland Community

At MANZ, we will monitor the rabbitbrush (*Ericameria nauseosa*) shrubland alliance for this protocol because of its spatial dominance (Figure 1.15). While MANZ is heavily modified from its natural state, it was a Japanese Internment camp during World War II and fruit orchards before that, the rabbitbrush shrubland is representative of the natural Great Basin shrubland vegetation found in the surrounding area. This community in MANZ encompasses the transition zone between the three dominant shrub species, rabbitbrush, saltbrush (*Atriplex* spp.), and sagebrush, each of which can respond to the level of the water table (Elmore et al. 2003).

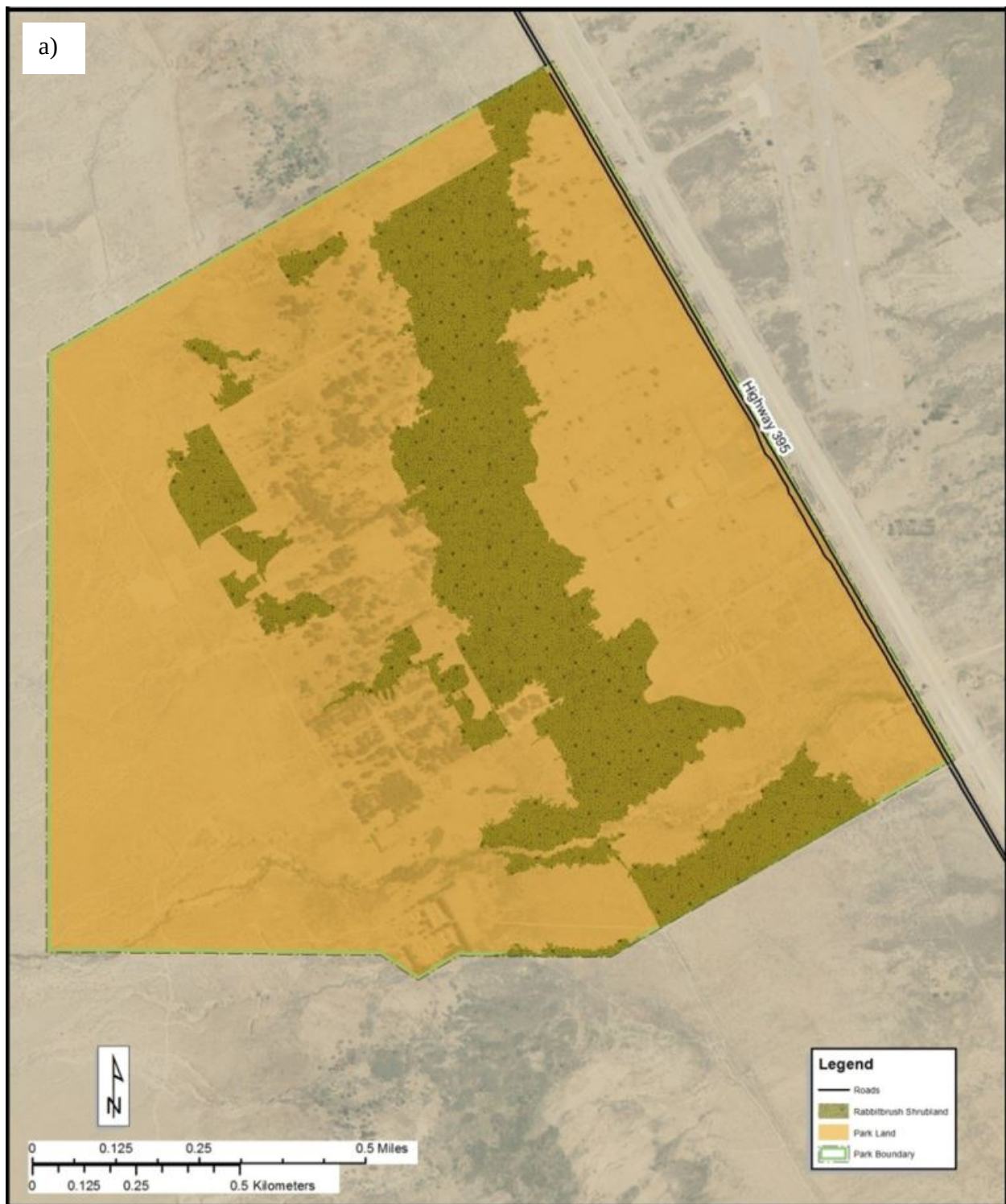


Figure 1.15. a) Distribution and b) example of the rabbitbrush (*Ericameria nauseosa*) shrubland community at Manzanar National Historic Site. Photo provided by J.E. Taylor, NPS.



Figure 1.15. a) Distribution and b) example of the rabbitbrush (*Ericameria nauseosa*) shrubland community at Manzanar National Historic Site. Photo provided by J.E. Taylor, NPS (continued).

1.4.6. MOJA – Joshua Tree Wooded Scrubland Community

The Joshua tree wooded scrubland community was selected for monitoring at MOJA because it is of special management concern and its sensitivity to environmental change (see section 1.4.3. *JOTR – Joshua Tree Wooded Alliance Community*). The Joshua tree variety found in MOJA, *Yucca brevifolia* var. *jaegeriana*, is different than that found at JOTR. The variety found in MOJA is commonly known as Jaeger’s Joshua tree and is distinguished from the var. *brevifolia* by its much smaller size [maximum height for var. *jaegeriana* is 3-4 m (9.8 to 13 ft), Figure 1.17b, and 15 m (49 ft) for var. *brevifolia*, Figure 1.16b]; similarly, the leaves of Jaeger’s Joshua tree ranges from 10 - 20 cm (4 – 8 in) (Figure 1.16a), where the largest leaves are in the range of the smallest leaves of var. *brevifolia* (McKelvey 1935).

MOJA is known for having the largest and densest population of Joshua trees in the world (Figure 1.17; NPS 2002b). As part of managing this exemplary resource, MOJA has specific management goals for their Joshua tree wooded scrublands, including “monitoring the extent, density, and age distribution of the Joshua tree woodland; ... and investigating fire management strategies that consider short and long-term fire effects on components of this community...”. The IU protocol can

provide valuable data to help meet the former goal and MOJN I&M's future *Fire and Fuel Dynamics* protocol can provide valuable data for the latter goal.



Figure 1.16. Photos of a) Jaeger's Joshua tree (*Yucca brevifolia* var. *jaegeriana*), the "dwarf" variety found at Mojave National Preserve and b) Joshua tree (*Yucca brevifolia* var. *brevifolia*), the variety found at Joshua Tree National Park. Photo of Jaeger's Joshua tree provided by Neal Darby, NPS, and var. *brevifolia* provided by JOTR.



Figure 1.16. Photos of a) Jaeger's Joshua tree (*Yucca brevifolia* var. *jaegeriana*), the "dwarf" variety found at Mojave National Preserve and b) Joshua tree (*Yucca brevifolia* var. *brevifolia*), the variety found at Joshua Tree National Park. Photo of Jaeger's Joshua tree provided by Neal Darby, NPS, and var. *brevifolia* provided by JOTR (continued).

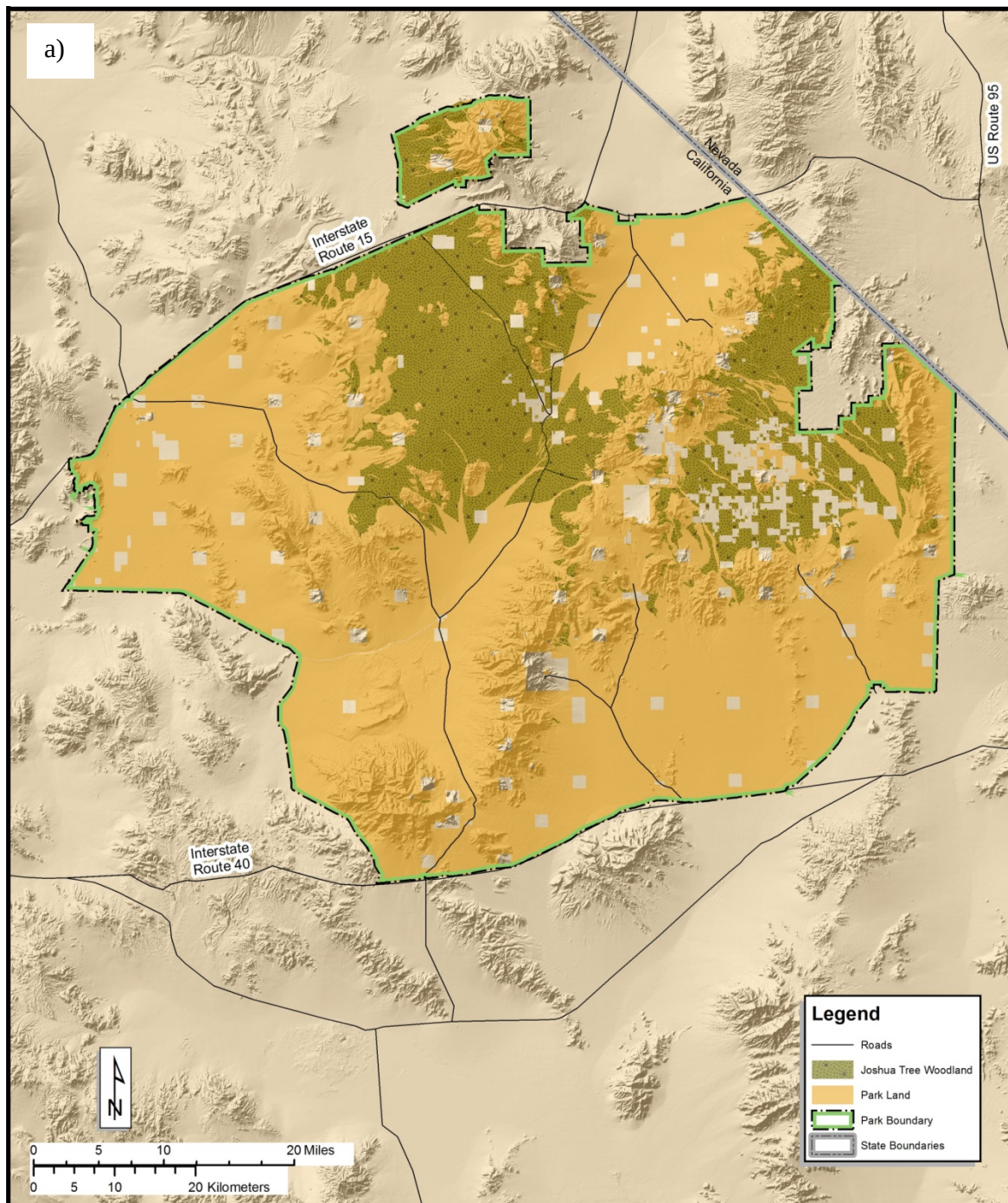


Figure 1.17. a) Distribution and b) example of the Joshua tree (*Yucca brevifolia* var. *jaegeriana*) wooded scrubland community at Mojave National Preserve. Photo provided by MOJA.



Figure 1.17. a) Distribution and b) example of the Joshua tree (*Yucca brevifolia* var. *jaegeriana*) wooded scrubland community at Mojave National Preserve. Photo provided by MOJA (continued).

1.4.7. PARA – Sagebrush Shrub Steppe Community

The sagebrush shrub steppe community was selected for monitoring at PARA because of its widespread spatial distribution and special management concern (Figure 1.18). Much of PARA is part of the Great Basin ecoregion and sagebrush shrub steppe communities are the characteristic and dominant shrub community within the Great Basin section of PARA. Big sagebrush (*A. tridentata*) is the most common species in these communities but several other species of sagebrush can also be dominant in the community (e.g., *A. bigelovii*, *A. filifolia*). Similar to sagebrush communities in other areas of the Great Basin ecoregion, sagebrush communities at PARA are experiencing encroachment by pinyon and juniper trees and invasion by annual grasses (see section 1.4.2. *GRBA – Sagebrush Shrub Steppe Community*). Monitoring changes in sagebrush shrub steppe communities is important for effectively managing these areas for grazing, as the continued administration of grazing leases is specified in PARA’s establishing Proclamation.

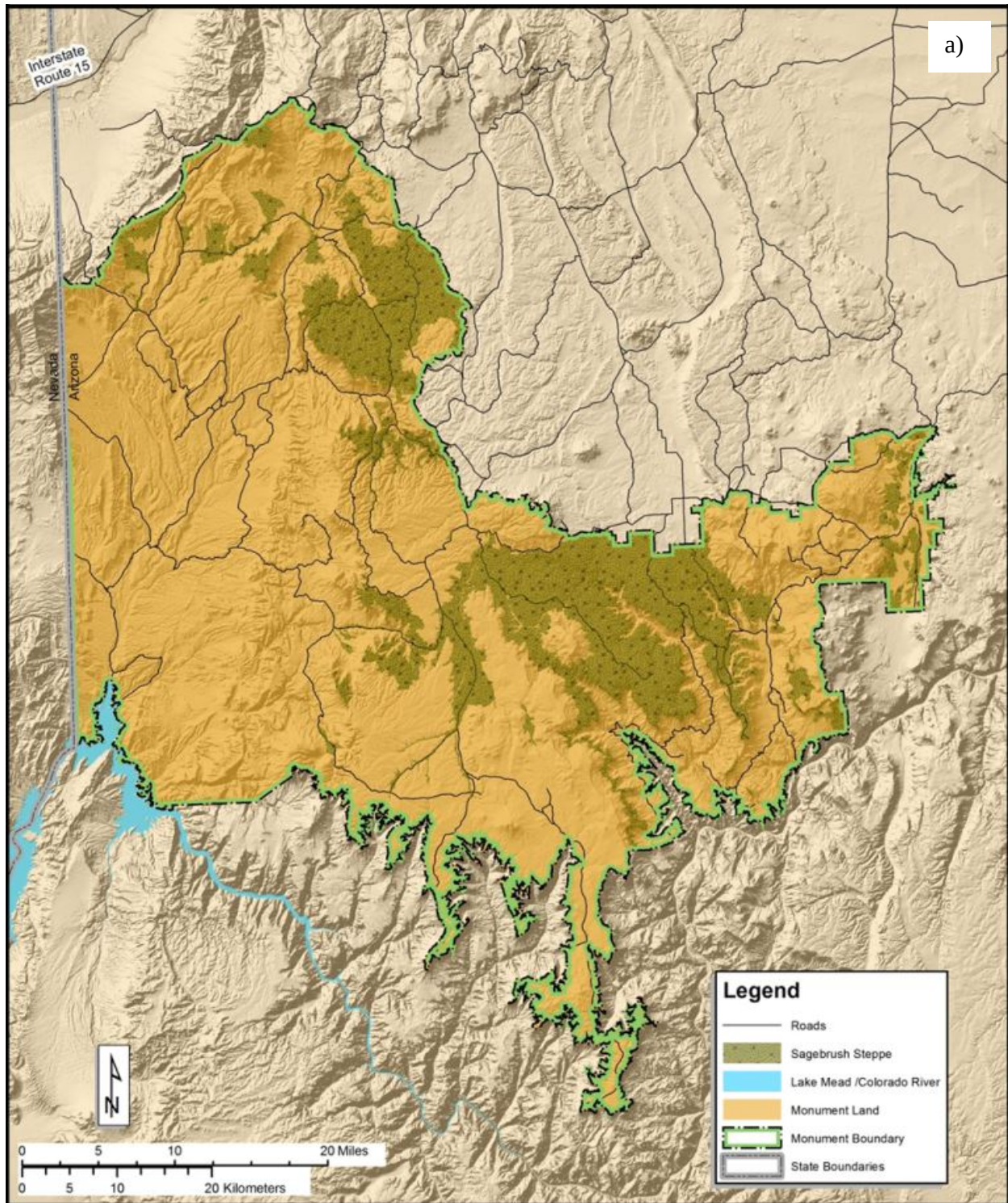


Figure 1.18. a) Distribution and b) example of the sagebrush (*Artemisia* spp.) shrub steppe community at Grand Canyon-Parashant National Monument. Photo provided by PARA.



Figure 1.18. a) Distribution and b) example of the sagebrush (*Artemisia* spp.) shrub steppe community at Grand Canyon-Parashant National Monument. Photo provided by PARA (continued).

1.5. Potential Integration with Other Protocols

The data collected as part of the IU protocol will primarily be used to address the seven vital signs of this protocol (see section 1.1 *Rationale for Monitoring Upland Communities in MOJN*). However, we anticipate that data collected for this protocol will also be used to understand other vital signs in secondary protocols that will be developed contingent on funding. These protocols include:

- *Invasive plants* as part of the *Riparian Vegetation* and *Invasive Plants - Early Detection* protocols (both protocols in development) – If any of the invasive plants monitored for status and trends are the same between this protocol and Riparian Vegetation, then data from the two protocols can be combined to understand the dynamics and model the spread of the targeted invasive species. Data obtained from this protocol will also help us to prioritize invasive species for *Early Detection* monitoring.
- *Landscape Dynamics* (in development; Protocol Lead: David Gundlach, MOJN I&M GIS Specialist) – The placement of our sample plots will be spatially balanced across the selected community within the park. Data from this protocol could provide on-the-ground information that could be used to understand large-scale vegetation dynamics across parks.

- *Fire and Fuel Dynamics* – A number of invasive annual plants selected for status and trends monitoring can promote and affect fire frequency in the desert (Brooks et al. 2004), particularly red brome and cheatgrass. Data on invasive species collected from this protocol can be incorporated into the Fire and Fuel Dynamics protocol.
- *At-Risk Populations* – Data from this protocol will provide information on the abundance of some upland plant species, which could provide an early warning on whether certain plant populations are decreasing. Vegetation provides important habitat for many organisms and data on upland communities could help managers determine whether habitat is deteriorating or being lost for at-risk populations.
- *Reptile Communities* monitored in the Reptile Communities protocol and *Small Mammal Communities* in the Small Mammal protocol – We plan on co-locating field sites for as many of our protocols as possible. Co-location is not only logistically and financially more economical, data from different protocols can be combined to provide a more comprehensive picture of the different communities. For example, vegetation data can help us to understand how vegetation changes will affect small mammal and reptile communities.

We also anticipate that data collected for other vital signs from other protocols will be incorporated into analyses for this protocol. The vital signs of particular interest are:

- *Basic Meteorology* from the Climate protocol (in development, Protocol Lead: Geoffrey Moret, MOJN I&M Hydrologist) - As described previously, climate is one of the primary influences on vegetation distribution. We will incorporate data from the climate protocol into IU statistical analyses to understand how climate is affecting MOJN park communities.
- *Ozone, Wet and Dry deposition, Visibility and Particulate Matter* in the Air quality protocol – Pollution and degradation of air quality is one of the biggest threats to a number of the MOJN parks. Data from the Air quality protocol can be used to understand the response of upland communities to changes in air quality and provide important information for park management of natural resources.

Lastly, all MOJN I&M staff engaged in field activities, including this protocol, will be trained and participate in early detection of invasive species (see *MOJN I&M SOP M1- Reporting Incidental Observations of Incipient Invasive Species*). Data from this activity will be provided to parks and to the Exotic Plant Management Team (EPMT) to help with management and control of invasive species.

2. Sampling Design

Sampling design is critical to ensuring that collected data will meet program objectives in a statistically rigorous manner. The sampling design includes specifying the populations of interest (*Population of Inference*), what data are collected (*Response Design*), the number of sampled sites per park and how these samples are distributed across the park (*Sample Size and Spatial Design*), and the timing and frequency of sampling events (*Sampling Frequency and Timing*). Designs inherently reflect trade-offs among the priorities of the monitoring program, resources available, and the logistical considerations and constraints associated with field sampling. While the aim of any sampling design is to provide optimal statistical robustness and scientific rigor, other considerations including personnel safety, fiscal and logistical constraints, and the ability to integrate data with other vital signs must also be considered.

2.1. Population of Inference

Given the large landscape of the MOJN parks (>3.3 million ha or 8.3 million ac), it is logistically impractical to monitor all upland vegetation in the MOJN parks. Therefore, MOJN I&M and park staff worked together to identify upland communities that were spatially dominant, of special management concern, or sensitive to environmental change for each park and articulated any park-specific constraints on site location (e.g., elevation, distance from roads) (Table 2.1). The selected park communities (described in detail in section 1.4. *Overview of Selected Upland Communities in MOJN Parks*) are the *population of inference*, or population of interest, for the park. All units, or elements, of the inference population have a chance of being part of the *sample*. The sample is a randomly-selected subset of units on which data are collected and inference is made. Units that have a sampling inclusion probability of 0 (e.g., private property) are not included in the sampled population and, therefore, not part of the population of inference.

The spatial distribution of selected communities within each park was evaluated using the best available currently mapped vegetation (Table 2.1). We buffered (i.e., removed) the area around park boundaries (100 m around the park boundary) to ensure that any sites selected would be well-within the park boundaries. Where possible, we also eliminated target vegetation areas that were too small to support the one hectare macroplot (see Table 2.1). The remaining areas served as the sampling frame from which the Generalized Random Tessellation Stratified (GRTS) is drawn (Figures 2.1-2.7) and is considered the population of inference.

Selected sites that become established macroplots will be visited on a 3-year rotation, with all macroplots from two parks sampled each year (see section 2.4 *Sampling Frequency and Timing* for more details).

Table 2.1. Elevation, area, and spatial dataset used to determine the distribution of communities selected for each park. Elevation represents the entire range of the selected shrub community, except for LAKE and DEVA¹. Elevation is rounded up or down as appropriate to the nearest 100 m or 100 ft.

Park	Community	Spatial dataset from (year) ² :	Elevation	Area
DEVA	Creosote bush-mixed desert shrubland	Central Mojave Vegetation Map (2004)	900 – 1,500 m (3,000 – 5,000 ft ¹)	182,264 ha (450,384 ac)
GRBA	Sagebrush shrub steppe	Provisional vegetation map (2011)	1,600 – 3,400 m (5,300 – 11,200 ft)	1338 ha (3,305 ac ³)
JOTR	Joshua tree wooded alliance	Vegetation map (2010)	1,000 – 1,400 m (3,200 – 4,500 ft)	16,292 ha (40,258 ac ³)
LAKE	Creosote bush – white bursage shrub community	Landfire (2006)	450 – 1,500 m (1,500 – 5,000 ft ¹)	148,285 ha (366,419 ac)
MANZ	Rabbitbrush shrubland alliance	Vegetation map (2010)	1,200 m (3,800 – 3,900 ft)	73 ha (181 ac ³)
MOJA	Joshua tree wooded scrubland	Central Mojave Vegetation Map (2004)	800 – 1,900 m (2,600 – 6,300 ft)	132,514 ha (327,448 ac)
PARA	Sagebrush shrub steppe	AZ strip dataset (2007)	1,100 – 2,200 m (3,600 – 7,200 ft)	77,216 ha (190,806 ac)

¹The elevation range represents a selected subset of the total elevation range of the shrub community (described in detail in section 1.4 *Overview of Selected Upland Communities in MOJN Parks*), the range that will be considered for monitoring. For DEVA, the area estimate only includes the area within 0.5-3 mi of roads.

²References for spatial datasets:

DEVA, MOJA: Thomas, K., Keeler-Wolf, T., Franklin, J., and P. Stine. 2004. Mojave Desert Ecosystem Program: Central Mojave vegetation database. U.S. Geological Survey Final Report. U.S. Geological Society, Sacramento, California;

GRBA: Cogan, D., J. E. Taylor, and K. Schulz. 2012. Vegetation inventory project: Great Basin National Park. Natural Resource Report NPS/MOJN/NRR—2012/568. National Park Service, Fort Collins, Colorado;

JOTR: La Doux, T., C. Lea, and E. Babich. 2013. A summary of the Joshua Tree National Park Vegetation Mapping Project: NPS Vegetation Inventory Program. Natural Resource Technical Report NPS/JOTR/NRTR—2013/723. National Park Service, Fort Collins, Colorado;

MANZ: Cogan, D., and J. E. Taylor. 2014. Manzanar National Historic Site: Vegetation classification and mapping project report. Natural Resource Technical Report NPS/MANZ/NRTR—2014/868. National Park Service, Fort Collins, Colorado;

LAKE, PARA: spatial vegetation datasets were obtained from the respective parks and are considered by the parks to be best available datasets.

³Area estimate is after parcels smaller than a macroplot (1 ha) were eliminated from the spatial distribution.

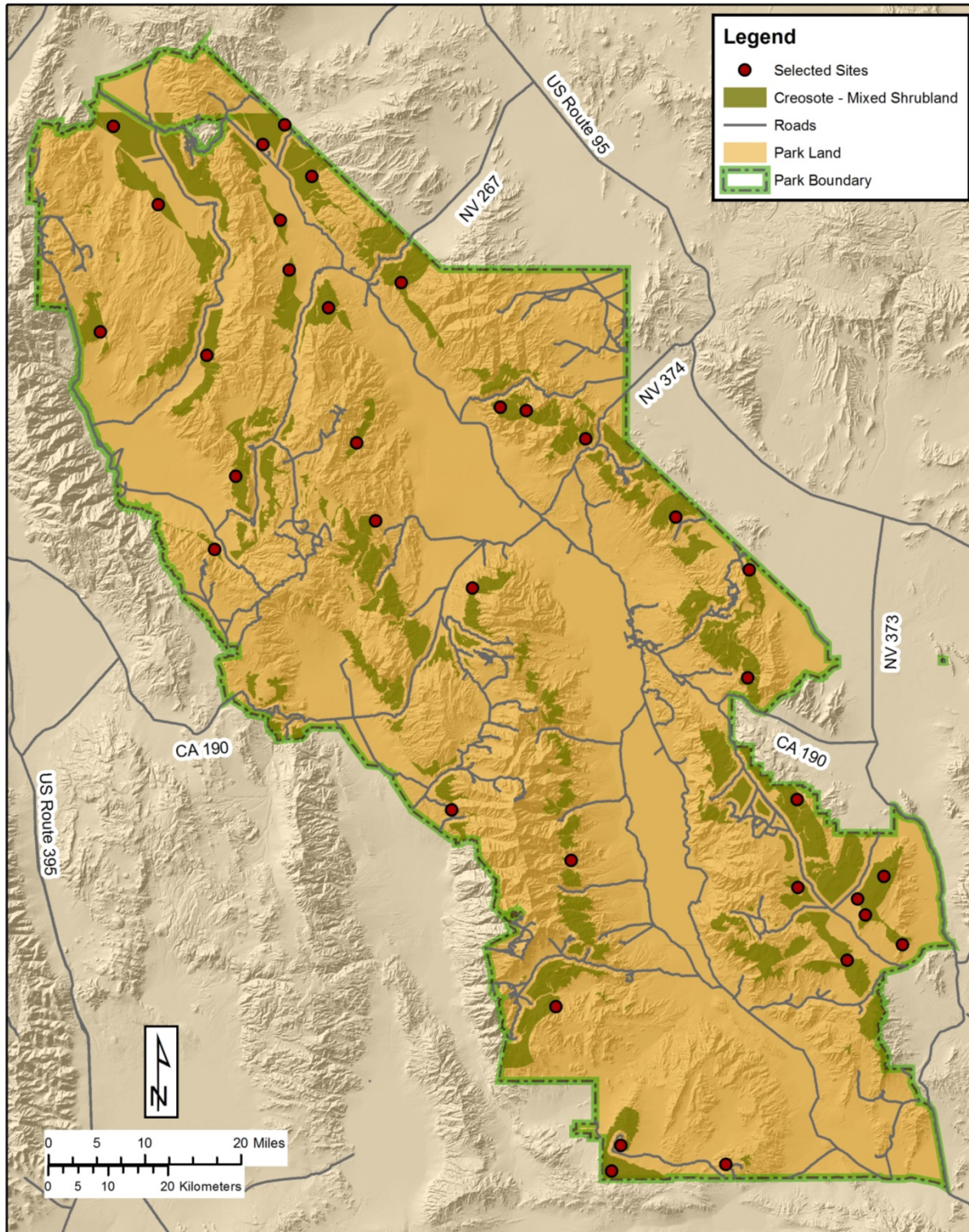


Figure 2.1. Generalized Random Tessellation Stratified (GRTS) draw for Death Valley National Park. The distribution of the first 35 field sites across the creosote bush (*Larrea tridentata*) mixed desert shrubland community between ~900 – 1,500 m (3,000-5,000 ft) and ½ to 3 mi of paved/unpaved roads is shown. Fewer than 35 individual circles are visible because some of the selected macroplots overlap each other at the scale shown.

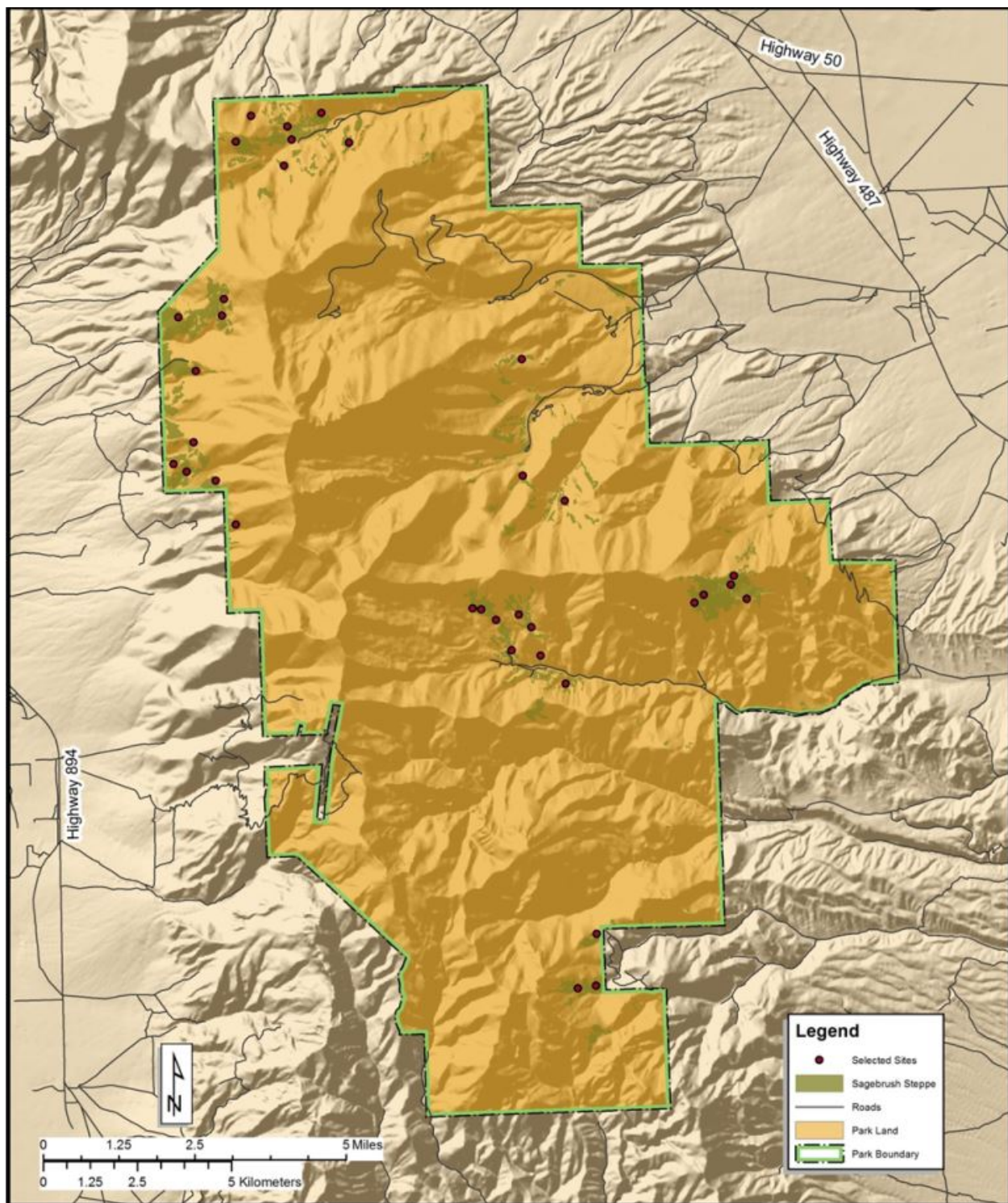


Figure 2.2. Generalized Random Tessellation Stratified (GRTS) draw for Great Basin National Park. The distribution of the first 35 field sites across the sagebrush (*Artemisia* spp.) shrub steppe community is shown.

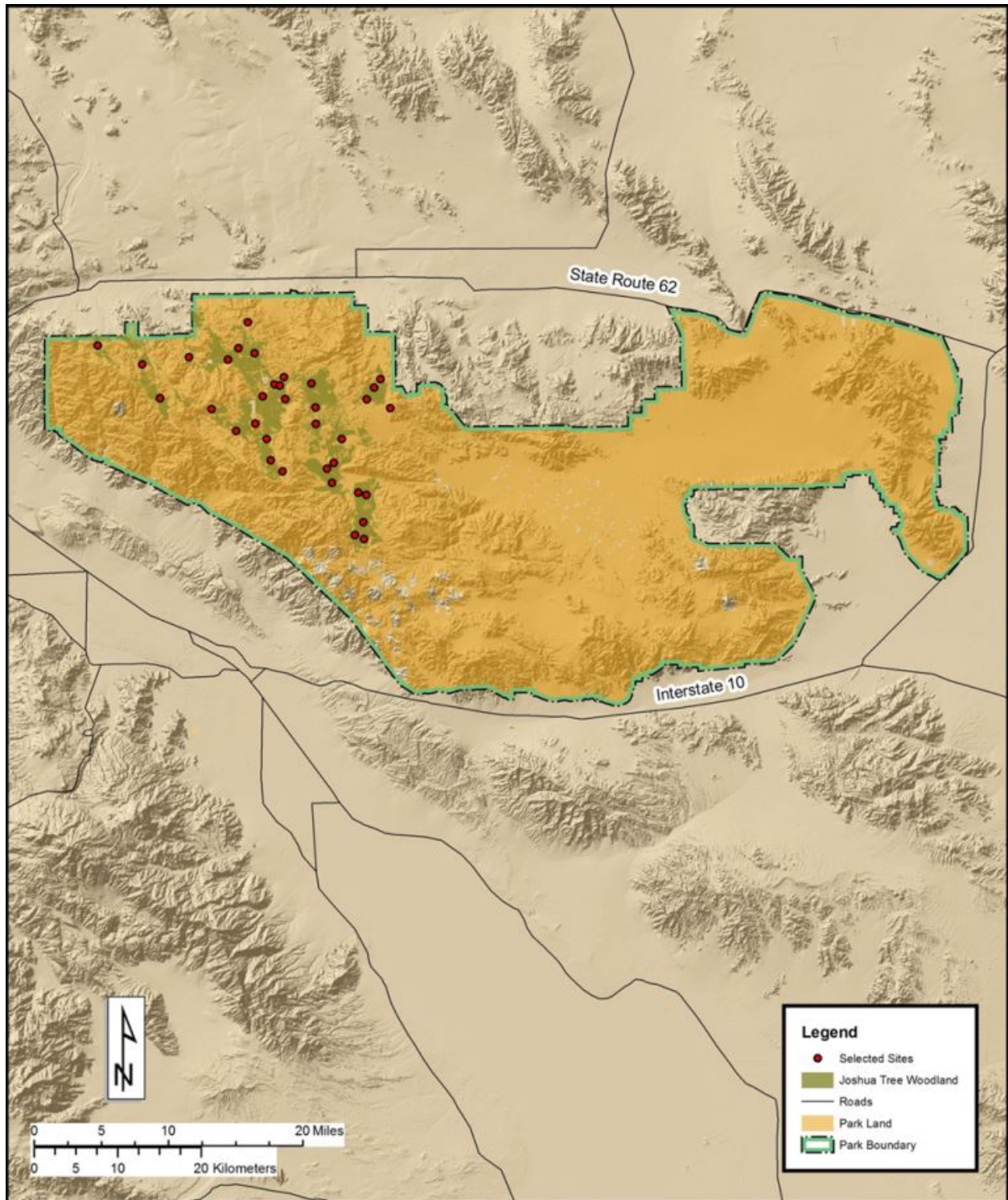


Figure 2.3. Generalized Random Tessellation Stratified (GRTS) draw for Joshua Tree National Park. The distribution of the first 35 field sites across the Joshua tree (*Yucca brevifolia* var. *brevifolia*) wooded alliance community is shown.

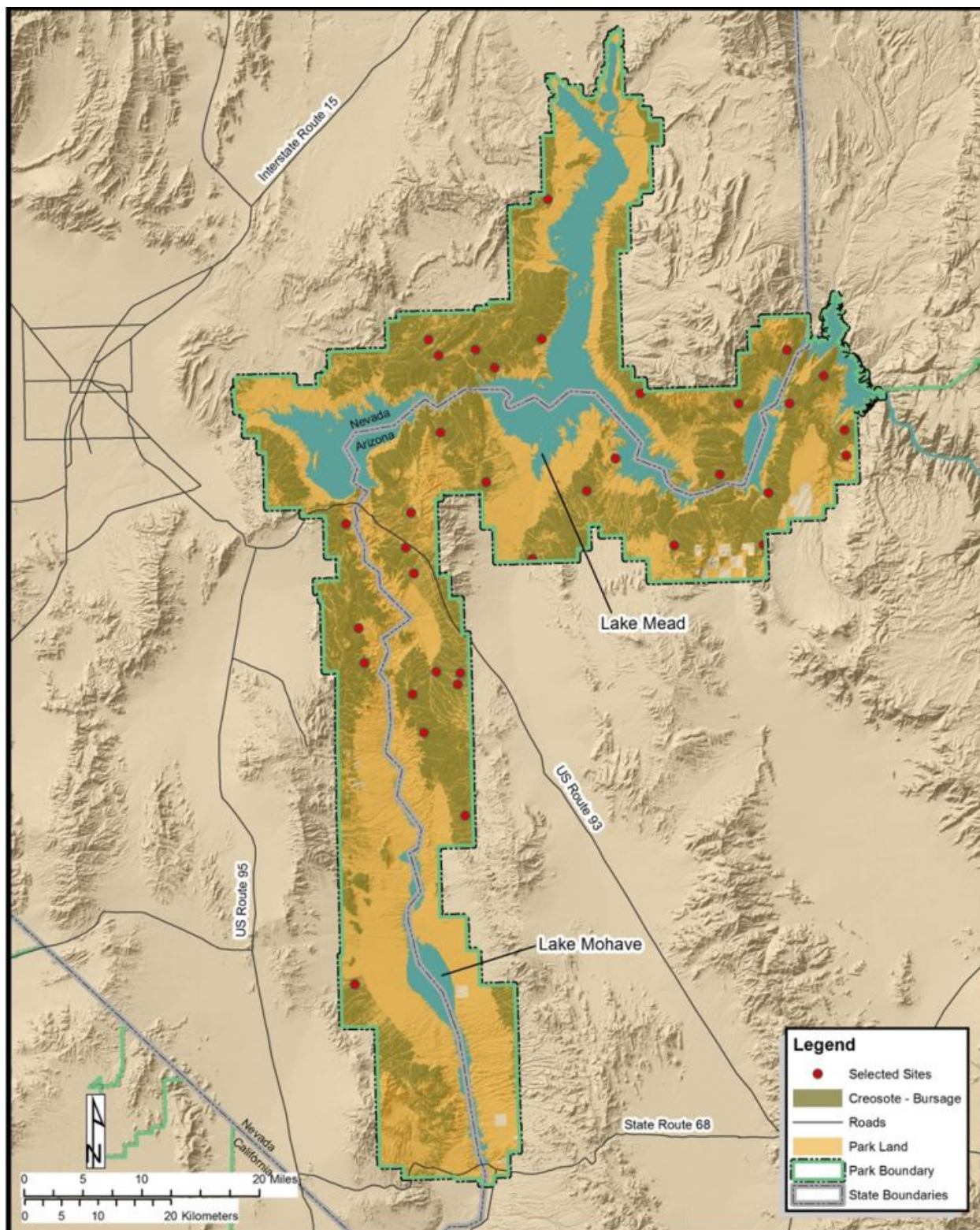


Figure 2.4. Generalized Random Tessellation Stratified (GRTS) draw for Lake Mead National Recreation Area. The distribution of the first 35 field sites across the creosote bush (*Larrea tridentata*) - white bursage (*Ambrosia dumosa*) shrub community between 450 to 1,500 m (1,500 to 5,000 ft) elevation is shown.

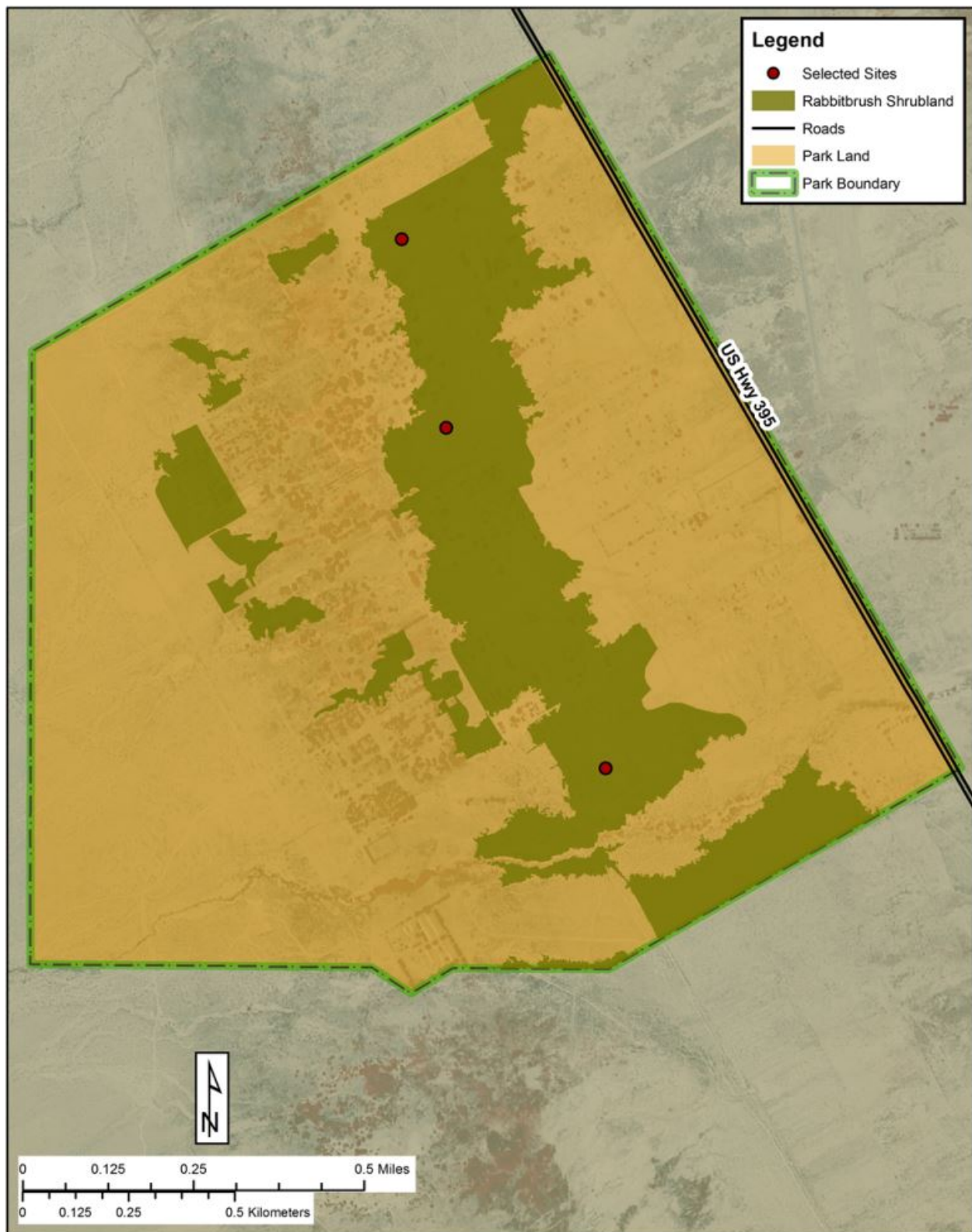


Figure 2.5. Generalized Random Tessellation Stratified (GRTS) draw for Manzanar National Historic Site. The distribution of the first 3 field sites across the rabbitbrush (*Ericameria nauseosa*) shrubland community is shown.

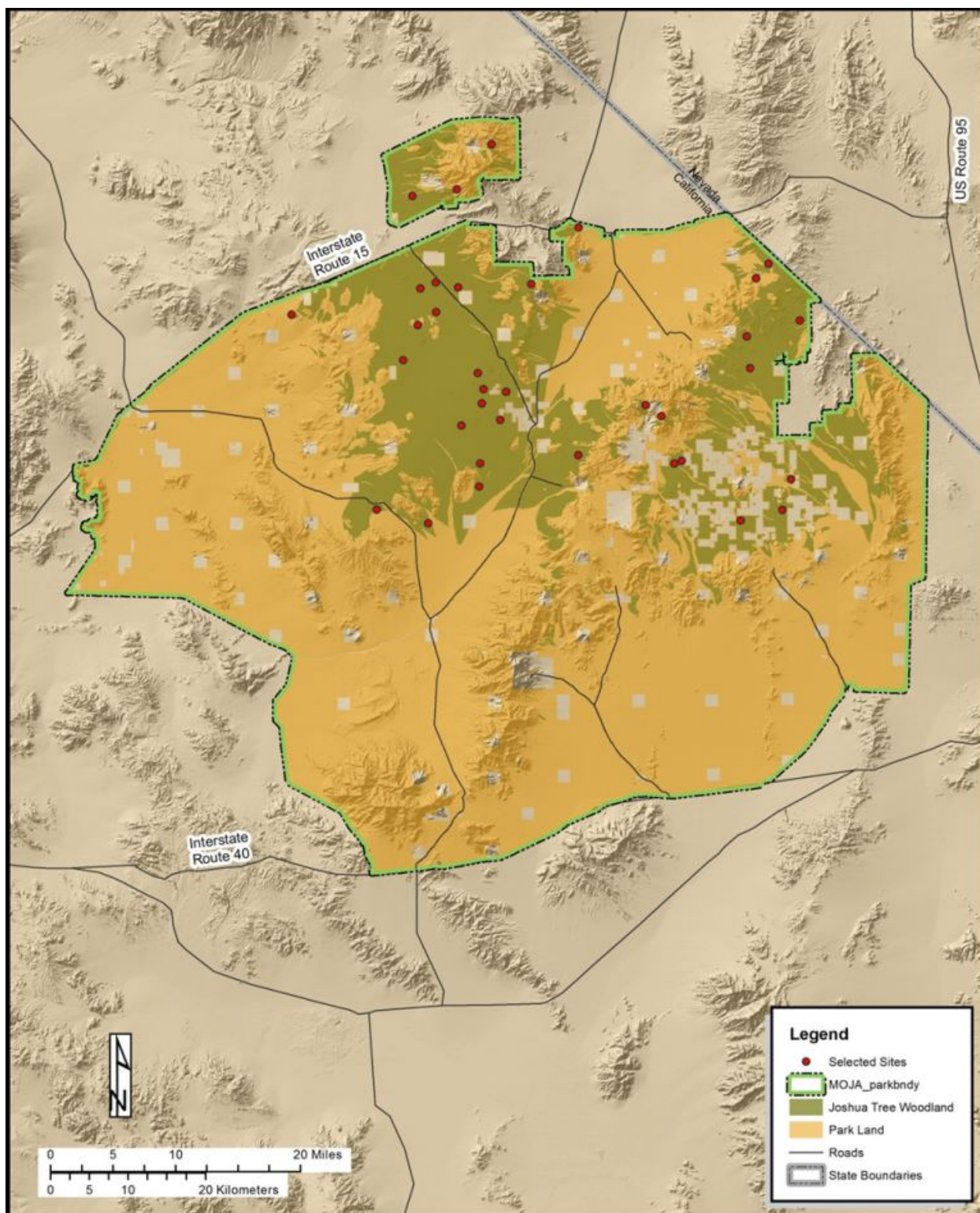


Figure 2.6. Generalized Random Tessellation Stratified (GRTS) draw for Mojave National Preserve. The distribution of the first 35 field sites across the Joshua tree (*Yucca brevifolia* var. *jaegeriana*) wooded scrubland community is shown.

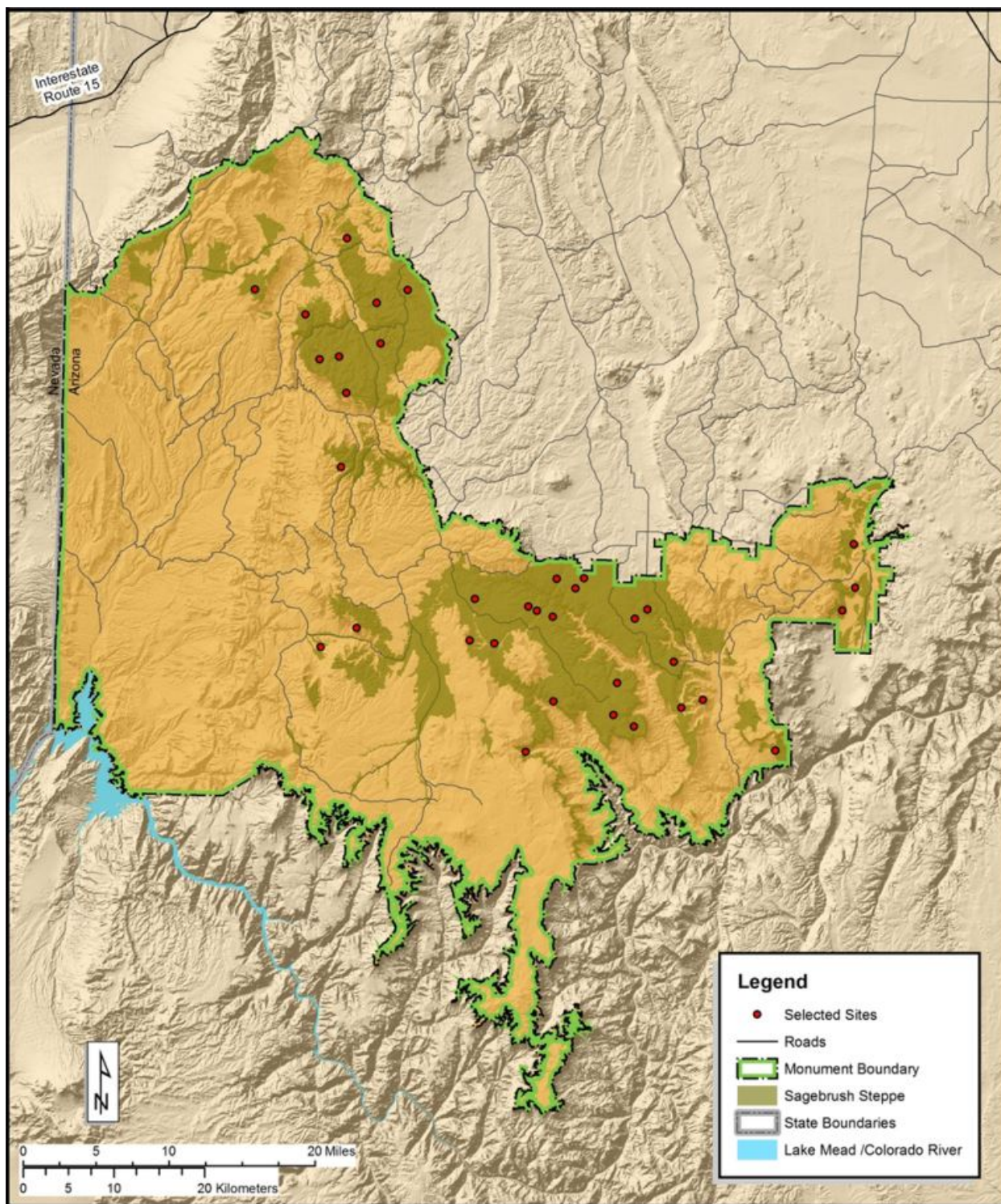


Figure 2.7. Generalized Random Tessellation Stratified (GRTS) draw for Grand Canyon-Parashant National Monument. The distribution of the first 35 field sites across the sagebrush (*Artemisia* spp.) shrub steppe community is shown.

2.2. Response Design

The response design is the process by which measurements are chosen for monitoring, obtained in the field, and summarized for analysis (Stevens and Urquhart 2000). While there are many potential measurements that can be taken in upland communities, we have chosen to minimize the number and detail of measurements taken within macroplots in an effort to increase the number of macroplots (i.e., replicates) sampled. Our goal is to have a minimum of one macroplot sampled per day, including traveling time to and from the macroplot. Our permanent macroplot design is based on the design used by the Northern Colorado Plateau I&M Network (NCPN) in their upland communities (Witwicki et al. 2010, based on Herrick et al. 2005). Permanently marked sample units can be directly compared through time and have more powerful statistical tests for detecting change (Elzinga et al. 2001). The spatial distribution of macroplots is described in section 2.3 *Sample Size and Spatial Design*.

Vegetation and invasive plant status and trends data are recorded along three parallel, 50-m transects spaced 25 m apart that are within a 100 m by 100 m macroplot (Figure 2.1). End locations of transects are permanently marked with rebar. Percent cover of vegetation (by shrub species, life forms, and targeted invasive species), soil surface features, and disturbance will be measured using a point-intercept method at every meter along the transect. Canopy and basal-gap measures between perennial plants are acquired along each transect using a line-intercept method. Frequency of targeted invasive species will be assessed using 0.25 by 0.25 m quadrats, placed every 1 m along the transects. An assessment of disturbance will also be made within the quadrats.

Additional vegetation and invasive plants data are collected at the macroplot level through a patterned walk. Macroplot-level vegetation data consists of a quick “tree” count and will only be collected for specific plant communities (e.g., Joshua tree woodlands). We included a tree count because we found that species with tree-like life forms were greatly under-detected in a pilot study testing the field methods of this protocol (Pan and Tallent 2013, 2014).

Sampling of soil parameters will be made at 12 points along the perimeter of each macroplot. There will be three sampling points per side of the macroplot (Figure 2.1). In the first year, the sampling points will be regularly spaced. In subsequent years, three points will be randomly located along each side of the macroplot (see *SOP 11 – Soil Measurements* for details).

Repeat photographs will provide qualitative data on vegetation changes within each macroplot. There will be one photograph taken of each transect and one overview photograph taken of the macroplot, all focusing on the vegetation (see *SOP 13 – Repeat Photos* for details). Soil erosion will also be evaluated with erosion specific photographs and a repeat overview photograph of the macroplot focusing on the soil.

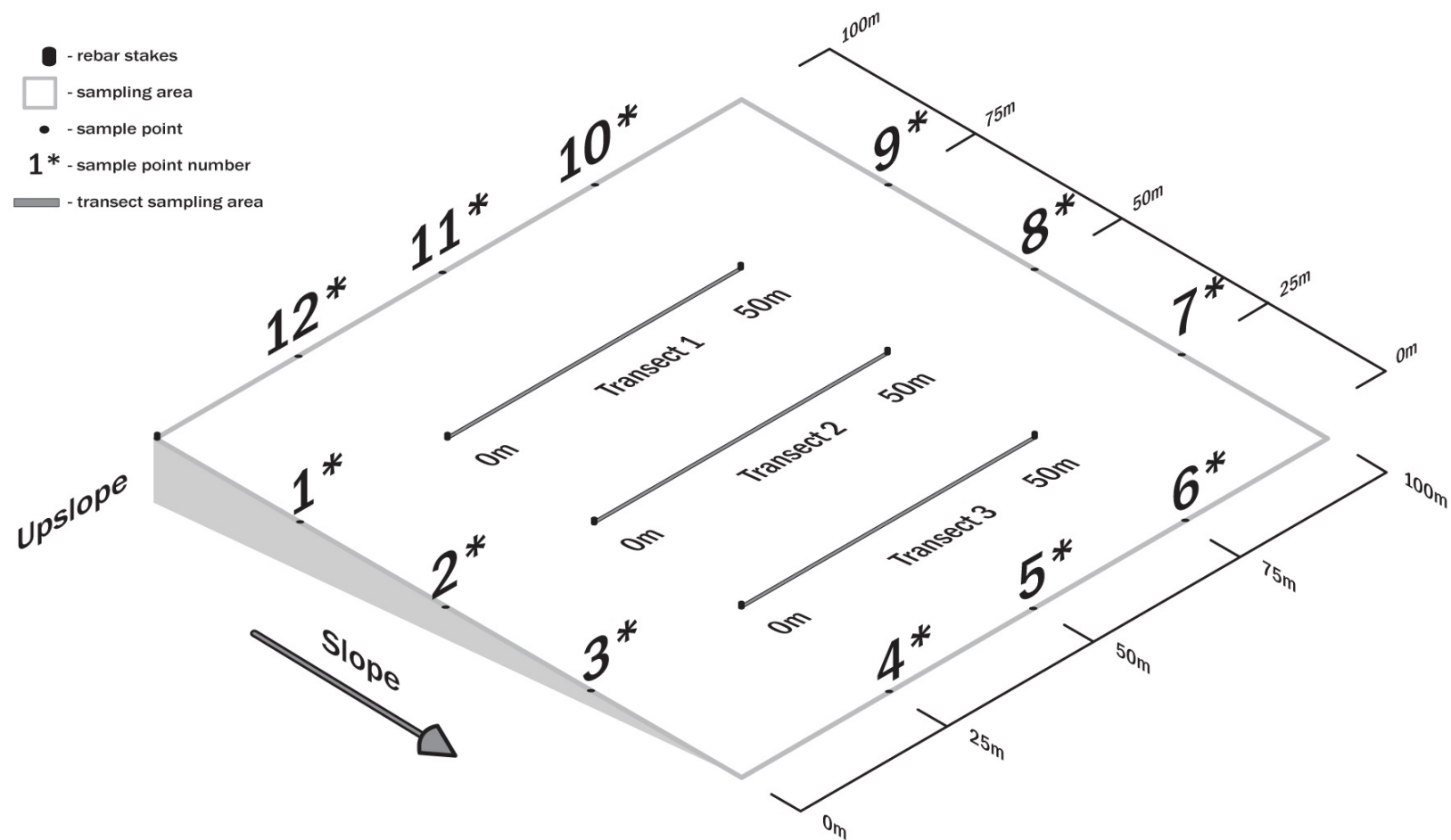


Figure 2.8. Standard macroplot and transect layout for upland monitoring. Locations on the edge of the macroplot indicated by an "*" are sampling locations for soil parameters. The number next to the "*" is the sampling location number.

Below we provide brief descriptions of the specific parameters that will be used to characterize upland communities and meet the measurable objectives of this protocol; this suite of parameters was selected based on scientific, logistical, and monetary considerations.

2.2.1. Vegetation

The primary vegetation measurements that we will use to characterize vegetation changes in upland communities will be determined along three transects within each macroplot. Absolute cover estimates by shrub species and plant life form will be taken using the point-intercept method. This method is considered to be the least biased method for estimating vegetation cover compared to ocular estimates and the line-intercept method (Elzinga et al. 2001). At each of the sampling points, soil surface features (e.g., biological soil crusts, rocks, etc.) will also be recorded. Spacing between perennial plants will be assessed by measuring canopy and basal gaps between shrub species.

Cover estimates: Cover is a measure that is closely linked to biomass and can provide an estimate of whether productivity is changing in upland communities (Elzinga et al. 2001). Data from this protocol will be used to monitor whether there are changes in cover for different shrub species and for different life forms. Differences in cover can indicate that conditions may be changing in upland communities. For instance, if cover of trees is increasing, with a concomitant decrease in other life forms, such as shrubs and grasses, this may indicate that there is tree encroachment in the community.

Shrub richness and composition: Since shrubs are the dominant physiognomic class in the selected upland communities, we will evaluate changes in shrub species numbers and composition through time to understand whether species replacement, encroachment, or both is occurring. Species that characterize a community and have tree-like growth forms (i.e., Joshua trees) will also be assessed with a count of the number of individuals on the macroplot (*SOP 12 – Site Assessment for Invasive Plant and Target Tree Species*).

Soil surface features: An important soil surface feature in desert systems are BSC. They contribute to upland communities through carbon fixation via photosynthesis, nitrogen enrichment of soils through biological nitrogen fixation, and secrete compounds to increase phosphorus availability (Rosentreter et al. 2007). BSC also play an extremely important role in stabilizing soil because crusts live within or on the surface of soils, adhering to soil particles and reducing their movement. Changes in BSC cover could have important effects on upland communities, including soil and nutrient losses. Because of the importance of BSC and its poor detection with the point-intercept method (Pan and Tallent 2013, 2014), we will also assess BSC in the frequency for targeted invasive species quadrats (*SOP 10 - Assessing Invasive Plant and Disturbance Frequency Using Quadrats*).

2.2.2. Soil

Soils parameters will be measured and described in accordance with the procedures developed by the Natural Resources Conservation Service (NRCS) and described in Schoeneberger et al. (2002). The NRCS procedures are the recognized standard methods for describing and sampling soils by practicing soil scientists. Only methods described in Schoeneberger et al. (2002) are included in this protocol in order to have data that is easily understood and interpretable world-wide.

The seven soil parameters that will be measured for this protocol are described below. Although soil properties are generally slow to change, we specifically chose these seven parameters because they provide important information about the soil, can act as a proxy for other soil properties, or they may change within a relatively short period of time. For example, soil texture, color, and consistence have been shown to change in just a few years (Graham and Wood 1991, Ulery and Graham 1993). Graham and Wood (1991) experimentally demonstrated that plant species can change soil texture in as little time as 41 years and that, starting from the same soil material, soil texture varied depending on the plant species growing in it.

Soil strength: Soil compaction is often measured by soil strength, since soil compaction is accompanied by increases in both soil bulk density and strength. With increasing soil compaction, macropore space is reduced to the point where root growth is inhibited and plants may die (Dubbin 2001). Another important consequence of increased bulk density is reduced capacity of soil to take in water and increasing erosion via surface runoff (Brady and Weil 2004). We will quantify soil strength by measuring the force needed to insert a penetrometer into the soil.

Quantity of carbonates: Soil chemistry can affect many soil properties, such as soil fertility and water holding capacity. Carbonates are common in desert soils because water dissolves carbonates from rock or soil particles and, as the water evaporates, large amounts of carbonates can be left behind. Carbonates play an important role in buffering soil pH (Natural Resources Conservation Service 2011) by interacting with acidic solutions (Bloom 2000). Carbonates may also facilitate the formation of soil aggregates by acting as a cementing agent, and may enhance surface stability (Dubbin 2001). We will be measuring the abundance of carbonates (e.g., CaCO_3) in soils using an effervescence test (see *SOP 11 – Soil Measurements*). Changes in carbonates through time may indicate that there are substantial changes in annual rainfall, as carbonates can be lost through leaching. The loss of carbonates would lead to changes in soil pH and affect soil chemistry.

Soil consistence: Soil consistence describes the response of a soil to pressure and its adhesion to objects upon contact (Buol et al. 1997). Specifically, it is defined as the degree and kind of cohesion and adhesion exhibited by the soil, or the resistance of soil to deformation or rupture under an applied stress (Schoeneberger et al. 2002). Soil consistence can be used to determine the resistance of soil to mechanical and natural (e.g., wind, water) stresses. Thus, soil consistence data can also be used to evaluate soil erosion.

In the field, evaluations of consistence include Rupture Resistance (Blocks, Peds, and Clods or Surface Crusts and Plates), Stickiness, and Plasticity (see *SOP 11 – Soil Measurements*). Rupture resistance is an evaluation of the force required to rupture or break a moist and dry soil aggregate. The stickiness of the soil refers to the capacity of the soil to adhere to other objects; soils with a high content of clay are often very sticky. Plasticity is an estimate of the soil's ability to deform without rupturing and is evaluated by forming a roll or wire with the soil and seeing how easily it is deformed. We will also evaluate soil color of the aggregates used for rupture resistance. Soil color provides information about the history and chemical composition of soils.

Soil texture: Soil texture is defined as the “relative proportions of the various soil separates (i.e., sand, silt, and clay-sized particles) in a soil” (Soil Science Society of America 2008). The textural classification may be modified by the addition of adjectives when particles >2 mm in diameter compose more than 15% of the soil material. Soil texture is likely the single most important variable determining surface stability, susceptibility to erosion, and several other fundamental soil properties (Dubbin 2001, Brady and Weil 2004). For example, silt-rich soils are highly susceptible to both wind and water erosion. Soil texture has a profound influence on many other soil properties including water holding capacity, aeration, drainage, ability to store nutrients, and many others (Kay and Angers 2000).

pH: Soil pH is often referred to as the “master variable” of soils because of its significant effects on a number of chemical reactions and processes (Bloom 2000, Sparks 2003). In acidic soils, generally defined as soils with a pH <5.0 to 5.5, macronutrient availability and microbial activity are restricted, aluminum (Al), iron (Fe), and manganese (Mn) become more soluble and may be toxic to plants, and the solubility and mobility of many potentially toxic trace elements is increased (Bloom 2000, Sparks 2003). Plants may also suffer nutrient deficiencies in soils with pH ≥ 8.5 .

Electrical conductivity: Electrical conductivity (EC) is the preferred index to evaluate soil salinity (Sparks 2003, Essington 2004). Soluble salts may accumulate in soils because there is insufficient water to leach soluble salts from the soil. Salinity can be high in arid regions due to high evapotranspiration rates, as salinity will increase as long as evapotranspiration exceeds leaching by rainfall. Increasing salinity may indicate a degradation in soil quality as it can lead to reductions in plant growth and production. Historically, a soil was classified as being saline if the EC exceeded 4 dS m⁻¹ (Essington 2004). More recently, threshold EC levels have been defined to indicate which types of crops can tolerate differing levels of soil salinity. For sensitive crops, saline soils are defined as having an EC >1.5 dS m⁻¹; EC >3.0 dS m⁻¹ for moderately sensitive crops; EC >6 dS m⁻¹ for moderately tolerant crops; and EC >10 dS m⁻¹ for tolerant crops.

Soil erosion: Erosion refers to the removal of the land surface by rainfall, wind, ice, or other natural or anthropogenic agents that abrade, detach, and remove geologic parent material or soil from one point on the earth’s surface and deposit it elsewhere (Soil Science Society of America 2008). While soil erosion is a natural process, accelerated loss of soils will lead to soil degradation, i.e., losses of the nutrient-rich upper horizons (which are also biologically active) and reduced water holding capacity.

We will evaluate both quantitative and qualitative soil parameters to assess soil erosion. Quantitative soil erosion parameters will be used to assess trend, while qualitative parameters will be used to assess status and as supporting data for trends. We will evaluate soil erosion quantitatively by estimating soil loss using macroplot permanent markers as “soil erosion pins” (Keay-Bright and Boardman 2009; see *SOP 11 – Soil Measurements*) and evaluating basal and canopy gap sizes (i.e., more and larger gaps indicate greater potential for soil erosion). We will evaluate soil erosion qualitatively by evaluating soil consistence and texture parameters for soil erosion potential (e.g., change in rupture resistance categories) and visually identifying, estimating the degree, and photo documenting the different types of erosion on macroplots.

2.2.3. Invasive Plant Species

Invasive species can have widespread effects in terrestrial systems, from displacing native species to changing ecosystem properties. In the MOJN park uplands, annual invasive plants (e.g., red brome) are a significant threat to the long-term stability of these communities by increasing fine fuel loads in and around shrubs, thereby increasing fire frequency and intensity (Brooks 1999, 2003, Brooks et al. 2004). In this protocol, we monitor the status and trends of invasive plant species that are relatively widespread and common (i.e., in the “spread” and “equilibrium” phases of population growth, Figure 1.2; see *MOJN I&M SOP M2 – Prioritizing Invasive Species for Status and Trends Monitoring* for details). Given that many invasive or non-native plant species are considered common in the MOJN parks, invasive species were prioritized using the procedure outlined in *MOJN I&M SOP M2 – Prioritizing Invasive Species for Status and Trends Monitoring* and high priority species were “targeted” for monitoring.

The assumed ubiquity of widespread invasive species has often led to the underreporting of these species during invasive plant surveys since these species are not prioritized for control or control efforts are not feasible (Abella et al. 2009). Moreover, negative data (or where species are absent) is rarely recorded. However, negative data have as much value as positive data in our understanding of distributions and habitat modeling (Václavík and Meentemeyer 2009). Assessing the status and trends of established invasive species will provide data on the spread and trajectory of these populations through time. Data for targeted invasive species includes cover estimates from the point-intercept method, frequency and phenology estimates within 0.25 by 0.25 m quadrats placed along transects, and a patterned walk within the macroplot (*SOP 12 – Site Assessment for Invasive Plant and Target Tree Species*).

Cover estimates: Changes in invasive species cover can indicate whether the species is increasing or decreasing in the community or whether the environment is becoming more or less favorable for the invasive species. We can also compare the relative cover of invasives between canopies and canopy gaps (a.k.a., interspaces) by integrating measurements of target invasives in the point-intercept method and invasive species frequency quadrats measures. These two microsite types, canopy vs. interspaces, are important drivers of invasive annual abundance and distribution (Holzapfel and Mahal 1999, Craig et al. 2010). Several target invasive annuals are found disproportionately beneath shrub canopies, but after several years of above-normal precipitation, these species (e.g., red brome) may fill the interspaces, creating a bridge of fuel between shrubs and promoting potentially devastating wildfires (Brooks 1999). Detecting changes in microsite distribution could lead to better predictions of where fuel loads are either increasing or decreasing and provide data that can tie in with the future *MOJN I&M Fire and Fuels Dynamics* protocol.

Frequency estimates: Frequency of invasive species occurrence will be measured as the proportion of quadrats with cover >0% for a target invasive species. Frequency complements cover estimates by providing a greater area that is monitored. Frequency estimates may also be less biased than cover estimates because it is dependent only on the presence or absence of a plant, regardless of abundance or biomass (Smith et al. 1986, Heywood and DeBacker 2007). It is particularly useful for monitoring annual invasives, which tend to exhibit less stringent precipitation requirements (Beatley 1966,

1974b, Gutierrez 1992, Brooks 1999) than most native annuals and tend to be the dominant annual plants in dry years (Brooks 1999). Beatley (1974b) found that red brome may vary in population size from year to year, but unlike most native annuals, it was always present every growing season.

The dominant phenological stage of target invasive species will also be assessed within each quadrat. Data on the timing of seedling establishment, plant growth, and seed dispersal will help us to understand the within season and between year trajectory of invasive species spread. Understanding when invasive species, particularly annual grasses, are active or senescent, may help us to initiate more effective control measures against incipient invasive species and also contribute to our understanding of the timing and intensity of potential fire events.

Within quadrats, the presence of soil disturbances, such as tracks and trails (see *SOP 10 - Assessing Invasive Plant and Disturbance Frequency Using Quadrats* for details), will also be measured. Because disturbance plays an important role in the facilitation of plant invasions, these data can be used to understand how disturbance type and magnitude affect plant invasions in the Mojave Desert and in invasive plant habitat modeling.

To effectively detect changes in frequency, it is suggested that frequency estimates should be between 20 to 80% (Despain et al. 1991). In the first few monitoring cycles, we will start with 50, 0.25 by 0.25 m quadrats per transect for a total of 150 quadrats per macroplot. Afterward, we will reassess and may increase the number of quadrats in order to ensure that we have enough quadrats to adequately detect change.

Patterned walk: Field crews will conduct a patterned walk of the macroplot to search for target invasive species that were not found on all three transects. Specifically, crews will walk around the edge of the macroplot, halfway between transects 1 and 3 and the edge of the macroplot, and halfway between transects 1 and 2 and 2 and 3 (Figure 2.8; see *SOP 12 – Site Assessment for Invasive Plant and Target Tree Species* for more details). For each invasive species sighting, crews will record: species code for the plant sighted, population dispersion type, cover estimate, and dominant phenological stage of the target invasive species within the macroplot. Crews will also plot the invasive plant sightings on a diagram of the macroplot. This data will provide a more comprehensive view of the extent of invasion in the macroplot and some spatial data to track invasive plant spread over time.

2.3. Sample Size and Spatial Design

2.3.1. Power Analysis for Sample Size

To determine a sample size suitable for detecting change of a given magnitude within each park, we conducted a power analysis using existing, suitable vegetation datasets from each park (see Appendix B for more details). Power analyses use estimates of status and variance composition from available data to determine the power of detecting a given level of change for a particular sample size and Type I error rate.

We conducted power analyses to detect 1% and 4% annual change in vegetation cover. We used a revisit design where each park is visited every three years (a [1-2] revisit design), with two parks visited each year. The power analyses results were provided for two monitoring periods, 20 and 30 years; here, we focus on the 20 year monitoring period results, as it provides a more reasonable time frame for park management needs.

For most parks, we would be able to detect 4% annual change with high power (>80%) with fairly low sample sizes (<10 plots, Figures 2.2, 2.3). However, 4% represents fairly high change at a net decline of 56% over 20 years. Thus, we will use the results from the 1% annual change, which is more conservative since it simulates a more realistic level of change detection at a net decline of 26% after 20 years.

The number of plots needed to detect 1% annual change over 20 years with 80% power ranged from ~30 plots (LAKE; Figure 2.2) to >80 plots (DEVA; Figure 2.3). Data from the three parks (GRBA, LAKE, MOJA) that used point-intercept methods more consistently indicated adequate power for small sample sizes (data not shown for GRBA, MOJA; see *Supplementary Materials – Power Analysis*). Necessary sample sizes were higher and more variable for DEVA, JOTR, and PARA (data not shown for JOTR, PARA; see *Supplementary Materials – Power Analysis*), where data were collected with different response designs (e.g., ocular estimates in quadrats). We expect that power to detect trend is more accurately reflected by analyses computed from variance component estimates obtained from data collected using point-intercept methods. Taking into account available sampling times and logistical constraints, we propose to start with a **sample size of 35** for all parks, except MANZ, and will re-run power analyses for parks, particularly DEVA, JOTR, PARA, after field implementation. Given its size and statistical needs, we propose a sample size of 2-4 plots for MANZ.

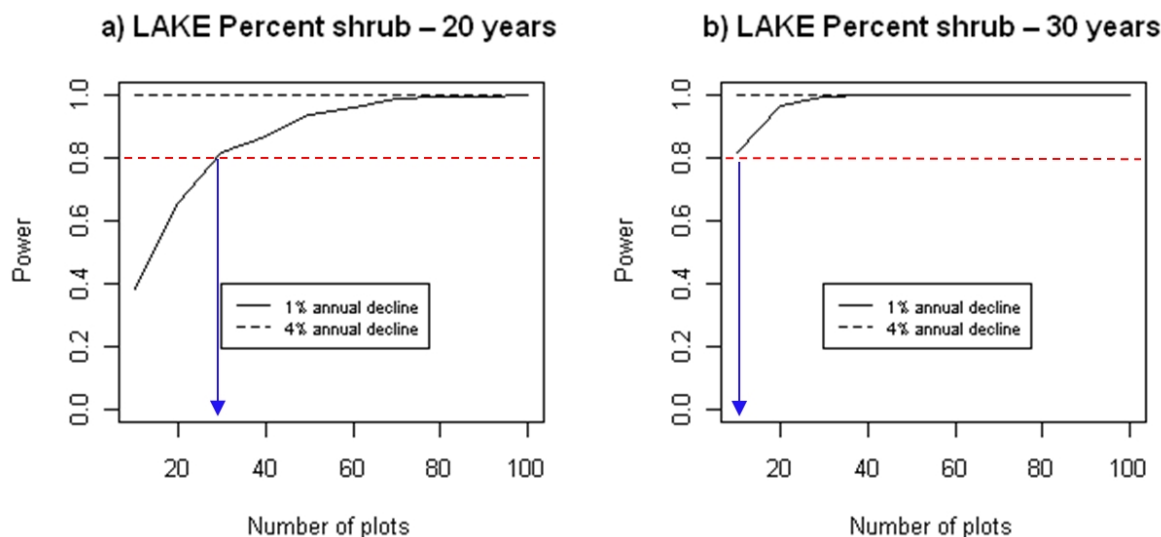


Figure 2.9. Simulation of power for trend testing at LAKE to detect annual change of 1% (solid line) and 4% (dotted line) in log(% shrub cover) metrics for a 1-2 revisit design (parks sampled every 3 years) over a) 20 years and b) 30 years. The approximate number of plots needed to have 80% power to detect change is indicated by the arrow.

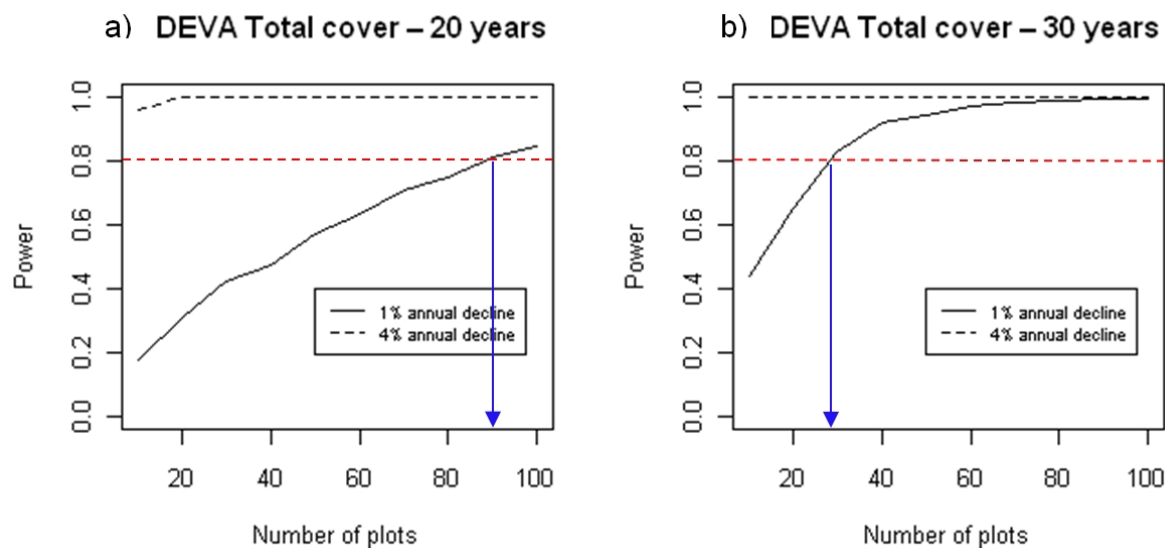


Figure 2.10. Simulation of power for trend testing at DEVA to detect annual change of 1% (solid line) and 4% (dotted line) in log(total cover) metrics for a 1-2 revisit design (parks sampled every 3 years) over a) 20 years and b) 30 years. The approximate number of plots needed to have 80% power to detect 1% annual change is indicated by the arrow.

Most of the available pilot data sets were collected in a single year and do not provide the basis for estimating year-to-year variation. Therefore, most of the power approximations examined in our analysis cannot account for this variance component, which can greatly impact the power to detect trend (Urquhart and Kincaid 1999). In order to assess whether our sample size is adequate for trend detection, we will reexamine the power to detect trend as a function of sample size after all parks have been visited at least three times. Revised power analyses based on the full suite of variance components will reveal if additional plots are necessary.

Vegetation and soils data may have substantially different variance, which may lead to different estimates of sample size needed to detect change for vegetation and soils. If power analyses for vegetation and soils data indicate drastically different sample sizes, we will consider both statistical and logistical constraints. The assessment for the vegetation data will take precedent, as the primary focus of this protocol is vegetation and the vegetation vital sign is of higher ranking than the soils vital signs. If the number of sampling plots estimated to detect change for soils is not logistically feasible (e.g., it would not be possible for us to sample 100+ macroplots per park each year), then we could increase sampling frequency for the soils parameters (e.g., annually instead of every three years). High site-to-site variation can be eliminated in a design in which each site is visited annually (Piepho and Ogutu 2002). However, given the disturbance caused by soil sampling, it is unlikely that annual sampling would be feasible, so consistent sampling over time may be the only method of overcoming a large variance component in long-term monitoring.

For soil sampling, we will use the coefficient of variation (CV) to evaluate whether more within macroplot samples are needed. Because soils can be extremely heterogeneous over very small spatial scales (Schlesinger et al. 1996), we will evaluate the variability of soil parameters using CV in

upland macroplots after the first year to determine whether 12 samples adequately represent a macroplot. If CV values indicate high variability (~25-50%), then soil sample sizes will be adjusted accordingly (Mulla and McBratney 2000). We will also use CV to assess the variability of soil parameters across years to determine how often soil parameters need to be sampled. Soil parameter data will be analyzed after the second monitoring cycle to help with future revisit design.

2.3.2. Spatial Design

Many of the parks in MOJN are extremely large and some areas of the parks may be very difficult to access safely. LAKE, MOJA, and PARA are over 400,000 ha (1 million ac) each and DEVA over 1.3 million ha (3 million ac). Thus, it is extremely important that we adopt a robust sampling design that will provide adequate spatial representation of the vegetation communities across the parks. Similar to many other NPS I&M networks, we have elected to use a spatially-balanced, probabilistic sampling design, specifically, the generalized random-tessellation stratified (GRTS) design (Stevens and Olsen 2004). With this design, sites are spatially dispersed over the population of interest so that sites maintain spatial independence. Moreover, the GRTS design is flexible, efficient, and statistically robust. It allows for the inclusion of new sample locations in response to sampling frame error, the unforeseen loss of plots, sampling design complexity, such as stratification or cluster sampling, or greater sampling with increased funding, while maintaining spatial balance.

Spatial data used for the GRTS draw and considered the population of inference is described in section 2.1 *Population of Inference*. Since we will reassess the number of plots to be monitored after implementation, we will have an initial draw of 35 sites for each park (except MANZ), with an oversample of 250 sites, which allows for elimination of sites due to sampling frame errors arising from map inaccuracies, as well as the addition of sites in the future. Before field implementation, we will use imagery to conduct office reconnaissance on the potential field locations and to eliminate any sites that are unsuitable (e.g., unsafe, inaccessible, incorrect habitat such as springs) in order to increase the productivity of field crews. Sites may also be rejected after field crews physically visit sites (see *SOP 6 – Site Characterization* for details on how field crews will evaluate whether field sites are acceptable for long-term monitoring). In both of these cases, site rejection is considered as nonresponse error and will be taken into account during statistical analyses (see *SOP 19 – Data Analysis and Reporting*).

2.4. Sampling Frequency and Timing

We adopt the terminology defined by McDonald (2003) to describe revisit designs. Specifically, we use the terms *panel* (group of units that are always sampled together) and *revisit design* (planned pattern or schedule of visits to units within a panel). Given the large size of the MOJN parks, we plan on monitoring all macroplots for two parks each year (three parks per year when MANZ is in the rotation), resulting in a three year monitoring cycle (Table 2.2). This revisit design will provide sufficient revisits within each park for trend analysis in a reasonable time frame, allow for increased time spent in each park if more plots are needed, and balance the substantial logistical and financial constraints of having extensive field travel within and between parks. Having a two year break between sampling periods for each panel also reduces potential disturbance from frequent repeat visits and measuring community responses to the frequency of monitoring (McDonald 2003). During

initial macroplot set-up, we will have at least five crew members, one field lead and four crew members, in order to accommodate the extra work involved in establishing field macroplots. In subsequent years, field crews will consist of one field lead and two crew members (see section 6. *Personnel Requirements and Training*).

The growing season for a majority of the MOJN parks will be fall through spring, with the exception of GRBA, which has a summer growing season. PARA also represents a special case as it receives snow in the winter but is extremely hot in the summer and often has summer monsoons that make its unpaved roads impassable. Thus, our field season will depend on which parks will be visited each year. Our proposed park rotation schedule is outlined in Table 2.2.

Although the fall sampling period will start relatively early in the growing season before all plants are out, it should have few effects on our measurements of upland communities as we focus on perennial plants. Moreover, some of our targeted invasive annual plants (e.g., grasses such as red brome and cheatgrass) should be identifiable, since they have fairly recalcitrant remains that generally persist for a year or two after they senesce (Hunter 1991).

Table 2.2. Proposed park monitoring schedule by year and season. At the end of year 3, the cycle will return to year 1. “W” stands for winter, “Sp” for spring, “Su” for summer, and “F” for fall. Cells with a “--” indicate periods when crews are not in the field. Initial implementation can start during any season or with any park and will depend on logistical constraints.

Year Season	Year 1			Year 2			Year 3		
	W-Sp	Su	F-W	W-Sp	Su	F-W	W-Sp	Su	F-W
Park	DEVA / MANZ	--	PARA*	--	GRBA*	MOJA*	JOTR	--	LAKE

*Start monitoring these parks as early as the weather permits.

Once macroplots are established within each park, MOJN I&M will establish a macroplot revisit order for each park that will be followed for all subsequent visits (see section 3. *Field Methods* for details). This macroplot revisit order will be flexible during the first few revisits to allow for the addition of sampling sites (macroplots) if necessary. We anticipate that after this initial period, the revisit order will be fairly fixed in order to consistently obtain replication over time and optimize power to detect trend in any given park.

2.5. Benefits of the Selected Design

The proposed sampling design and measured parameters reflect a reasonable and logistically feasible compromise of the priorities of the MOJN I&M monitoring program, available resources, and constraints associated with field sampling, while providing statistical robustness and scientific rigor. We also have greater sampling flexibility because of the modular design of our approach, which treats vegetation, soils, and invasives measurements as separate procedures. As we learn more about the variation in our upland communities after the initial few visits, we can increase the time between revisits for some parameters (e.g., soil) and retain revisit times for other parameters (e.g., invasives), while still addressing monitoring questions and meeting monitoring objectives.

Variations of the proposed macroplot design have been effectively used by other networks in similar environments (e.g., NCPN, Sonoran Desert Network). Most of the proposed vegetation and invasive plant response design methods are based on *The Monitoring Manual for Grassland, Shrubland and Savannah Ecosystems* (Herrick et al. 2005). These methods have been utilized by a number of agencies for monitoring rangeland health for many years, are amenable to small field crews, easy to learn, and highly repeatable (Miller et al. 2007). Furthermore, the selected vegetation parameters are commonly measured in vegetation studies (Elzinga et al. 2001). The proposed soil field methods are standardized by the NRCS and will allow us to compare soil parameters from MOJN parks to soil parameters taken at other locations world-wide.

The GRTS sampling approach provides sampling sites that are randomly selected but spatially dispersed across the landscape. It also provides greater flexibility with the ability to increase or replace sample plots in future years without affecting the spatial balance of the sample population. For instance, in years where full implementation of the IU protocol cannot be completed due to unforeseen circumstances, the remainder of the sampling sites can be filled in the following field season or the next time that the park is scheduled for monitoring. Moreover, variable probability sampling may be incorporated into the GRTS design. Neighborhood variance estimates, which account for the GRTS design, were found to be 22% to 58% smaller than variances computed assuming an independent random sample (Stevens and Olsen 2003).

3. Field Methods

3.1. Standard Operating Procedures

The Standard Operating Procedures included in volume 2 of this protocol (*Integrated Upland Protocol of the Mojave Desert Network, Volume 2, Standard Operating Procedures*) provide step-by-step field sampling methods, logistics, data collection and entry methods, data management, and data analysis and reporting procedures (Table 3.1). SOPs are organized by field sampling procedure and activities. For example, all activities to be performed by the crew each day are outlined in *SOP 3 – Daily Field Activities*. Personnel that are part of the IU protocol are required to have read and be familiar with the IU-specific SOPs and any network-wide SOPs that are mentioned as part of the IU SOPs, in particular *MOJN I&M SOP M4 – Safety* and *MOJN I&M SOP M3 - GPS*.

Table 3.1. Standard Operating Procedures (SOPs) for the IU protocol.

Title	Description
SOP 1: Preparations and Equipment Setup Prior to the Field Season	This SOP outlines tasks and equipment preparation and purchases that need to take place before the field season begins.
SOP 2: Training Observers	This SOP describes the training that MOJN I&M will provide field crews in field methodology and data management procedures for the IU protocol.
SOP 3: Daily Field Activities	This SOP provides the procedures that field crews must follow each field day.
SOP 4: Spatial Data Naming Conventions	This SOP describes how to name spatial data on the GPS unit and how to name it once it has been downloaded and converted into appropriate formats.
SOP 5: Crust-Friendly Field Procedures	This SOP describes the procedures that crews must follow to minimize disturbance to BSC.
SOP 6: Site Characterization	This SOP describes the procedure for determining whether a site is suitable for monitoring.
SOP 7: Macroplot Establishment and Revisit Set-Up	The SOP describes how to set-up a macroplot for the first time and for revisits.
SOP 8: Measuring Cover of Vegetation and Soil Surface Features Using Point-Intercept Sampling	The SOP describes how to measure vegetation and soil surface features and disturbances using the point-intercept sampling on transects.
SOP 9: Measuring Basal and Canopy Gaps Using Line-Intercept Sampling	The SOP describes how to measure basal and canopy gaps between perennial plants on transects.
SOP 10: Assessing Invasive Plant and Disturbance Frequency Using Quadrats	The SOP describes the procedures for assessing invasive plant, BSC, and disturbance frequencies using quadrats along transects.
SOP 11: Soil Measurements	The SOP describes how and where to take soil measurements along the edge of the macroplot.
SOP 12: Site Assessment for Invasive Plant and Target Tree Species	This SOP describes procedures for a patterned walk to search for target invasive and tree species not found on transects.
SOP 13: Repeat Photos	This SOP describes the photos that need to be taken for monitoring and how to set-up photopoints for repeat photos.
SOP 14: Unknown Shrub Species	This SOP describes the procedure for handling unknown shrub species found during sampling.

Table 3.1. Standard Operating Procedures (SOPs) for the IU protocol (continued).

Title	Description
SOP 15: End of Field Tour and Season Activities	This SOP describes each of the tasks that need to be completed at the end of the field day, tour, and season.
SOP 16: Information Management Workflow and Tasks	This SOP describes the workflow for acquiring and managing data from the field to data reporting.
SOP 17: Data Management	This SOP describes the procedures for managing data for the IU protocol.
SOP 18: Database Design	This SOP details and illustrates the relational database objects, structure, and data dictionaries.
SOP 19: Data Analysis and Reporting	This SOP details data analysis and reporting procedures, including annual reports and periodic comprehensive reports, for MOJN I&M.
SOP 20: Protocol Revision and Review	This SOP describes how to document revisions to the protocol narrative and SOPs.

3.2. Logistics

3.2.1. Permitting

NPS research permits (along with BLM research permits for PARA) are required for field implementation of the IU protocol at each MOJN park (DEVA, GRBA, JOTR, LAKE, MANZ, MOJA, PARA). The permitting process will need to be started early (~3-6 months) to allow for sufficient time for processing (see *SOP 1 – Preparations and Equipment Setup Prior to the Field Season*). It is crucial that the proper channels be followed in dealing with permits. NPS permits can be submitted online at: <https://irma.nps.gov/rprs/>.

After these permits have been granted, Investigator Annual Reports (IARs) are due every year prior to March 31. IARs can be submitted online at: <https://irma.nps.gov/rprs/>.

3.2.2. Hiring the Field Crew

Field crew members will be hired for each field season. This process needs to be started early (about 4-6 months before the beginning of the field season) to provide sufficient time for posting the job ad and running background checks so that field crew members will be available at the start of the field season. The hiring process and required crew skills are described in section 6. *Personnel Requirements and Training*.

3.2.3. Arranging for Training

Safety - Many of the field sites will be located in isolated areas, so it is critical that crews are well-versed in back-country safety and communication procedures. Back-country safety procedures and a Job Hazard Analysis (JHA) for the IU protocol can be found in Appendix A of *SOP 2: Training Observers in the Integrated Upland Protocol of the Mojave Desert Network, Volume 2, Standard Operating Procedures*. MOJN I&M will arrange for First Aid and Wilderness First Aid training for all crew members before they begin field work. Crew members will also be trained in the proper use of communication devices (e.g., radios, satellite phones, SPOT device).

4WD and back-country driving – One of the primary safety issues related to working in isolated areas is travel in remote areas. As part of crew training, MOJN I&M will arrange for all crew members to participate in 4WD and back-country driving training before beginning field work.

3.2.4. Field Season Preparations

The Field Lead is responsible for ensuring that preparations are made for the ensuing field season (see *SOP 1 – Preparations and Equipment Setup Prior to the Field Season* for details). Preparations include selecting field sites, office reconnaissance of field sites (for accessibility, disturbance, and safety criteria; see section 2. *Sampling Design* for more details), scheduling park and macroplot sampling schedules, scheduling field crew training prior to the field season, arranging for camping or park housing, acquiring back-country permits, coordinating with parks about when and where crews will be, preparing and ordering equipment, vehicle maintenance and preparation, and preparing field forms, park-level species lists, and other necessary documentation. The Protocol Lead or Field Lead will work with the GIS Specialist to insure that appropriate spatial data are prepared and provided to the crew, including maps and GPS units with UTM coordinates for all macroplots to be sampled.

Prior to entering the field, crew members must review the entire protocol, including the SOPs in the accompanying document *Integrated Upland Protocol of the Mojave Desert Network, Volume 2, Standard Operating Procedures*, and participate in a 2-week training session. The Field Lead must ensure that crew members understand all procedures and evaluate their understanding during the required training (*MOJN I&M SOP M4 – Safety; SOP 2 – Training Observers* and *SOP 3 – Daily Field Activities*). Training involves GPS procedures for navigating to macroplots (*MOJN I&M SOP M3 - GPS*), disturbance reducing procedures (*SOP 5 – Crust-Friendly Field Procedures*), macroplot layout and establishment (*SOP 7 – Macroplot Establishment and Revisit Set-up*), and all sampling procedures (including *SOP 8 – Measuring Cover of Vegetation and Soil Surface Features Using Point-Intercept Sampling*, *SOP 9 – Measuring Basal and Canopy Gaps Using Line-Intercept Sampling*, *SOP 11 – Soil Measurements*, and *SOP 13 – Repeat Photos*). The field crew will also practice plant identification and sampling techniques on sites that will be similar to monitored communities. Crews will also be trained in the identification of a list of target invasive species, which they will be on the look-out for as they travel to their field sites (*MOJN I&M SOP M1 – Reporting Incidental Observations of Incipient Invasive Species*). Crews are expected to pass competency tests before beginning field work.

3.3. Field Methods

Table 3.1 summarizes the field methods that will be implemented at each field site, from macroplot set-up to end of day check-in activities. The methods are summarized below and presented in detail in the SOPs, including field forms, in the accompanying document *Integrated Upland Protocol of the Mojave Desert Network, Volume 2, Standard Operating Procedures*.

3.3.1. Daily Field Activities

At the beginning and end of each field day, crew members will follow *SOP 3 – Daily Field Activities*. Crew members will prepare the field vehicle and all equipment for field activities each evening before field work. At the end of each day, crew members will double-check all field forms as part of data QA/QC to make sure that all data are legible and all fields have been completed

correctly. All electronic data files, including spatial and images, need to be backed up onto an external drive daily. Crews are expected to check in with the MOJN I&M office each evening by cell phone and/or satellite device.

3.3.2. Site Characterization, Macroplot Set-up and Revisit

The Protocol Lead and Field Lead will evaluate and provide an order for the field sites based on the GRTS draw. Sites must be visited in the order provided. Crews will navigate to a given location on the macroplot (origin of transect 1) using a GPS unit (see *MOJN I&M SOP M3 - GPS* for details) and assess whether the site is acceptable (see *SOP 6 – Site Characterization* for details). If a site is rejected, the crew will document why the site was rejected and proceed to the next site on the list. Macroplots are established (see *SOP 7 – Macroplot Establishment and Revisit Set* for details) only on acceptable sites.

During the first revisit, the Field Lead will establish a macroplot order that takes into account site phenology (e.g., lower elevation sites have earlier phenology than high elevation sites) and crew travel time. Once this macroplot schedule is created, all subsequent crews will follow the established order to reduce temporal/seasonal variation. Revisit procedures are described in *SOP 7 – Macroplot Establishment and Revisit Set-up*.

3.3.3. Vegetation Monitoring

There are four main SOPs related to upland vegetation community monitoring: *SOP 8 – Measuring Cover of Vegetation and Soil Surface Features Using Point-Intercept Sampling*, *SOP 12 – Site Assessment for Invasive Plant and Target Tree Species*, *SOP 13 – Repeat Photos*, and *SOP 14 – Unknown Shrub Species*. *SOP 8 – Measuring Cover of Vegetation and Soil Surface Features Using Point-Intercept Sampling* details procedures that will provide an estimate of overall vegetation cover, cover by life form, shrub species, or target invasive species, canopy complexity, and soil surface features. Point-intercept transects are 50 m in length, with data taken at each meter mark, for a total of 50 data points per transect. All plants intersecting the pin flag/stake at each point will be recorded by life form or shrub species. If the field crews come across shrub species they cannot easily identify, they will follow the procedure outlined in *SOP 14 – Unknown Shrub Species* to process and collect plant material.

To reduce trampling, all transect related procedures (*SOP 8 – Measuring Cover of Vegetation and Soil Surface Features Using Point-Intercept Sampling*, *SOP 9 – Measuring Basal and Canopy Gaps Using Line-Intercept Sampling*, and *SOP 10 – Assessing Invasive Plant and Disturbance Frequency Using Quadrats*) should be implemented sequentially on each transect, rather than completing one SOP at a time across the macroplot (i.e., completing SOP 8 on all transects and then completing SOP 9 on all transects).

The Joshua tree woodland community, selected for monitoring at JOTR and MOJA, is characterized by the Joshua tree, which has more of a tree-like life form. In order to provide data on this species, a quick count of “trees” will be conducted using the procedure described in *SOP 12 - Site Assessment for Invasive Plant and Target Tree Species*.

During each revisit, repeat photographs will be taken of the macroplot and each transect in order to qualitatively document vegetation changes on the macroplot. Procedures for the photos are described in *SOP 13 – Repeat Photos* and management of photos in *MOJN I&M DM SOP M11 – Image Management*. Photos from the previous sampling period can also be used to help with relocation of field sites.

3.3.4. Soils Monitoring

Changes in the soils vital signs will be addressed in: *SOP 8 – Measuring Cover of Vegetation and Soil Surface Features Using Point-Intercept Sampling*, *SOP 9 – Measuring Basal and Canopy Gaps Using Line-Intercept Sampling*, *SOP 11 – Soil Measurements*, and *SOP 13 – Repeat Photos*. Soil surface features are measured as part of SOP 8 and soil disturbances as part of SOPs 8 and 10. The potential for soil erosion is monitored in SOP 9. Canopy gaps are measured by recording gaps of at least 20 cm long between canopies of perennial plants along the 50 m transect. Basal gaps are recorded in a similar manner, working from the 50-m end back to the origin and recording each segment (≥ 20 cm) that lacks any plant base. How to photo-document the occurrences and types of erosion in the macroplot are described in *SOP 13 – Repeat Photos*.

Twelve locations along the perimeter of each macroplot will be measured for surface soil parameters. Sampling locations will be regularly spaced in the first year and randomly chosen in subsequent years. Small amounts of surface soil will be used to conduct the soil measurements. Seven soil parameters will be measured for each point: soil strength, abundance of carbonates, soil color, soil consistence, soil texture, pH, and electrical conductivity. Details on the sampling design and procedures are described in *SOP 11 – Soil Measurements*. Soil erosion will be assessed by measuring the height of soil pins (our permanent rebar markers; see *SOP 11 – Soil Measurements*) and the number and size of gaps between vegetation (*SOP 9 – Measuring Basal and Canopy Gaps Using Line-Intercept Sampling*).

3.3.5. Invasive Plant Species - Status and Trends Monitoring

Status and trends monitoring of target established invasive plant species will be conducted in each park. Determination and prioritization of target invasive species for each park is described in detail in *MOJN I&M SOP M2 – Prioritizing Invasive Species for Status and Trends Monitoring*. Specifically, status and trends invasive species are widely established, may be found in relatively undisturbed natural communities, and are abundant. Field crews will be provided with the target list of species for each park and a field guide to aid in species identification at the beginning of each field season. Target invasive species lists will be reassessed periodically (~3-5 years) to reflect new data on invasive species and park management goals.

An estimate of target invasive species cover will be obtained from three SOPs: the point-intercept (*SOP 8 – Measuring Cover of Vegetation and Soil Surface Features Using Point-Intercept Sampling*), which is described above, the invasive species frequency quadrats (*SOP 10 - Assessing Invasive Plant and Disturbance Frequency Using Quadrats*), and the site assessment for invasives (*SOP 12 - Site Assessment for Invasive Plant and Target Tree Species*) procedures.

Since soil disturbance plays an important role in plant invasions (e.g., Hobbs and Huenneke 1992, Burke and Grime 1996, Lozon and MacIsaac 1997), we will measure soil disturbance data along with invasive species data. The frequency of target invasive plant species, BSC, and soil disturbance features along each transect will be estimated using 0.25 by 0.25 m square quadrats placed at 1 m intervals along each of the 50 m transects (see *SOP 10 - Assessing Invasive Plant and Disturbance Frequency Using Quadrats*). Quadrats will be placed on the uphill side of the transect tape at the appropriate meter mark. Invasive species will be considered within the quadrat if they are at least 50% rooted within the frame. The dominant status (live vs. dead), phenological stage, and microsite location (canopy vs. interspaces) of the individuals within the quadrat will be recorded. The quadrat will be examined for the presence or absence of developed BSC. Finally, crews will record soil disturbance features found within each quadrat (*SOP 10 - Assessing Invasive Plant and Disturbance Frequency Using Quadrats*); features include both natural and anthropogenic disturbances, e.g., ant mounds, small animal burrows, and vehicle tracks.

Field crews will also search for target invasive species that occur away from transects using a patterned walk (*SOP 12 - Site Assessment for Invasive Plant and Target Tree Species*). Any target invasive species that were not found on all three transects will be monitored as part of the patterned walk. The patterned walk was designed so that crew members can scan the 25 m buffer zone from transects to the perimeter of the macroplot. For each target invasive species found, we will record the species code, describe the spatial distribution (dispersion) of the species, cover class, and dominant phenology across the macroplot.

3.3.6. End of Field Tour and Season Activities

Field crews will have tasks that need to be completed at the end of each field day, tour, and season (i.e., before heading to the next park). At the end of each field day, crews will need to account for and organize field forms, QA/QC field forms, organize any unknown specimens, make sure they have the necessary field equipment for the next day, and review site packet information for the next day. The following activities depend on whether there is access to electricity and/or a computer (e.g., returning to the office at the end of each day, car camping): backup data from camera, GPS unit, and recharge batteries or any electronic equipment. After returning to office, store site packets and field forms in designated location.

At the end of each field tour, all equipment that was in the field must be inspected for damage, decontaminated, and cleaned, replaced if necessary, consumables replenished, batteries recharged, computer returned to Data Manager, and GPS units returned to GIS specialist, and (see *SOP 15 – End of Field Tour and Season Activities* for more details). The vehicle must be thoroughly cleaned (inside and out) and inspected for mechanical issues and damage. If repairs need to be made, they should be made before the next field tour. Field forms must be checked again (to be sure that all are present), scanned, and placed in the designated location. Scanned field forms must be checked to make sure that everything is readable and in the correct order. If files/images were backed up on the computer in the field, then all files must be transferred to the designated location on the network drive. Other data management tasks may include renaming images, database, and GIS files using the correct naming conventions (see *SOP 17 – Data Management*).

At the end of the field season, all equipment will be checked in, cleaned/decontaminated, organized, and stored in labeled bins (see *SOP 15 – End of Field Tour and Season Activities* for details). A list of missing or broken equipment and expendable supplies will be generated so that repairs or replacement materials can be ordered during the off-season. All electronic equipment, including GPS units and satellite devices, will have batteries removed to prevent corrosion and leaking. The field vehicle will be washed and thoroughly inspected for damage and needed repairs; any needed repairs will be made during the off-season. Maps of parks and field sites will be filed for the next field season; any damaged or lost maps will be reported to the Field Lead and GIS Specialist so that new ones can be generated for the next field season. Data management tasks include data entry, generation of geospatial files, naming of images, quality assurance/quality control of data, generation of metadata, and data certification.

All unknown shrub species will be identified or an attempt made to identify the specimen. Identified unknown species will be updated in the IU database and a description of the species will be generated for the next field crew.

Data entry on incidental observations of invasive species (*MOJN I&M SOP M1 - Reporting Incidental Observations of Incipient Invasive Species*) will be completed as soon as possible, so that locations of targeted invasive species can be provided to park staff and the EPMT for removal. Ideally, incidental observations of invasive species will be continually entered into the database, so that parks will receive periodic reports after each field tour.

Field crews will be debriefed by MOJN I&M staff, Protocol Lead, and the Field Lead. Crews will be asked to make suggestions on logistics, training, field methods improvement, equipment needs, etc. Adopted suggestions will be incorporated into the relevant SOPs before the next field season.

4. Data Management

This section outlines the general procedures and guidance for data handling, analysis, and report development. Details and procedural steps are documented in the SOPs (*SOP 16 – Information Management Workflow and Tasks*, *SOP 17 – Data Management*, and *SOP 18 – Database Design*) and *Supplementary Materials*, which will be updated as required (e.g., changes in technology and data management solutions). Additional details and context for this section may be found in the *MOJN I&M Vital Signs Monitoring Plan* (Chung-MacCoubrey et al. 2008), and the *MOJN I&M Data Management Plan* (DMP; MOJN 2008).

4.1. Project Information Management Overview

Effective data management of network protocols requires a comprehensive project information management strategy that is detailed and structured within an annual cycle, designed for refinement as needed, and is sustainable throughout the lifecycle of the protocol (Figure 4.1).

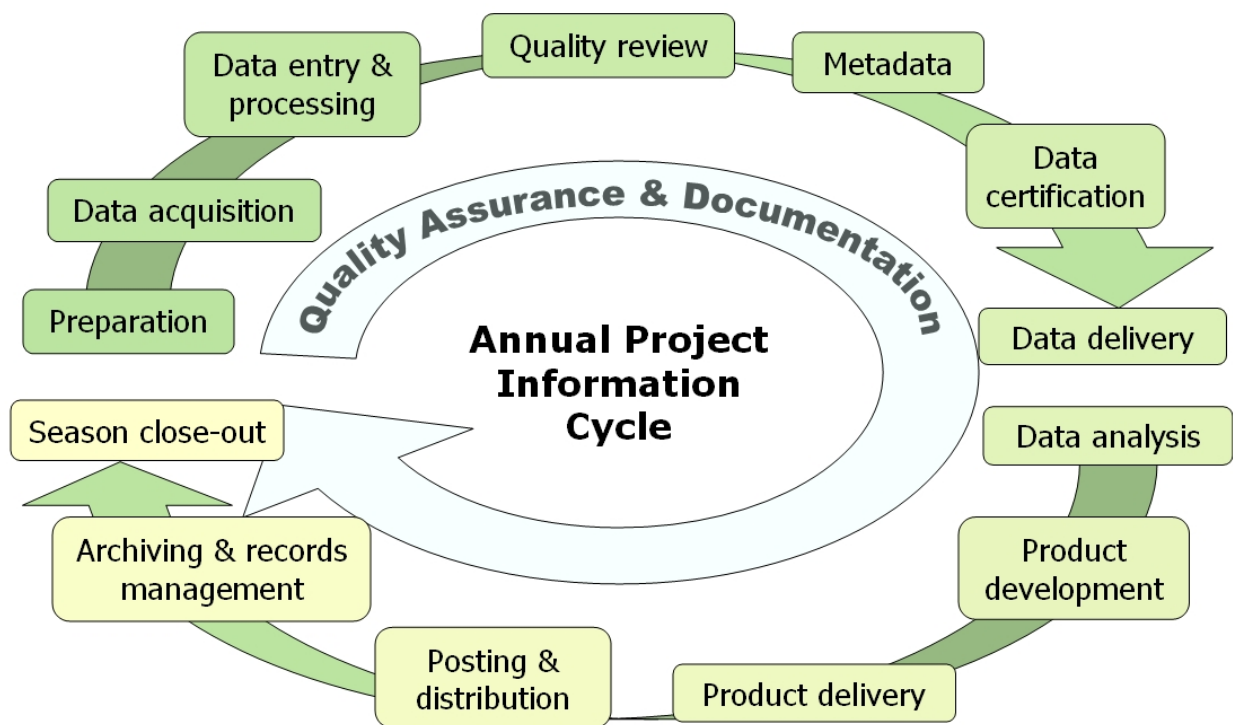


Figure 4.1. Idealized flow schematic of the stages of project information management, from pre-season preparation to season close-out. Note: Quality assurance and documentation are thematic and not limited to any particular stage. Figure provided by John Boetsch, North Coast and Cascades Network data manager.

Primary responsibility for the project data management resides with the MOJN I&M Data Manager, who is assisted by network staff and cooperators. Detailed documentation of roles and responsibilities appears in the *MOJN I&M DMP* and the *MOJN I&M Vital Signs Monitoring Plan* (Chung-MacCoubrey et al. 2008). A brief synopsis of each stage of the project management cycle follows (Siegel et al. 2007):

- *Preparation:* Training (e.g., database data entry, tabular metadata, data management overview, file naming), logistics planning (e.g., securely and accurately protect and deliver data), printing field forms, and maps
- *Data acquisition:* Field trips to acquire data
- *Data entry & processing:* Data entry and uploads into the working copy of the database, Global Position System (GPS) data processing
- *Quality review:* Data are reviewed for quality and logical consistency
- *Metadata:* Documentation of the year's data collection and results of the quality review
- *Data certification:* Data are certified as complete for the period of record
- *Data delivery:* Certified data and metadata are delivered for archiving and uploaded to the master project database
- *Data analysis:* Data are summarized, a flat file created for statistical analysis, and analyzed
- *Product development:* Reports, maps, and other products are developed
- *Product delivery:* Deliver reports and other products for posting and archive
- *Posting & distribution:* Distribute products as planned and/or post to NPS clearinghouses
- *Archiving & records management:* Review analog and digital files for retention (or destruction) according to Records Schedule Resource Management and Lands (N1-79-08-1). Retained files are renamed and stored as needed
- *Season closeout:* Review and document needed improvements to project procedures or infrastructure, complete administrative reports, develop work plans for the coming season

Central to project data management is an information management workflow or road map that outlines the schedule of tasks and mechanisms or tools to manage the data (i.e. software and databases) within the structure of the Project Information Management Cycle (Figure 4.1). *SOP 16 - Information Management Workflow and Tasks* presents an overall workflow for the data generated and managed for this protocol and details the individual steps associated with the workflow. The database architecture, tables, and attributes and their features are provided in *SOP 18 - Database Design*. An overview of the database management strategy is provided in the following section.

4.2. Overview of Database Design

4.2.1. Tabular Databases

Custom relational database applications, implemented in Microsoft Access, will be designed to store and manipulate the data associated with the IU protocol. The design of the databases will be

consistent with Natural Resource Database Template version 3.2 (NPS 2007) and national standards (WASO Inventory and Monitoring Program 2004). Details of the databases, including a description of core and peripheral tables and an entity relationship diagram of table relationships, are presented in *SOP 18 - Database Design*. Throughout the life cycle of the monitoring protocol, all databases will undergo annual revisions to keep pace with changes in the protocol as well as changes in software and potential upgrades to new custom relational database applications, e.g. migrating to Microsoft SQL Server. Once implemented, the databases will continue to undergo revisions as needed, which will be reflected in *SOP 18 - Database Design*.

The general database strategy is to have two databases, a *master* database and a *working* database. The *master* database is used for storing and retrieving multiple years of data and empty versions of the master database tables will be used to create the annual working database. The *working* database is used to facilitate annual data entry, error-checking, and validation of a given season's field-collected data. The working database will also include data entry forms (i.e., custom screens to input and display data) with rigorous quality controls, automated and manual functions (i.e., queries, visual basic scripts) for quality assurance reviews, scripts for summarizing the data, and generating annual report outputs. After all data in the working database have been validated and annual report elements have been generated, the data are migrated to the read-only master database. This strategy protects validated data from corruption, and the master version will facilitate multi-year analyses. Following data extraction, the working databases will be compressed and archived as outlined in *MOJN I&M DM SOP M5- Archiving*.

4.2.2. Spatial Databases

Geospatial data will be handled in a similar manner as tabular databases. A geodatabase will be developed annually for storage and manipulation of spatial data associated with the IU protocol. All spatial datasets (i.e., feature classes) associated with the protocol will be loaded into the geodatabase annually and stored within feature datasets (e.g., by macroplot) by park and year. Once the data has been quality reviewed and certified as complete with required metadata, the data will be migrated to a "master version" of the geodatabase. This database will be stored as a read only version.

The preferred file format for GIS-based data will be ESRI personal geodatabases because they:

- Can include domains, topology, and other advanced GIS functionality like ArcSDE geodatabases.
- Accommodate file management by being a single-file database that can contain many feature classes.
- Can include (or be linked to/with) MS Access database front-ends, allowing an interface customized to user needs.

4.3. Preparation

Network data management preparation for protocols requires a mix of application, documents, and equipment organization before the field season is initiated. For instance, the master and working database tables may require updating if there are procedural changes from the previous season.

Because the working database data entry forms will be designed to closely resemble the field forms, any changes to either the procedures or field forms may also require an update to the data entry forms. SOPs must be updated to reflect lessons learned when the data were processed, reviewed for quality, analyzed, and archived. Preparation for the upcoming year is an ongoing process during the previous year as the needs for changes or adjustments to the information and database emerge.

4.4. Data Acquisition

The IU protocol integrates many different monitoring activities into a single protocol (see section 1. *Background and Objectives*), resulting in several different types of data (i.e., field, images, geospatial). All data are subject to quality assurance as described in *MOJN I&M DM SOP M7- Data Quality*.

Field data will be entered or uploaded to the working databases promptly after field collection and reviewed for outliers and erroneous data. Any unknown shrubs that were assigned a temporary plant code (as described in *SOP 14 – Unknown Shrub Species*) will be added to the working database after they have been identified and the temporary plant code will be replaced by the appropriate USDA species plant code. GPS and camera images will be downloaded at the end of each field tour throughout the season to the appropriate receiving folders on the MOJN I&M network drive. If the data are not provided in a format that lends itself to a digital download, then MOJN I&M staff will enter all information into the database. Other information will be entered into the working database by MOJN I&M staff from either hard copy or electronic field sheets.

4.5. Data Entry and Processing

Data entry will proceed as described in *SOP 17 – Data Management*. MOJN I&M field crews will initially record data on paper forms, with the exception of spatial data, which will be recorded on GPS units. Data entry forms will be designed within the working database for ease of use, i.e., similar appearance to paper and electronic field forms, efficiency, and quality control. We plan to pilot electronic field data collection systems to eventually migrate to paperless data collection.

All images will be downloaded from the camera as jpg files as described in *MOJN I&M DM SOP M11 – Image Management*. The images required in the protocol that are available for processing will be re-named and metadata entered as described in *MOJN I&M DM SOP M11 – Image Management*. Images will be linked to spatial and macroplot data, where appropriate.

Management of geospatial data involves multiple steps: recording, backup, conversion to useable formats, creation of associated metadata, and QA/QC of data (see *SOP 17 – Data Management*, *MOJN I&M DM SOP M7- Data Quality*). Spatial data will be downloaded from the GPS unit as raw data in dot text format and backed up daily to an external drive to prevent catastrophic data loss. At the end of each field tour, spatial data will be converted to shapefile format using DNRGarmin (see *MOJN I&M SOP M3- GPS* for details). These shapefiles will then be added to protocol specific geodatabases. On-unit GPS data, downloaded data, and converted data will be named using the convention described in *SOP 4 – Spatial Data Naming Conventions*.

4.6. Quality Review

There are two parts of quality review associated with data acquisition (see *MOJN I&M DM SOP M7 – Data Quality*). First, all field data entry will be reviewed for quality assurance following the guidelines presented in the NPS National Data Management Plan (2008a). The primary steps for Field Data Quality Assurance are outlined in Table 4.1.

Table 4.1. Data Management Quality review process for data entry.

Review Process Step	Responsibility
Review field datasheets for omissions or obvious errors	Field crew at the end of each field day; <i>must</i> occur prior to data entry
Post data entry, review 100% of the data entry values with field data sheets for errors and omissions	A second data-entry individual
Cross check a minimum of 15% of the data entry values with the field data sheets	Data Manager or Protocol Lead.
Cross-reference sample events (sites and samples dates) with field datasheets to ensure all field datasheets are entered; verify sample events list with Protocol Lead	Data Manager and Protocol Lead implement and resolve discrepancies

Second, the Protocol Lead, Data Manager, and Program Manager need to validate the data for quality, completeness, and logical consistency before data certification (see *MOJN I&M DM SOP M7 – Data Quality* for details). Pre-designed queries facilitate an automated process to check for data integrity, data outliers, missing values, illogical values, and inconsistencies between related fields or tables. A report of errors is generated and the Protocol Lead will evaluate the errors, edit the errors where appropriate, and document the edits. If any errors and inconsistencies cannot be fixed, the issues will be documented and included in the metadata (see *MOJN I&M DM SOP M9 - Documentation Non-Spatial*). Data correction procedures are documented and archived as detailed in *MOJN I&M DM SOP M5 - Archiving*. Once the validation is complete, the data are certified in the working database and the data certification form is completed (see *MOJN I&M DM SOP M7 – Data Quality* for details).

4.7. Metadata

Data documentation is a critical step toward ensuring that both spatial and tabular datasets are useable for their intended purposes well into the future. Documentation involves the development of metadata, which can be defined as structured information about the content, quality, and condition of data. Additionally, metadata can be used to catalog datasets within intranet and internet systems, making data available to a broad range of potential users through simple data searches. Metadata can take many different forms, including formal Federal Geographic Data Committee (FGDC)-compliant metadata, reference records, and protocol version information. Metadata for all MOJN I&M monitoring data will conform to NPS guidelines, and will contain all components of supporting information such that the data may be confidently manipulated, analyzed, and synthesized. Detailed guidelines are provided in the following SOPs:

1. *MOJN I&M DM SOP M10 - Documentation Spatial*

2. *MOJN I&M DM SOP M9 - Documentation Non-Spatial*

Metadata creation is generally the most time consuming and critical the first time it is developed. In subsequent years, most information remains static with updates reflecting current publications, references, taxonomic conventions, contact information, data disposition and quality, and to describe any changes in collection methods, analysis approaches, or quality assurance for the project.

In addition to the standards outlined in *MOJN I&M DM SOP M10 - Documentation Spatial* and *MOJN I&M DM SOP M9 - Documentation Non-Spatial*, the Protocol Lead, with the Data Manager's assistance, will create and update an FGDC- and NPS-compliant metadata record. Detailed procedures are described in:

1. *MOJN I&M DM SOP M12 - NPS Metadata Tools and Editor*
2. *MOJN I&M DM SOP M6 - Biological Data Profile*

At the conclusion of the field season, the Protocol Lead will be responsible for providing a completed, up-to-date metadata record to the Data Manager (tabular datasets) and/or GIS Specialist (geospatial datasets). The Data Manager will facilitate metadata development by assisting with parsing the metadata records and posting the records to national clearinghouses.

4.7.1. Sensitive Information

An element of metadata development includes determining whether or not the data include any sensitive information (e.g., specific locations of rare, threatened, endangered, or commercially valuable species). Prior to completing metadata, the Protocol Lead, Park Resource Managers and/or Vegetation Working Group (VWG) need to identify any sensitive information in the data. Any decisions will be documented and communicated to the Data Manager. Sensitive information could potentially be present in the IU data (see *MOJN I&M DM SOP M14 – Sensitive Data*). The spatial location of sensitive data will be distorted using GIS applications or the spatial attributes could be removed as described in *MOJN I&M DM SOP M14 – Sensitive Data*.

4.8. Data Certification

To ensure that only data of the highest possible quality are included in reports and other project deliverables, the data certification step is an annual requirement for all tabular and spatial data. Data certification is a benchmark in the project information management process that indicates the data: 1) are complete for the period of record, 2) have undergone and passed the quality assurance checks, and 3) are appropriately documented and in a condition for archiving, posting, and distribution. Certification is not intended to imply that the data are completely free of errors or inconsistencies that may not have been detected during quality assurance reviews. The Protocol Lead is primarily responsible for completing certification procedures with the assistance of the Data Manager. Final certification requires that the MOJN I&M Program Manager approve the data, at which point, the data are ready for analysis and made available for distribution as appropriate. Details of the certification and delivery processes are described in *MOJN I&M DM SOP M7 - Data Quality*.

4.9. Data Delivery

After the data certification form is signed by the Program Manager, the Data Manager will transfer all data from the annual working database to the master database. Data will be provided to the Protocol Lead in a series of data output files that can be used for data analysis. Following certification of the data, geospatial data will be received and stored in protocol specific geodatabases.

4.10. Data Analyses and Product Development and Delivery

Once informational products (e.g., reports, presentations, posters) have been developed (see section 5. *Data Analysis and Reporting*), the Protocol Lead will deliver the products to the Data Manager for posting and distribution. Reports and delivery schedules are detailed in *SOP 19 - Data Analysis and Reporting*. The organization and general standards for project deliverables are detailed in *MOJN I&M DM SOP M13 - Project Deliverables*.

4.11. Posting and Distribution

Data and reports are posted on the MOJN I&M intranet, internet, and the national web-accessible secure databases supported by the NPS Washington Office (WASO) or National I&M program. These include:

Integrated Resource Management Applications (IRMA) Data Store: This portal is a gateway to NPS natural resource data and information available at <http://irma.nps.gov/>

MOJN I&M Internet Web Site: This public web site for the MOJN I&M natural resource data and information available at <http://science.nature.nps.gov/im/units/mojn/index.cfm>

MOJN I&M SharePoint site: This internal site for the MOJN I&M natural resource data and information is available only to employees of the NPS at <http://inpniscvsp05:39904/im/networks/MOJN/default.aspx>

MOJN I&M Intranet Web Site: This internal web site for the MOJN I&M natural resource data and information is available only to employees of the NPS at <http://www1.nrintra.nps.gov/im/units/mojn/>

4.12. Archiving and Records Management

After the data certification form is signed by the Program Manager, the Data Manager will archive digital and non-digital data as outlined in *MOJN I&M DM SOP M5 - Archiving*. Master databases and annual project deliverables and reports will also be archived as described in *MOJN I&M DM SOP M5 - Archiving*.

4.13. Season Closeout

A review of archive and expendable data products will be undertaken by the Protocol Lead and Data Manager during a close-out session after each park's field season to ensure that all data, metadata, and documents are properly organized, archived, and disseminated to the appropriate locations. Decisions concerning what to retain and what to destroy will follow the guidelines stipulated in NPS Director's Order 19 (NPS 2001b). An example of an expendable data product is an intermediate draft of an annual report that was saved during report preparation and may be discarded once the final

report is generated. Details pertaining to data management season closeout are provided in *MOJN I&M DM SOP M15 - Season Closeout*.

5. Data Analysis and Reporting

Annual and comprehensive reports will be generated by MOJN I&M annually and periodically, respectively. Annual reports will be generated on an individual park basis. Reports will be produced ~12-15 months after field sampling and generally include status of the field monitoring and upland communities; the time gap between data collection and reporting is to allow for sufficient time for data entry, certification, and analyses. One to two page briefs geared toward park interpretive staff will be produced annually and based on the respective parks' annual report.

Periodic comprehensive reports will be generated on a park by park basis and provide trend information for the previous monitoring cycles at each park. The Protocol Lead is responsible for performing the data analyses including descriptive statistics and appropriate statistical tests for status and trend through time. *SOP 19 - Data Analysis and Reporting* provides a detailed description of the procedures described below.

Before data analysis and reporting can occur, data collected from the field must be processed. Data processing for this protocol entails calculating a macroplot-level measurement for each response variable of interest, as macroplots are the replicate unit for all statistical analyses. For example, vegetation and invasive plant species data will be averaged across each of the three transects. For soils, data will be averaged across each of the 12 sampling points.

5.1. Data Analysis

5.1.1. Status

Upland community status results will be provided to parks approximately one year after they are monitored. We will use a design-based estimation approach based on the GRTS sampling design (Stevens and Olsen 2004; see *SOP 19 – Data Analysis and Reporting* for details) for each variable of interest. Descriptive measures of status may be obtained for parameters of interest and may include the calculation of the mean, median, variance, minimum, maximum, sample size, and range; MOJN I&M will provide summary statistics and graphs of these data.

Examples of status estimates include % vegetation cover, % cover by life forms or shrub species, species richness and community composition, average distance (gap) between perennials, mean values of soil parameters, % cover of targeted invasive species, frequency of targeted invasive species, and % cover of disturbance (Table 5.1). Percent vegetation cover, % shrub cover, and proportion of shrub to total cover will be used to assess the relative abundance and composition of vegetation in upland communities. Percent biological soil crust and % bare ground will be used to determine change in soil crust abundance. Canopy and basal gap size will be used to assess interplant distance, which influences the potential for water infiltration, wind and water erosion, and weed invasion (Herrick et al. 2005). Soil parameters that will be statistically analyzed are soil strength (penetration resistance), soil erosion, effervescence, pH, and EC.

We will also integrate data from other vital signs and MOJN I&M protocols to conduct statistical analyses for subpopulations identified by weather, precipitation, fire, or other factors. Plant

community measures or soil parameters may be grouped together for multivariate analyses (McCune and Grace 2002) to find the parameters that have the greatest influence on dissimilarity of macroplots. The parameters that have the greatest influence on upland communities can be explored further through other studies.

Table 5.1. Examples of response variables from the IU protocol used to assess vital signs. SOPs are in *Volume 2, Standard Operating Procedures* of the IU protocol.

Response variable	Data from:	Vital Sign
% vegetation cover	Point intercept on transects (SOP 8)	Vegetation change
% cover by shrub species	Point intercept on transects (SOP 8)	Vegetation change
% cover by life form	Point intercept on transects (SOP 8)	Vegetation change
% biological soil crusts	Point intercept on transects (SOP 8)	Biological soil crusts
	0.25 by 0.25 m quadrats along transects (SOP 10)	
% disturbance	Point intercept on transects (SOP 8)	Soil surface disturbance
	0.25 by 0.25 m quadrats along transects (SOP 10)	
Mean basal gaps	Line-intercept on transects (SOP 9)	Soil erosion & deposition
Soil strength	Soil measurements from sampled points (SOP 11)	Soil hydrologic function
Soil pH	Soil measurements from sampled points (SOP 11)	Soil chemistry & nutrient cycling
Soil EC	Soil measurements from sampled points (SOP 11)	Soil chemistry & nutrient cycling
% cover of targeted invasive species	Point intercept on transects (SOP 8)	Invasive plants
Frequency of invasives	0.25 by 0.25 m quadrats along transects (SOP 10)	Invasive plants

5.1.2. Trend

Trend is defined here as population-level directional change over time and may be expressed as annual change or net change over a period of time (Urquhart and Kincaid 1999). While trend may not be solely linear over time, trend that generates management action will exhibit a substantial linear trend. In order to detect a pattern, data from multiple sampling periods are needed, but will not be available for this protocol for many years. We anticipate starting to perform trend analyses after three monitoring cycles (or nine years with a three-year monitoring cycle), with subsequent trend analyses conducted at regular intervals afterward for each park. Trend analyses may be calculated more frequently in response to particular park mandates or if requested by park resource managers.

Several methods of trend estimation may be considered. Parametric approaches (VanLeeuwen et al. 1996, Piepho and Ogutu 2002) allow greater flexibility to simultaneously estimate trend, variance components, and the effects of covariates but require more rigorous assumptions. Nonparametric approaches such as the seasonal Kendall test (Hirsch and Slack 1984) provide a trend test statistic, and the robustness of nonparametric tests provides a useful check for parametric test results. We anticipate starting with a parametric approach, specifically linear mixed models, but suggest that a variety of trend tools be used before the results are used as a case for management action.

A linear mixed-model is used to test for trend at randomly-selected sites (VanLeeuwen et al. 1996, Piepho and Ogutu 2002). A mixed model allows some effects to be considered fixed and some to be considered random. Fixed effects contribute to the mean of the outcome and random effects contribute to the variance. Random effects are used to estimate variation of linear trends among subjects (macroplots) and over time (years). Since the linear mixed model is a parametric model, the assumptions of data independence and normally distributed errors with equal variance need to be met.

We will test whether the trend observed for the data collected in this protocol indicates a significant trend in either direction (H_0 : slope = 0 vs. H_a : slope $\neq$ 0). If trend analyses show that there is a significant trend through time, we can estimate whether the trend is positive or negative, and make interpretations depending on the direction of the trend (Table 5.2). For example, if statistically significant increases in soil EC values are found, then it can be inferred that concentrations of soluble salts are increasing over time. If the differences are not statistically significant, the differences may be attributed to inherent soil heterogeneity and/or additional sampling and analyses may be warranted.

Model-based approaches to trend estimation also allow the incorporation of covariate information to assess relationships between outcomes of interest and variables that might impact these outcomes over time. Model predictors might include environmental covariates, observer effects, and potential stressors. Significance of model covariates may be assessed with t-tests or by comparing models with and without the covariate of interest using information criteria such as AIC or BIC (Gurka 2006). Graphical tools, tests of association and correlation, and nonparametric ordination techniques will be implemented to examine relationship between potential predictors and the outcomes of interest. Trends that are largely explained by stressors may inform management decisions.

To address specific questions on community change (e.g., community change in ecotones vs. non-ecotones, at low vs. high elevation locations), we can post-stratify sampling sites (Holt and Smith 1979) and make comparisons in trend across particular strata. Post-stratification requires weighting adjustment to account for the relative size of post-strata and these adjustments are incorporated into the Horvitz-Thompson (1952) estimator for design-based inference (see *SOP 19 – Data Analysis and Reporting* for details). In the finite-population inferential setting, relative population size is used to adjust weighting for domain-level estimation. For sampling in continuous domains (as in this protocol), relative areas falling in each post-stratum are used to adjust weights. This application requires post-stratum information for all sampling units in the population, so elevational strata or ecotone definitions may be used as post-strata if spatial coverages can accurately provide this information for the entire area of interest. Specific questions about changes in plant species range will not be directly addressed using this protocol because this protocol was not specifically designed to monitor changes in species range. However, data from this protocol can be used to examine the presence or absence of a shrub species through time on macroplots and in a spatially-balanced approach.

Table 5.2. Possible interpretations of changes in soil parameters through time.

Soil Parameter	Increasing	Decreasing	Possible Causes and Consequences
Penetration Resistance	X		Soil bulk density and strength are increasing, likely because of compaction. Penetration of plant roots is inhibited in soils with high strength and bulk density, particularly if the soil is relatively dry. The amount of plant available water may also be decreased as bulk density and strength increase.
		X	Soil bulk density and strength are decreasing, indicating that root penetration should improve.
pH	X		Minimal leaching; atmospheric deposition of calcium and magnesium (Ca^{2+} and Mg^{2+}); addition of carbonates and/or bicarbonates. In slightly to moderately alkaline soils (pH 7.4 to 8.1), molybdenum (Mo) and all of the macronutrient elements (except phosphorus [P]) are available to plants. However, concentrations of plant available iron (Fe), manganese (Mn), zinc (Zn), copper (Cu) and cobalt (Co) may be low enough to restrict plant growth.
		X	Accumulation of organic matter; leaching of basic cations such as Ca^{2+} and Mg^{2+} ; atmospheric deposition of sulfuric acid (H_2SO_4) and nitric acid (HNO_3). In strongly acidic soils (pH <5.5), availability of the macronutrients Ca, Mg, potassium (K), phosphorus (P), nitrogen (N) and sulfur (S) and the micronutrients molybdenum and boron (B) to plants is reduced. In contrast, availability of many micronutrient cations including Fe, Mn, Zn, Cu, and Co increases at low pH and may be toxic to plants.
Electrical Conductivity	X		Concentrations of soluble salts in the soil are increasing, because of increased atmospheric deposition of salts and/or reduced leaching. The growth of some sensitive plant species may be reduced when the $\text{EC} > 2 \text{ dS m}^{-1}$
		X	Concentrations of soluble salts in the soil are decreasing, because of increased leaching. Reductions in soluble salt concentrations with increased leaching might enhance vegetative growth through greater water availability.

5.2. Reporting

MOJN I&M will generate three primary types of reports: annual reports, annual briefs, and comprehensive reports (see *SOP 19 – Data Analysis and Reporting* for details). Moreover, results from annual reports will be integrated into the larger Vital Signs Monitoring Program reports, the Annual Administrative Report, and Work Plan. All reports will be provided to the MOJN Board of Directors (BoD), technical committee (TC), and relevant park staff. We anticipate submitting annual reports and comprehensive reports for publication in the NPS Natural Resource Technical Report Series or a peer-reviewed scientific journal. Published reports and associated products will be made available on the MOJN I&M inter- and intranet sites

(<http://science.nature.nps.gov/im/units/mojn/index.cfm> and <http://www1.nrintra.nps.gov/im/units/mojn/>, respectively), and the IRMA Data Store (<https://irma.nps.gov/App/Reference/Welcome>).

5.2.1. Annual Reports

MOJN I&M will produce an annual summary report of protocol activities for each park monitored the previous field season. We anticipate a 12-15 month interval between field sampling and report production, with the slightly longer interval needed when reporting is initiated and a subsequent reduction in time interval as procedures and reporting are standardized. The interval between field sampling and reporting is necessary because of the time it takes to collect, enter, certify, and analyze the data. Since field data collection occurs every year, we anticipate that MOJN I&M will produce at least one annual report for the IU protocol each year.

Annual reports will be produced for each park and include the following information (Figure 5.1):

- Park sampled, number of macroplots sampled, and a map of the macroplot locations for the park
- Documentation of any deviations from the protocol, such as missed sites or samples
- Assessment of the sample size and revisit design for the protocol
- Planned activities for the next field season (e.g., modifications to the protocol)
- General summary statistics (i.e., mean, variance) for each component (i.e., vegetation, soils, invasives) of the protocol (Figures 5.2-5.3; Table 5.3)

These reports are intended to serve as an overall status report for the protocol (i.e., what has been accomplished in the previous sampling year), as well as provide the status of upland communities for each of the parks monitored in the previous field season.

5.2.2. Annual Briefs

From each annual report, MOJN I&M will prepare a 1-2 page resource brief for the IU protocol that will provide a concise summary of the status of the protocol. These annual briefs will be provided to interpretative staff at parks that were monitored in the previous field season and written in a style that will allow interpretative staff to directly use relevant sections. Associated electronic materials, such as figures, can also be made available to parks, if needed.

5.2.3. Comprehensive Reports

Comprehensive reports will be produced for each park after all macroplots at a park have been monitored at least three times (approximately nine years) to allow for adequate data for trend analyses. Subsequent comprehensive reports are planned every ten years, or after approximately three sampling periods for all parks. Comprehensive reports will include the following information:

- overview of the protocol status and major accomplishments

- in-depth statistical analyses and interpretation of protocol data
- trend analysis to understand how park resources are changing through time (Figures 5.4-5.6)
- discussion of results, including management implications
- assessments of whether the monitoring design is meeting protocol goals
- incorporation of resource condition status into Park Condition Reports

We will also generate an annual brief for each comprehensive report. This brief will summarize the status of the protocol, trends of the monitored vital signs in the upland communities, and data from other protocols that are being integrated into the upland community analyses.

Contents

	Page
Figures.....	v
Tables.....	vii
Executive Summary	xi
Acknowledgments.....	xii
Acronyms.....	xiii
1 Introduction.....	1
2 Methods.....	3
2.1 Field Sampling.....	3
2.2 Field Methods	6
2.3 Statistical Analyses.....	8
3 Results.....	11
3.1 Vegetation.....	11
3.2 Soils	13
3.3 Invasive Plants	15
4 The Next Field Season.....	17
5 Literature Cited	21

Figure 5.1. Example table of contents from an annual report from the MOJN integrated upland protocol.

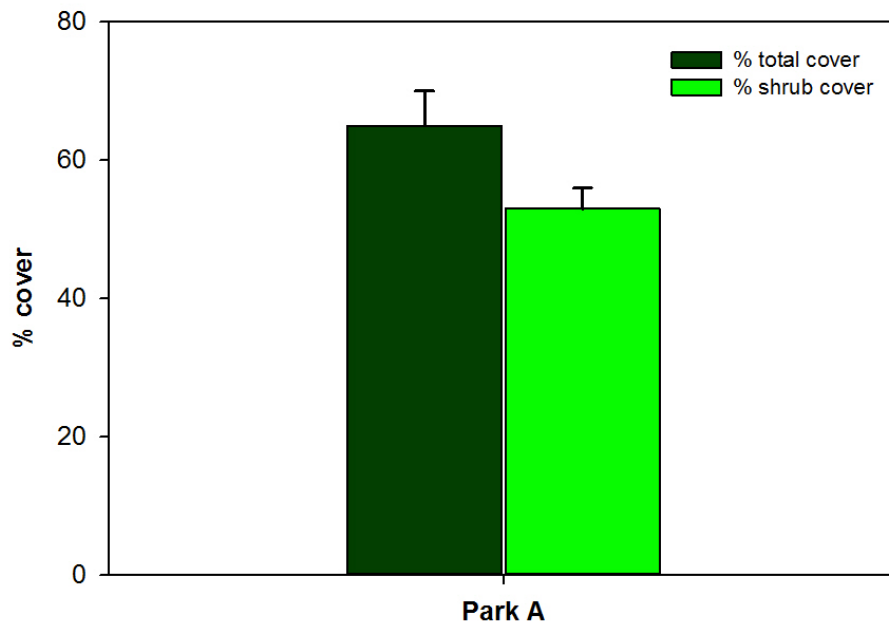


Figure 5.2. Example figure for vegetation status. Percent total and shrub cover (+SE) for hypothetical Park A. Sample size is 35 macroplots for Park A.

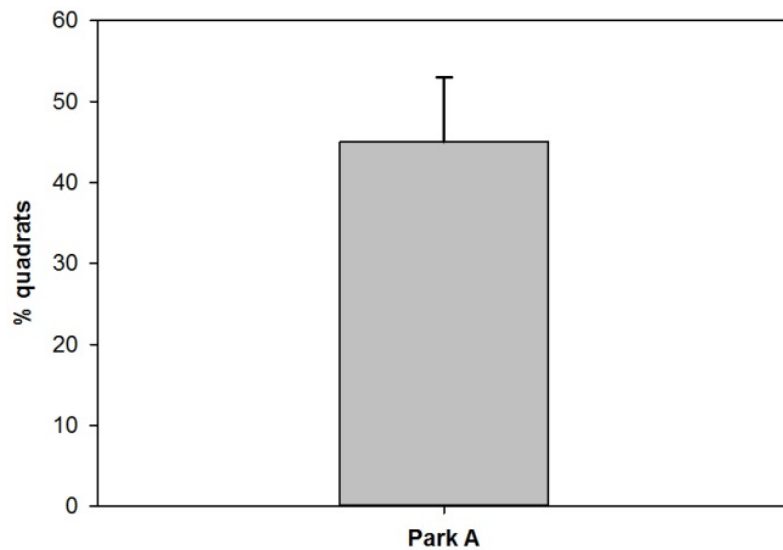


Figure 5.3. Example figure for invasive plant status. Frequency (% quadrats $\pm$ SE) of *Bromus rubens* on macroplots for hypothetical Park A. Sample size is 35 macroplots.

Table 5.3. Example table for status of soil parameters at hypothetical Park A. Sample size is 35 macroplots.

Soil Parameter	Mode of response	Range of responses
Effervescence ¹	VS	NE - SL
Soil Consistence		
<i>Rupture resistance</i> ²	S	L - MH
<i>Soil stickiness</i> ³	SO	SO – SS
<i>Soil plasticity</i> ⁴	SP	PO - MP

¹NE – noneffervescent, VS – very slightly effervescent, SL – slightly effervescent

²L – loose, S – soft, SH – slightly hard, MH – moderately hard

³SO – non-sticky, SS – slightly sticky

⁴PO – non-plastic, SP – slightly plastic, MP – moderately plastic

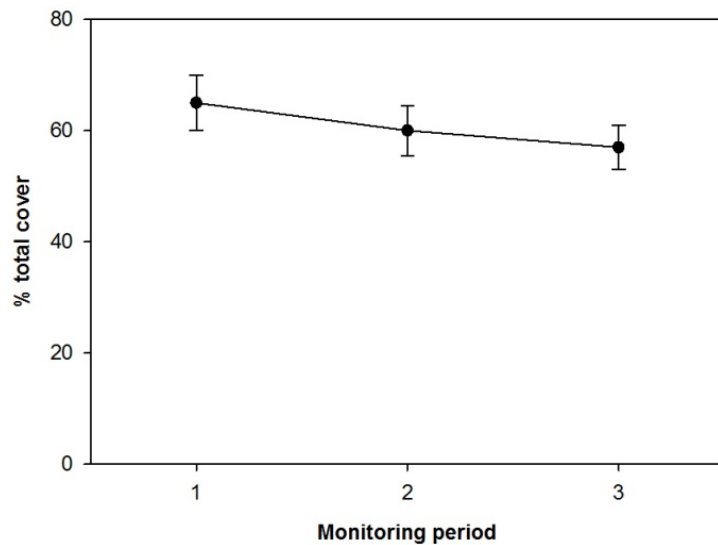


Figure 5.4. Example trend figure for % total cover (vegetation parameter) ($\pm$ SE) after the first three sampling periods for hypothetical Park A. Percent total cover is showing a slight downward trend at Park A. Sample size is 35 macroplots for Park A.

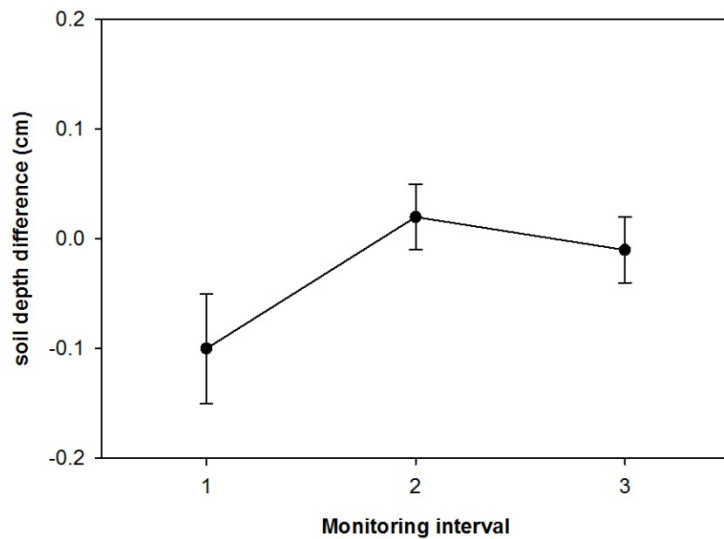


Figure 5.5. Example trend figure for soil erosion (soil parameter) ($\pm$ SE) after the first three monitoring intervals for hypothetical Park A. Soil depth differences are calculated as changes in soil depth between visits (e.g., $t_2 - t_1$, $t_3 - t_2$). Thus, there can be no change in ("0"), loss in ("-"), and gain in ("+") soil depth. Monitoring intervals represent: 1 = $t_1 - t_0$, 2 = $t_2 - t_1$, 3 = $t_3 - t_2$, where t_0 represents the soil depth at the beginning of monitoring. Supporting qualitative soil erosion data for Park A includes rupture resistance (mean value = soft), soil stickiness (mean value = non-sticky), and soil plasticity (mean value = non-plastic). Changes in soil depth are low at Park A, indicating very little erosion. Sample size is 35 macroplots.

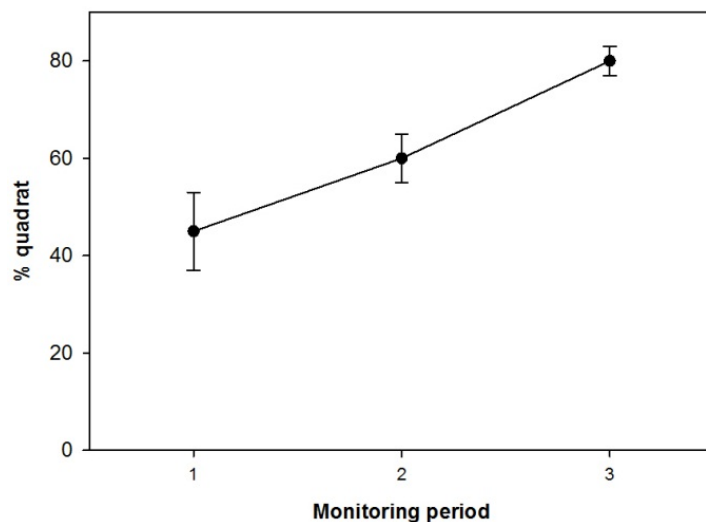


Figure 5.6. Example trend figure for invasive plant status. Frequency (% quadrats $\pm$ SE) of *Bromus rubens* on macroplots for hypothetical Park A. *Bromus rubens* is increasing. Sample size is 35 macroplots.

5.2.4. Protocol Review

Protocol implementation success will be thoroughly reviewed by MOJN I&M staff and the VWG yearly for the first three year monitoring cycle. Thereafter, the MOJN I&M staff will informally review protocol implementation success yearly until the first comprehensive report. If changes need to be implemented, the VWG will be consulted before implementation. After the first comprehensive report is produced, if necessary, the protocol will be formally assessed and evaluated by MOJN I&M staff and the VWG after each three year monitoring cycle.

Formal technical review of the IU protocol also will be initiated by the national I&M program after five years of implementation.

If substantial changes to the protocol are recommended at any point, recommendations will be presented to the BoD and TC for consideration at their respective annual meetings and to the Regional I&M Program Manager.

6. Personnel Requirements and Training

6.1. Personnel Requirements

This protocol requires close collaboration between MOJN I&M staff and the staff of the network parks. Key MOJN I&M staff members include the: Ecologist (Protocol Lead), Program Manager, Data Manager, GIS Specialist, Field Lead, and field crew staff. The roles and responsibilities of all personnel are summarized in Table 6.1.

The Protocol Lead will be supervised by the MOJN I&M Program Manager and will frequently interact with the network Data Manager to coordinate database development and data archiving. The Field Lead will work with the Protocol Lead to implement field work and schedule field crew time. The Field Lead will also work with the Data Manager and GIS Specialist to ensure that all data management procedures are followed.

6.2. Roles and Responsibilities

The Protocol Lead will perform data analysis and reporting and coordinate with the appropriate staff to oversee field implementation, data collection, and archiving of data.

The Program Manager will supervise the Protocol Lead and provide overall administrative and scientific leadership for all monitoring activities.

The Data Manager will develop and maintain databases for data generated by this protocol, maintain data management SOPs and all data for the protocol, and upload data to national databases.

The GIS Specialist will provide support for spatial data for the protocol, including GPS equipment spatial data management and oversee spatial data management.

The Field Lead will oversee the field crew both in the field and in the office. The Field Lead will organize all field logistics, including obtaining park research permits, organizing field schedules, organizing necessary field equipment, and contacting appropriate park personnel. He/she will also provide QA/QC of field data, including conducting field crew checks to minimize observer bias, schedule field crew time for data entry, help the Protocol Lead and Data Manager with data management, and provide the initial data quality check against the field forms. The Field Lead is a critical link between the crew and MOJN I&M office and will be the first to hear about any protocol implementation issues.

The Data Management Technician assists with data entry, QA/QC of data, and assists the Data Manager and GIS Specialist on managing the protocol data.

The Field Crew implements the field procedures at each park and collects the field data.

The Park Resource Managers consult on all aspects of the protocol, from protocol review to implementation, and will generally serve as the point of contact to MOJN I&M during field implementation at their respective parks.

Table 6.1. Roles and responsibilities for implementing the IU protocol. Data management activities are indicated by an “*”.

Role	Responsibilities	Name/Position
Protocol Lead	• Manages project oversight and administration. • Collaborates with Program Manager on tracking project objectives, budget, personnel requirements, and progress toward meeting monitoring objectives. • Facilitates communications with park managers. • Coordinates and ratifies changes to protocol. • Coordinates field work with the Field Lead. • Performs data summaries and analyses.* • Manages project operations and implementation.* • Certifies data for quality and completeness.* • Completes reports, including permitting reports, metadata, and other products.* • Trains field crews.	MOJN I&M Ecologist
Program Manager	• Provides supervision and oversight of the Protocol Lead and Data Manager. • Manages administration and budget. • Consults on all phases of protocol review and implementation. • Reviews annual and 4-year reports. • Ensures safety of field crews.	MOJN I&M Program Manager
Data Manager	• Consults on data management activities.* • Facilitates check-in, review, and posting of data, metadata, reports and other products to national databases.* • Maintains and updates database application.* • Provide database and data management training as needed.* • Serves as primary steward of protocol database and GIS data and products.* • Maintains and archives project records.*	MOJN I&M Data Manager
GIS Specialist	• Provide spatial products for field work, including office reconnaissance of field sites and UTM coordinates of field macroplots.* • Provides training to field crew in GPS use, spatial data management, and QA/QC of spatial data.* • Works with Data Manager to update and archive spatial data.*	MOJN I&M staff or cooperator
Field Lead	• Prepares field equipment. • Assists Protocol Lead with training. • Oversees and coordinates field work in network parks, including field logistics (e.g., travel, housing). • Oversees data compilation, data entry, field QA/QC, and field equipment management, as needed.* • Prepares, submits and tracks monitoring permits.	Park, Cooperator, and/or MOJN I&M staff person

Table 6.1. Roles and responsibilities for implementing the IU protocol. Data management activities are indicated by an “*” (continued).

Role	Responsibilities	Name/Position
Data Management Technician	- Enters field and geospatial data, office QA/QC of data.* - Works with Data Manager and GIS Specialist to manage protocol data.*	Cooperator, MOJN I&M staff person, or interns (e.g., SCA)
Field Crew	- Assists with field preparation. - Collects, records, enters, and verifies data.* - Maintains field equipment.	Seasonal MOJN I&M, Park, cooperator, or interns (e.g. SCA)
Park Resource Managers	- Consultant on all phases of protocol review and implementation. - Facilitates logistics planning coordination. - Communicate management and restoration plans and associated information to Protocol Lead. - Reviews reports, data, and other project deliverables.	MOJN I& M TC or representatives (i.e., VWG)

6.3. Qualifications, Training, and Calibration

We expect the Field Lead and field crew to have strong botanical skills, great attention to detail, and backcountry travel and camping skills. Ideally, they will be familiar with plants of the Mojave Desert and nearby regions, and have the ability to identify any unknown shrub species that they come across. Additional qualifications are knowledge of basic soil science, experience taking vegetation monitoring measurements, familiarity with local environmental conditions and hazards (travel in remote backcountry, rough terrain, and extreme heat), good physical fitness, familiarity with GPS units, basic orienteering skills, and basic computer data entry. The Field Lead should also have field logistics experience and good organizational skills. Field crew members should also have good organizational skills, memory retention, and the ability to work methodically and consistently under difficult conditions.

All crew members will train together. At the start of each field season and before starting at each park, the Field Lead will calibrate procedures across the crews in the field. At the beginning of the field season and under the guidance of the Field Lead, each crew will practice locating and setting up a test macroplot and taking vegetation, soils, and invasive species status and trends measurements. Crew members will reciprocally measure the test macroplot to make sure that crew members’ measurements are consistent with each other. Calibration will continue until each crew member is consistently counting within 5% of the “true value”, as established either by precision within successive counts, or, if necessary, as established by the Field Lead. Precision and reproducibility measuring exercises undertaken throughout the field effort will provide additional opportunity for refinement and calibration of field techniques. Macroplot vegetation, soils, and invasive species training should be accomplished in three to four days, with the caveat being that additional days will be needed to expose crews to a project overview, GPS, data management, safety, and other training as needed.

Before entering the field, field crew members will undergo basic backcountry and safety training (e.g., NPS Operational Leadership, CPR/first aid, wilderness first aid), 4WD training, field methods training, and shrub and invasive species training. Field crews must be proficient in all aspects of the sampling procedures, adept at using a GPS and/or compass and map to navigate to field sites, and able to work independently and safely in the backcountry. Details on training for safety, the protocol methods, and park specific training requirements are outlined in *SOP 2 – Training Observers*.

7. Operational Requirements

7.1. Annual Workload and Schedule

The annual workload of this monitoring protocol is outlined by the responsibilities listed above in Table 6.1. The annual implementation schedule is provided in Table 7.1, which should be cross referenced with the proposed sample design (Table 2.2) as different parks will be sampled in different years and sampling periods. An evaluation of the protocol and any necessary changes must be made four months prior to each sampling period. Since the MOJN parks have different growing seasons, the exact timing of the implementation schedule will vary slightly from year to year and depend on individual parks and weather conditions.

Table 7.1. Annual implementation schedule for IU monitoring. Tasks are performed by the Protocol Lead (PL), Data Manager (DM), Field Lead (FL), and Crew (C). Data management activities constitute approximately 36% of all tasks performed for the IU protocol (see Table 7.2 for more information).

Month	Administration	Sampling Period			Data Management
		Spring (Mar – May)	Summer (Jun – Aug)	Fall (Sep – Nov)	
January	Draft IU Annual Report for parks monitored during previous field season (PL).	Procure spring field supplies and equipment as needed (FL).	Posts job ads for summer bio-techs as necessary (PL, FL).		Reconcile and upload previous summer's data to Master database (DM).
February	Submit draft Annual Report to MOJN I&M Program Manager and VWG. (PL) Finalize any modifications to protocol and SOP(s) for summer (PL, FL).	Assemble spring field sampling kits. Prepare field maps and data packets. Prepare spring field sampling and training schedules. Coordinate with appropriate parks for spring season (FL).			Summer season close-out (PL, DM) Compile data needs for IARs (DM, PL). Update protocol and data management SOPs from summer (DM).
March	Complete required permitting reports (IARs) for current and upcoming years (PL). Training of spring field crews (PL, FL).	Acquire data for spring parks (FL, C).			
April			Procure summer field supplies and equipment as needed (FL).		Reconcile and upload previous fall's data to Master database (DM).

Table 7.1. Annual implementation schedule for IU monitoring. Tasks are performed by the Protocol Lead (PL), Data Manager (DM), Field Lead (FL), and Crew (C). Data management activities constitute approximately 36% of all tasks performed for the IU protocol (see Table 7.2 for more information) (continued).

Month	Administration	Sampling Period			Data Management
		Spring (Mar – May)	Summer (Jun – Aug)	Fall (Sep – Nov)	
May	Finalize any modifications to protocol and SOPs for Fall monitoring (PL, FL).		Assemble summer field sampling kits. Prepare field maps and data packets. Prepare summer field sampling and training schedules. Coordinate with appropriate parks for summer season (FL).	Posts job ads for fall bio-techs, as needed (PL, FL).	Fall season close-out. Update protocol and data management SOPs for Fall (DM).
June	Training of summer field crews (PL, FL).		Acquire data for summer parks (C, FL).		Initiate spring data entry – hire/train technician. Upload device data (DM, FL).
July	Start data analysis of previous summer and fall data collection (PL).			Procure fall field supplies and equipment as needed (FL).	Continue data entry and/or data upload (C, FL).
August				Assemble fall field sampling kits. Prepare field maps and data packets. Prepare fall field sampling and training schedules. Coordinate with appropriate parks for fall season (FL).	Reconcile and upload spring results to Master database (DM). Continue data entry and/or data upload (C, FL).
September	Training of fall field crews (PL, FL).			Acquire data for Fall parks (C, FL).	Spring season close-out (PL, DM). Initiate summer data entry – hire/train technician. Upload device data (DM, PL, FL).

Table 7.1. Annual implementation schedule for IU monitoring. Tasks are performed by the Protocol Lead (PL), Data Manager (DM), Field Lead (FL), and Crew (C). Data management activities constitute approximately 36% of all tasks performed for the IU protocol (see Table 7.2 for more information) (continued).

Month	Administration	Sampling Period			Data Management
		Spring (Mar – May)	Summer (Jun – Aug)	Fall (Sep – Nov)	
October					Continue data entry and/or data upload (C, FL). Compile spring data for Protocol Lead (DM).
November					Certify spring data. Transition data to Master database and geodatabases (DM).
December	Finalize any modifications to protocol and SOP(s) for spring. (PL, FL).	Posts job ads for seasonal bio-techs if previous sampling crew are not retained (PL, FL).			Initiate fall data entry and/or upload (C, FL). Update protocol and data management SOPs for Spring (DM). Upload summer summary data to Master database (DM).

7.2. Facilities and Equipment Needs

A list of necessary and recommended field sampling equipment is described in *SOP 1 - Preparations and Equipment Setup Prior to the Field Season* and *SOP 3 - Daily Field Activities*. The Field Lead will ensure that all equipment is in good working order and that there is an adequate supply of any consumables.

Field crews will use park housing, when available, or camp at designated campgrounds when working at more centrally located field sites. They may need to backcountry camp for remote sites. MOJN I&M staff will work with park staff to arrange for housing in advance of the field season.

A minimum of one dedicated 4WD vehicle will be required to support each field season for this protocol. Periodic access to at least another 4WD vehicle is necessary for MOJN I&M staff to meet with crews and conduct field checks. Currently, MOJN I&M has three 4WD vehicles, enough to support this and other protocols. If additional vehicles are needed, MOJN I&M has been able to periodically borrow 4WD vehicles from LAKE when they are not in use. Backcountry safety procedures require that all 4WD vehicles be equipped with at least two spare tires when traveling to PARA.

7.3. Budget

The estimated annual operating budget for the IU protocol is outlined in Table 7.2.

Table 7.2. Estimated annual IU protocol budget. Approximately 34-40% of the budget will be spent on data management¹.

Annual Estimates	Annual Cost – Initial Establishment	Annual Cost – Recurring
Equipment and Supplies	5,000	
Replacement cost of sensitive field equipment (e.g., cameras, field computers, GPS, SPOT/satellite phone)		5,000
Labor		
Ecologist (Protocol Lead; 0.33 time/year)	31,000	31,000
GS-7/9 Biotech (Field Lead; 0.50 time/year)	12,000	12,000
GS-5 Biotech (Field Crew; 4 – 6 crew members per 2 sampling periods and 2 parks per yr)	60,000	60,000
Data Management Team (consisting of Data Manager, Data Management Technician, GIS Specialist)	27,000	15,000
Travel (e.g., per diem, vehicle)	7,000	6,500
Total Annual Cost	142,000	129,500

¹Forty percent of the total budget (\$56,333) is spent on data management activities during initial establishment and decreases to 34% (\$44,333) in subsequent years. The Protocol Lead and Field Lead will each spend 1/3 of their time and the field crew will spend 1/4 of their time towards data management. 100% of the salary allocation for the data management staff is attributed towards data management.

Comprehensive reports will be produced approximately every ten years. The production of comprehensive reports will primarily involve the network ecologist and statistical consultant. During the first year that comprehensive reports will be produced, we anticipate that the network ecologist will spend approximately 0.25 time/year (\$22,500) and the statistical consultant 40 hours (\$4000). This time includes the production of an annual brief and other products (e.g., figures) that will be directly available to the parks. We anticipate that subsequent comprehensive reports will require less time from the network ecologist, as a general report template will be established.

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Appendix A: Status and Trend Invasive Species for the MOJN Parks

Table A1. Invasive plant species for status and trends monitoring at Death Valley National Park.

Species	Common name	Invasion phase	MOJN rating	Habitat of concern
<i>Bromus rubens</i>	Red brome	Equilibrium	High	Upland and Riparian
<i>Bromus tectorum</i>	Cheatgrass	Spread/Equilibrium	High	Upland and Riparian
<i>Erodium cicutarium</i>	Redstem filaree	Equilibrium	Medium	Upland and Riparian
<i>Phoenix dactylifera</i>	Date palm	Spread	Medium	Riparian
<i>Salsola</i> spp. (<i>S. tragus</i> and <i>S. paulsenii</i>)	Russian thistle	Spread/Equilibrium	Medium	Upland and Riparian
<i>Schismus</i> spp. (<i>S. arabicus</i> and <i>S. barbatus</i>)	Mediterranean grass	Equilibrium	Medium	Upland and Riparian
<i>Sisymbrium irio</i>	London rocket	Spread	Medium	Upland and Riparian
<i>Tamarix</i> spp. (<i>T. ramosissima</i> , <i>T. chinensis</i> , <i>T. aphylla</i> , <i>T. parviflora</i>)	Saltcedar	Spread/Equilibrium	High	Riparian

Table A2. Invasive species for status and trends monitoring at Great Basin National Park.

Species	Common name	Invasion phase	MOJN rating	Habitat of concern
<i>Bromus inermis</i>	Smooth brome	Spread	Medium	Riparian
<i>Bromus tectorum</i>	Cheatgrass	Equilibrium	High	Upland and Riparian
<i>Cirsium</i> spp. (<i>C. arvense</i> , <i>C. vulgare</i>) and <i>Carduus nutans</i>	Thistles	Spread	High	Riparian
<i>Erodium cicutarium</i>	Redstem filaree	Equilibrium	Medium	Upland and Riparian
<i>Melilotus</i> spp. (<i>M. officinale</i> , <i>M. albus</i>)	Sweetclovers	Spread	Medium	Upland and Riparian
<i>Salsola</i> spp. (<i>S. tragus</i> and <i>S. paulsenii</i>)	Russian thistle	Spread/Equilibrium	Medium	Upland and Riparian
<i>Sisymbrium altissimum</i>	Tumble mustard	Spread	Medium	Upland and Riparian

Table A3. Invasive species for status and trends monitoring at Joshua Tree National Park.

Species	Common name	Invasion phase	MOJN rating	Habitat of concern
<i>Brassica tournefortii</i>	Sahara mustard	Spread	High	Upland and Riparian
<i>Bromus rubens</i>	Red brome	Equilibrium	High	Upland and Riparian
<i>Bromus tectorum</i>	Cheatgrass	Spread/Equilibrium	High	Upland and Riparian
<i>Erodium cicutarium</i>	Redstem filaree	Equilibrium	Medium	Upland and Riparian
<i>Schismus</i> spp. (<i>S. arabicus</i> and <i>S. barbatus</i>)	Mediterranean grass	Equilibrium	Medium	Upland and Riparian
<i>Sisymbrium irio</i>	London rocket	Spread	Medium	Upland and Riparian
<i>Tamarix</i> spp. (<i>T. ramosissima</i> , <i>T. chinensis</i> , <i>T. aphylla</i> , <i>T. parviflora</i>)	Saltcedar, tamarisk	Spread/Equilibrium	High	Riparian

Table A4. Invasive species for status and trends monitoring at Lake Mead National Recreation Area.

Species	Common name	Invasion phase	MOJN rating	Habitat of concern
<i>Brassica tournefortii</i>	Sahara mustard	Spread	High	Upland and Riparian
<i>Bromus rubens</i>	Red brome	Equilibrium	High	Upland and Riparian
<i>Bromus tectorum</i>	Cheatgrass	Spread/Equilibrium	High	Upland and Riparian
<i>Erodium cicutarium</i>	Redstem filaree	Equilibrium	Medium	Upland and Riparian
<i>Schismus</i> spp. (<i>S. arabicus</i> and <i>S. barbatus</i>)	Mediterranean grass	Equilibrium	Medium	Upland and Riparian
<i>Sisymbrium irio</i>	London rocket	Spread	Medium	Upland and Riparian
<i>Tamarix</i> spp. (<i>T. ramosissima</i> , <i>T. chinensis</i> , <i>T. aphylla</i> , <i>T. parviflora</i>)	Saltcedar	Spread/Equilibrium	High	Riparian

Table A5. Invasive species for status and trends monitoring at Manzanar National Historic Site.

Species	Common name	Invasion phase	MOJN rating	Habitat of concern
<i>Bromus rubens</i>	Red brome	Equilibrium	High	Upland and Riparian
<i>Bromus tectorum</i>	Cheatgrass	Equilibrium	High	Upland and Riparian
<i>Erodium cicutarium</i>	Red stem filaree	Equilibrium	Medium	Upland and Riparian
<i>Salsola</i> spp. (<i>S. tragus</i> and <i>S. paulsenii</i>)	Russian thistle	Spread/Equilibrium	Medium	Upland and Riparian
<i>Schismus</i> spp. (<i>S. arabicus</i> and <i>S. barbatus</i>)	Mediterranean grass	Equilibrium	Medium	Upland and Riparian
<i>Tamarix</i> spp. (<i>T. ramosissima</i> , <i>T. chinensis</i> , <i>T. aphylla</i> , <i>T. parviflora</i>)	Saltcedar	Spread/Equilibrium	High	Riparian

Table A6. Invasive species for status and trends monitoring at Mojave National Preserve.

Species	Common name	Invasion phase	MOJN rating	Habitat of concern
<i>Brassica tournefortii</i>	Sahara mustard	Spread	High	Upland and Riparian
<i>Bromus rubens</i>	Red brome	Equilibrium	High	Upland and Riparian
<i>Bromus tectorum</i>	Cheatgrass	Equilibrium	High	Upland and Riparian
<i>Erodium cicutarium</i>	Red stem filaree	Equilibrium	Medium	Upland and Riparian
<i>Salsola</i> spp. (<i>S. tragus</i> and <i>S. paulsenii</i>)	Russian thistle	Spread/Equilibrium	Medium	Upland and Riparian
<i>Schismus</i> spp. (<i>S. arabicus</i> and <i>S. barbatus</i>)	Mediterranean grass	Equilibrium	Medium	Upland and Riparian
<i>Sisymbrium irio</i>	London rocket	Spread	Medium	Upland and Riparian
<i>Tamarix</i> spp. (<i>T. ramosissima</i> , <i>T. chinensis</i> , <i>T. aphylla</i> , <i>T. parviflora</i>)	Saltcedar	Spread/Equilibrium	High	Riparian

Table A7. Invasive species for status and trends monitoring at Grand Canyon-Parashant National Monument.

Species	Common name	Invasion phase	MOJN rating	Habitat of concern
<i>Bromus rubens</i>	Red brome	Equilibrium	High	Upland and Riparian
<i>Bromus tectorum</i>	Cheatgrass	Equilibrium	High	Upland and Riparian
<i>Erodium cicutarium</i>	Red stem filaree	Equilibrium	Medium	Upland and Riparian
<i>Schismus</i> spp. (<i>S. arabicus</i> and <i>S. barbatus</i>)	Mediterranean grass	Equilibrium	Medium	Upland and Riparian
<i>Tamarix</i> spp. (<i>T. ramosissima</i> , <i>T. chinensis</i> , <i>T. aphylla</i> , <i>T. parviflora</i>)	Saltcedar	Spread/Equilibrium	High	Riparian

Appendix B: Power to Detect Trend in Cover Metrics in Mojave Desert Network Parks

By Leigh Ann Starcevich, Ph.D., Statistical Consultant

The Integrated Upland protocol of the Mojave Desert Network (MOJN) will incorporate vegetative cover monitoring in randomly selected plots within its parks so that trends in time may be detected. A power analysis is conducted to determine if trends in these metrics may be detected with adequate power. Pilot data from vegetation surveys conducted in six MOJN parks are used to assess power to detect trends estimated from linear models.

Pilot data

Details of the pilot data sets from the six MOJN parks are provided in Table B1. The pilot data were collected with different response designs. For each pilot data set, the following metrics are computed: total cover, percent shrub, percent grass, percent tree, and percent other. For this power analysis, power to detect trends in total cover and percent shrub is examined. Boxplots of the two outcomes indicate variability within and among parks in MOJN (Figure B1).

The proposed response design for the vegetation monitoring in the MOJN Integrated Upland protocol is to use 100 m square macroplots, with three parallel 50 m transects spaced 25 m apart. The transects will start 25 m from each edge of the macroplot. MOJA and LAKE pilot data were collected with a similar response design: 50 m square plots, with seven 50 m transects that were separated by 7 m. GRBA employed a wagon-wheel design, with four 100 m transects originating from the same center and oriented in the cardinal directions, with random points examined within each meter section. Means were taken across transects to obtain plot-level responses for trend analysis. The other three datasets (DEVA, PARA, JOTR) were obtained from vegetation surveys or mapping data with multiple plots of variable size and ocular cover estimates.

The GRBA data were collected in 2008, 2009, and 2010. However, the 2010 data were collected in a survey of restoration sites so these sites may not be representative of the larger GRBA population. Boxplots indicate that the difference may be more extreme for the percent shrub response (Figure B2).

Table B1. Pilot data details.

Park	Years	No. plots	Plot design	Notes
DEVA	2009	45	11.3m radius, circular plots, ocular cover estimates by life forms	Removed the 4 plots affected by fire from original 49 plots.
GRBA	2008-2010	22, 4, 26	2008-wagon-wheel, line-point intercept transect, where center of wheel was a mammal burrow and 4, 50 m transect spokes in the cardinal directions, w/ 1 point within every meter	Sagebrush shrub steppe communities, no sites visited twice, 2010 sites are restoration sites and may not be appropriate to include. We examine the 2008-09 and the 2008-10 data in separate analyses.
JOTR		94 (45 in subset)	Vegetation mapping data; 20 m by 20 m plots, ocular cover estimates by species	
LAKE	2009	4	7, 50-m transects that were 7 meters apart taken for each plot; line-point intercept data taken for each transect w/ point intercepts at every meter	
MOJA	2009	4	7, 50-m transects that were 7 meters apart taken for each plot; line-point intercept data taken for each transect w/ point intercepts at every meter	
PARA	2007	142	Part of PARA that was included in LAKE veg mapping; 20 m by 20 m plots, ocular cover estimates by species	2008 data were not used because the sample size was too small (2 plots).

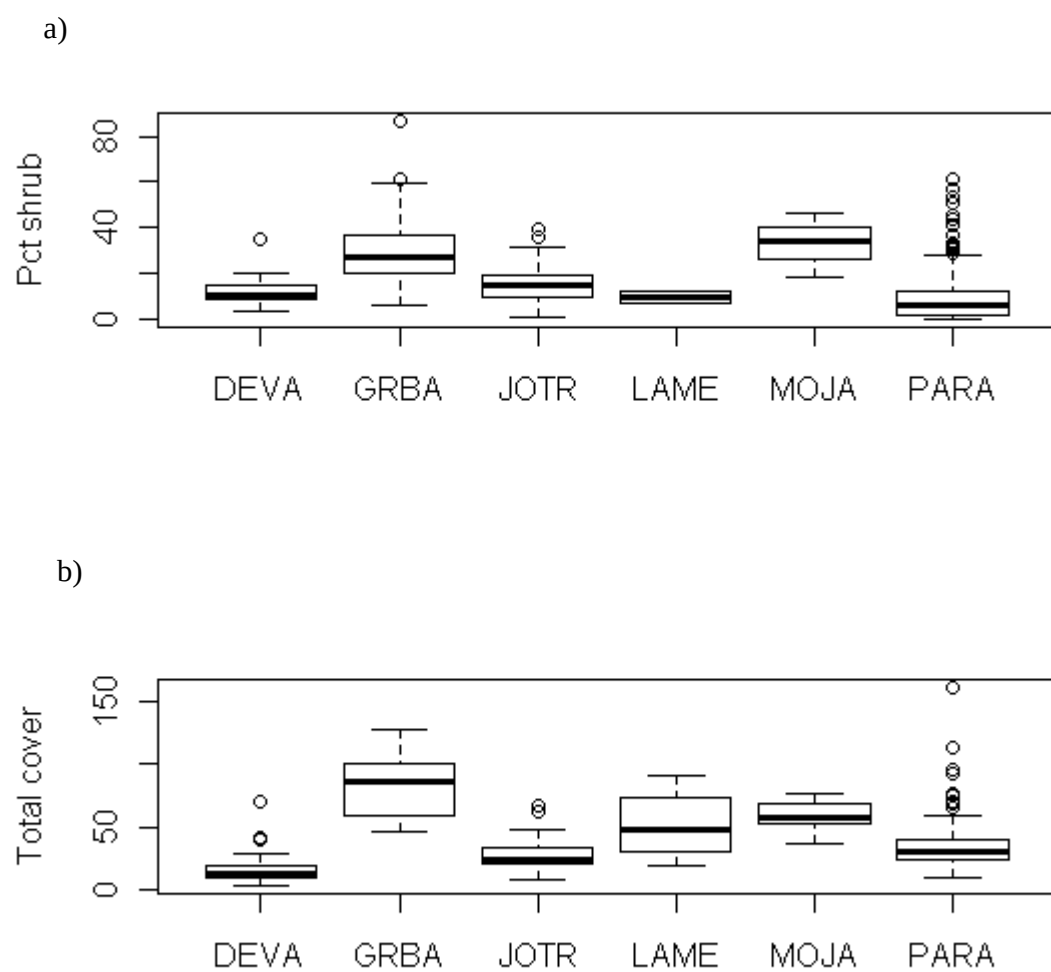


Figure B1. Boxplots of a) percent shrub and b) total cover in the pilot data for each park.

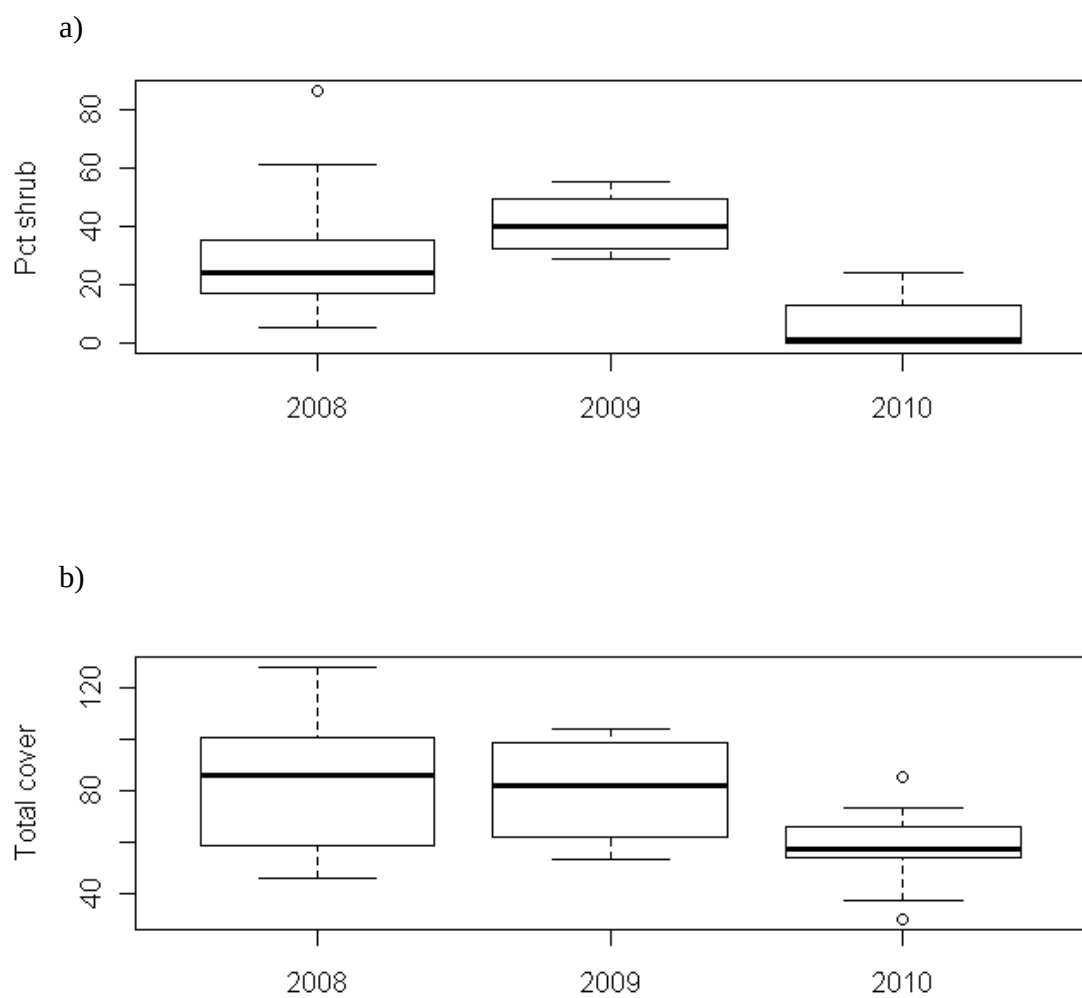


Figure B2. Boxplots of a) percent shrub and b) total cover for the 2008-2010 GRBA pilot data.

Revisit design

The power analysis was conducted assuming a revisit design in which each park is visited once every three years (a [1-2] revisit design) with two parks visited each year. Park-level inference can be obtained for this design, but network-level inference will be difficult due to the confounding of park visits over time and differences among communities within parks. Initial power analyses were also conducted for a [1-5] revisit design, but the longer revisit cycle of 6 years resulted in much lower power to detect trends in the time frames of interest. Furthermore, revisit cycles of more than 4 years require nearly a decade to obtain a complete replicate, enter data, and conduct the analysis (Urquhart and Kincaid 1999).

Trend model

The pilot data trend analysis was conducted with an amended mixed model proposed in VanLeeuwen et al. (1996) and Piepho and Ogutu (2002). Mixed models include fixed effects, which contribute to the mean of the outcome of interest, and random effects, which contribute to the variance. Random effects are used to estimate variation of linear trends among sites and over time. The full mixed linear model used for trend estimation is:

$$\log(y_{ij}) = \beta_0 + w_j\beta_1 + a_i + b_j + w_jt_i + e_{ij},$$

where $i = 1, \dots, m_a$; $j = 1, \dots, m_b$; and

m_a = the number of plots in the sample;

m_b = the number of consecutive years in the sample;

w_j = constant representing the j^{th} year (covariate);

β_0 = fixed intercept;

β_1 = fixed effect coefficient of the linear time trend;

a_i = random intercept of i^{th} plot, i.i.d. $N(0, \sigma_a^2)$;

b_j = random intercept of j^{th} year, i.i.d. $N(0, \sigma_b^2)$;

t_i = random slope of i^{th} plot, i.i.d. $N(0, \sigma_t^2)$;

e_{ij} = unexplained error, i.i.d. $N(0, \sigma_e^2)$.

Limitations of the pilot data over time and space made estimation of random effects impossible in most cases. For pilot data sets not exhibiting replication over time, the linear model reduces to the following linear mixed model:

$$\log(y_{ij}) = \beta_0 + w_j\beta_1 + a_i + e_{ij}.$$

Model results

Residual diagnostics revealed that residuals better meet assumptions of normality when the plot-level cover means were logarithmically-transformed, so logarithmic transformations are used in this analysis. This transformation also provides convenient interpretation of trend as a multiplicative factor over time. Model selection was conducted with Bayes Information Criterion (BIC). In all but one model, the model with the lowest BIC value did not contain the random site effect.

The estimates of fixed effects and variance components for percent shrub cover and total percent cover are provided in Tables B2 and B3, respectively. Note that the trend analysis of percent shrub cover was not conducted for the 2008 - 2010 GRBA dataset. As indicated in Figure B2, the shrub cover was much lower for the 2010 restoration sites and the three-year analysis of percent shrub cover exhibited zero inflation. In this case, the linear mixed model is not appropriate and was not implemented. However, the residual diagnostics for the total percent cover analysis indicated no violations of assumptions, so the linear mixed model was applied. The year-to-year variation was inestimable and the random site-to-site variance was not included in the final model selected by BIC, so the 2010 data were not useful in obtaining additional information about variance composition. The estimated trend is reported in Table B3 and indicates a significant annual absolute decline of 12.8% in total percent cover over the three-year period ($p < 0.0001$). However, because the 2010 restoration sites were chosen differently from the 2008 and 2009 sites, *inference from this trend is dubious*.

Power simulation

Power is assessed by Monte Carlo simulation. The populations are generated 500 times using the fixed intercepts and random effects variance components, and then the population is simulated to decline over time at a known rate. For a possible number of plots ranging from 10 to 100, the power to detect a significant trend in a two-sided hypothesis test of no trend is assessed as the proportion of times the null hypothesis of no trend is rejected at the Type I error rate of 0.10. The power results are provided for two outcomes, two levels of change (1% and 4% annual declines), two monitoring periods (20 and 30 years), and six parks in Figures B3 through B8.

Table B2. Transformations, fixed effects estimates, and variance components estimates by park for percent shrub cover.

Park	Subset	Transformation	$\hat{\beta}_o$ Est. Intercept	$\hat{\sigma}_a^2$ (transect-to-transect variance)	$\hat{\sigma}_e^2$ (residual variation)
DEVA	ALL	Log	2.3153	-	0.2387
GRBA	2008-09	Log	3.2536	-	0.4569
JOTR	ALL	Log	2.2931	-	0.6566
LAKE	ALL	Log	2.1960	-	0.1145
MOJA	ALL	None	33.5000	-	58.2000
PARA	ALL	Log	1.3894	-	2.7613

Table B3. Transformations, fixed effects estimates, trend test results, and variance components estimates by park for total percent cover.

Park	Subset	Transformation	$\hat{\beta}_0$ Est. Intercept	$\hat{\beta}_1$ Est. trend (SE)	Trend test p-value (two-sided)	$\hat{\sigma}_a^2$ (transect-to-transect variance)	$\hat{\sigma}_e^2$ (residual variation)
DEVA	ALL	Log	2.5922			-	0.3307
GRBA	ALL (2008-10)	None	83.9880	-12.8132 (2.9622)	<0.0001	-	418.48
GRBA	2008-09	None	82.6860			-	653.75
JOTR	ALL	Log	3.1208			-	0.2387
LAKE	ALL	Log	3.7876			-	0.4452
MOJA	ALL	Log	4.0522			-	0.0390
PARA	ALL	Log	3.4288			-	0.2026

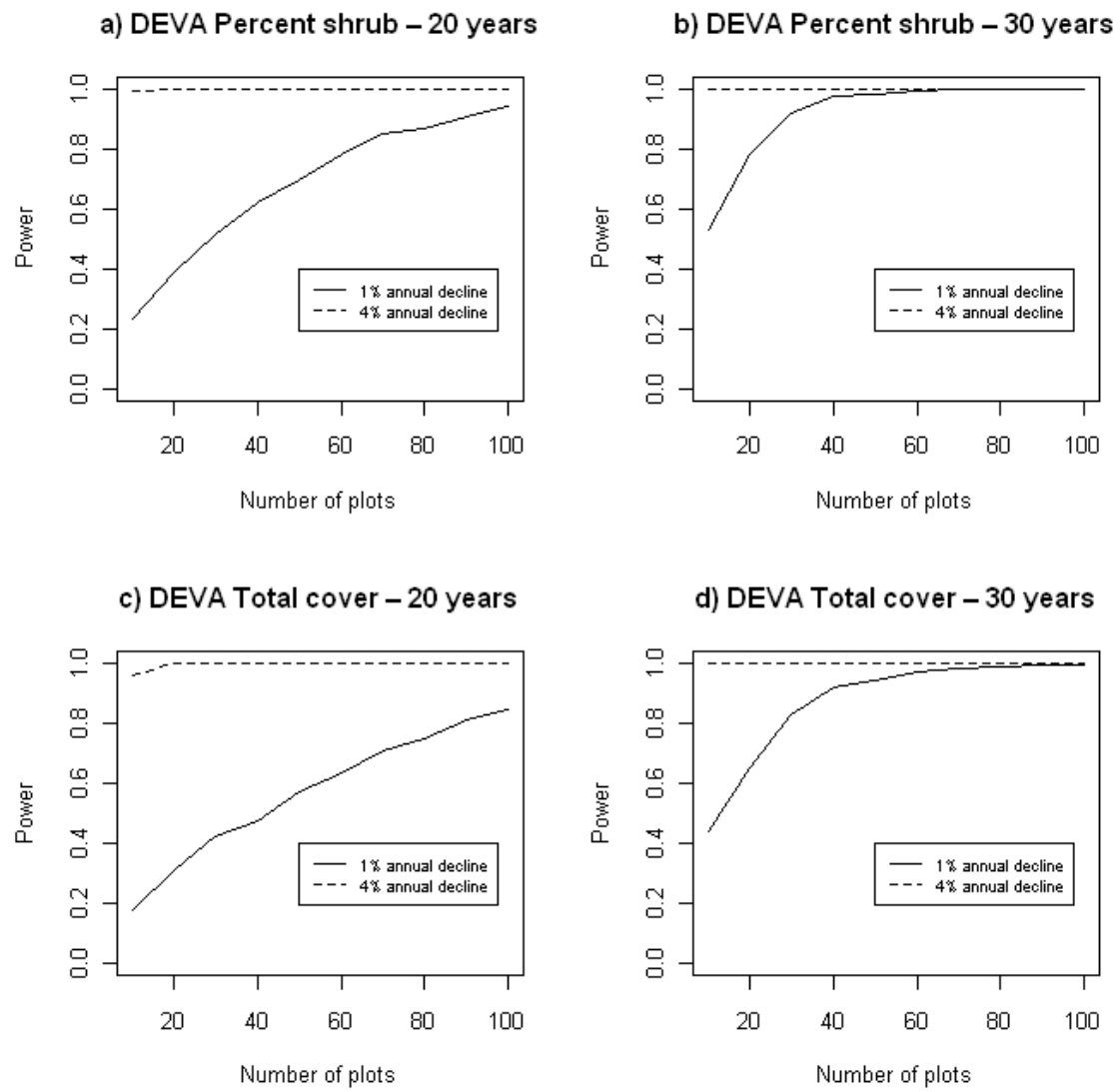


Figure B3. Simulation power for trend testing of cover in DEVA for annual declines of 1% and 4% in log transformed a) percent shrub cover over 20 years, b) percent shrub cover over 30 years, c) percent total cover metrics over 20 years, and d) percent total cover metrics over 30 years for a [1-2] revisit design.

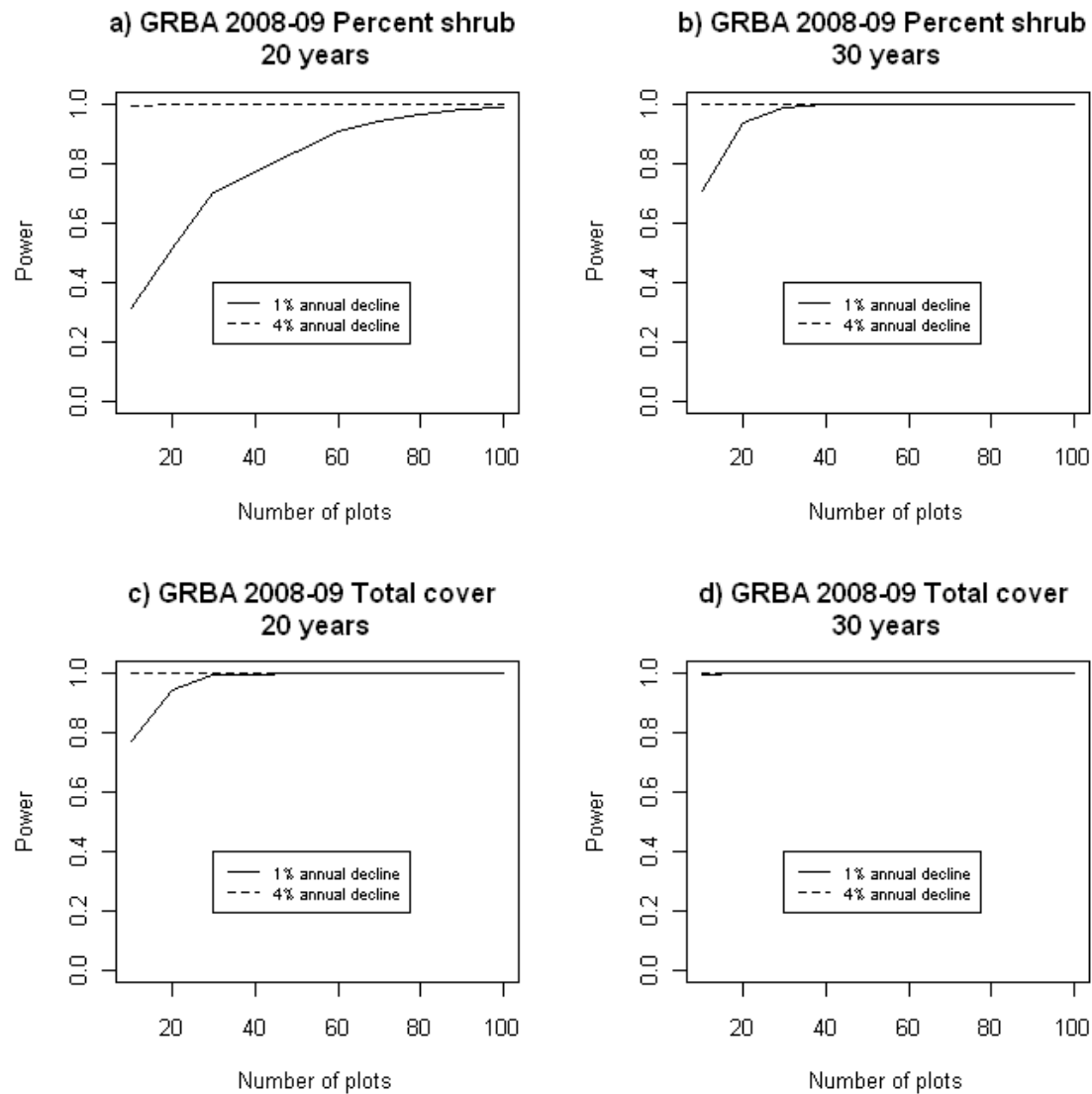


Figure B4. Simulation power for trend testing of cover in GRBA for annual declines of 1% and 4% in log transformed a) percent shrub cover over 20 years, b) percent shrub cover over 30 years, c) percent total cover metrics over 20 years, and d) percent percent total cover metrics over 30 years for a [1-2] revisit design (based on pilot data from 2008-09 only).

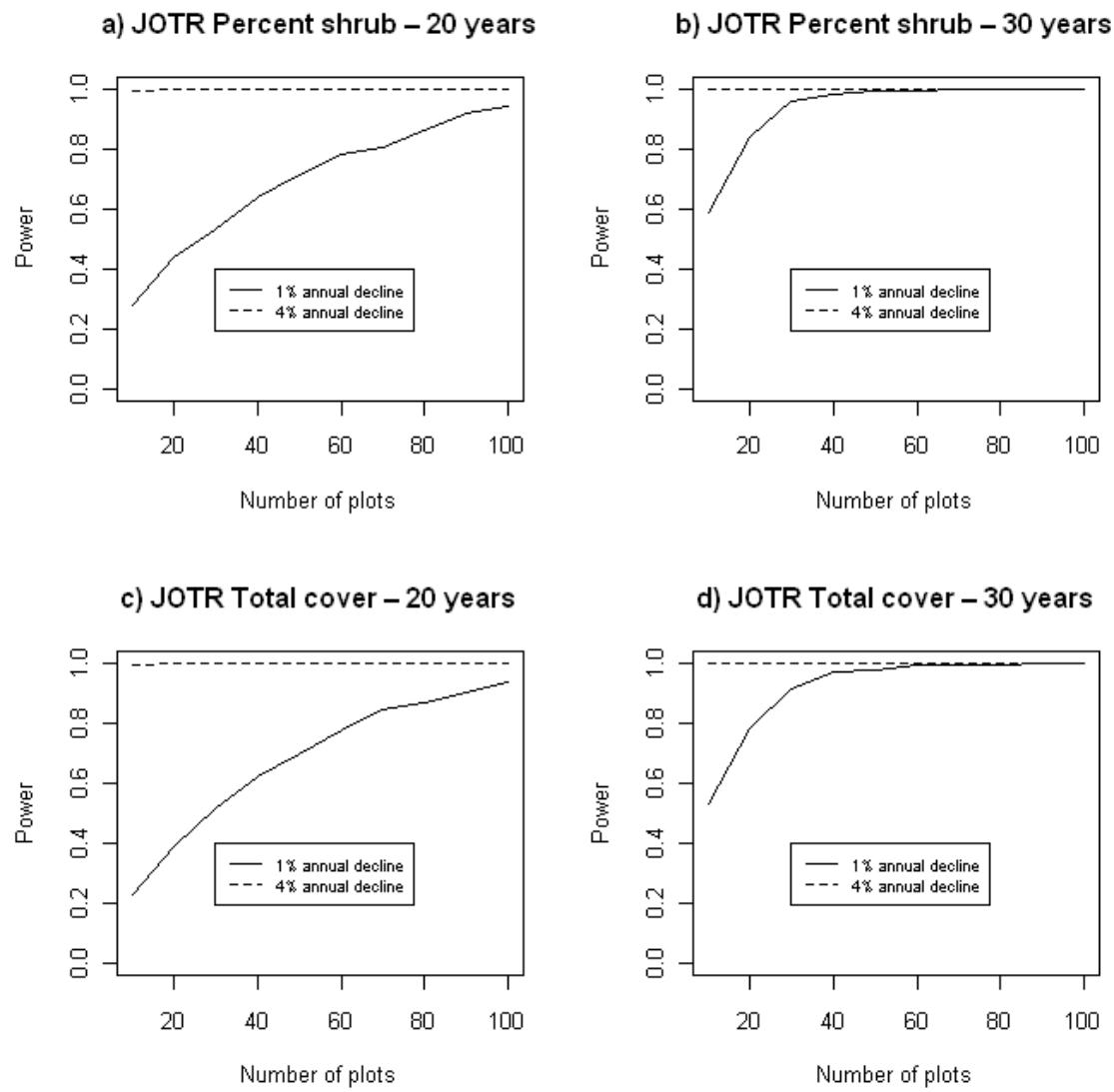


Figure B5. Simulation power for trend testing of cover in JOTR for annual declines of 1% and 4% in log transformed a) percent shrub cover over 20 years, b) percent shrub cover over 30 years, c) percent total cover metrics over 20 years, and d) percent total cover metrics over 30 years for a [1-2] revisit design.

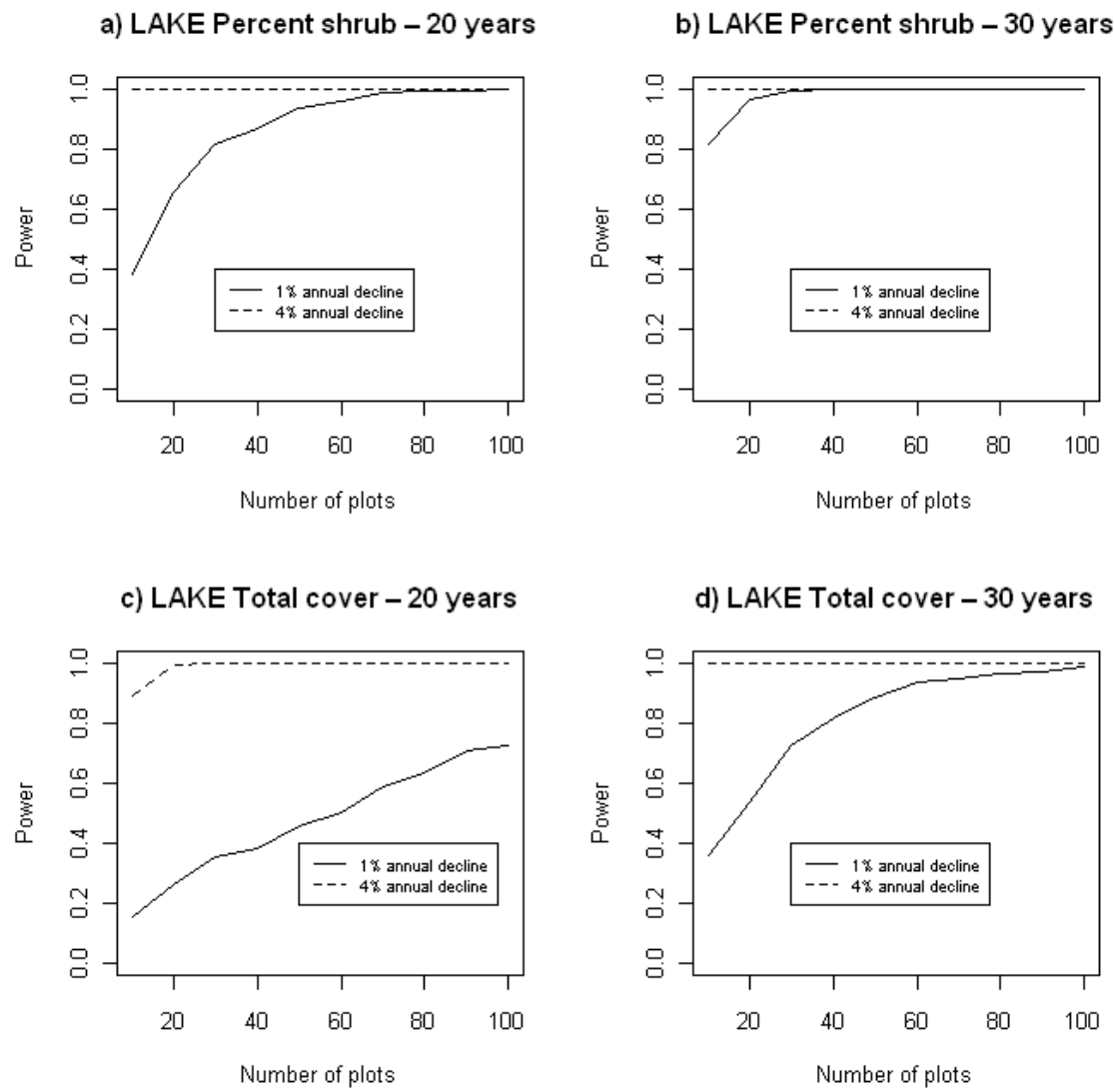


Figure B6. Simulation power for trend testing of cover in LAKE for annual declines of 1% and 4% in log transformed a) percent shrub cover over 20 years, b) percent shrub cover over 30 years, c) percent total cover metrics over 20 years, and d) percent total cover metrics over 30 years for a [1-2] revisit design.

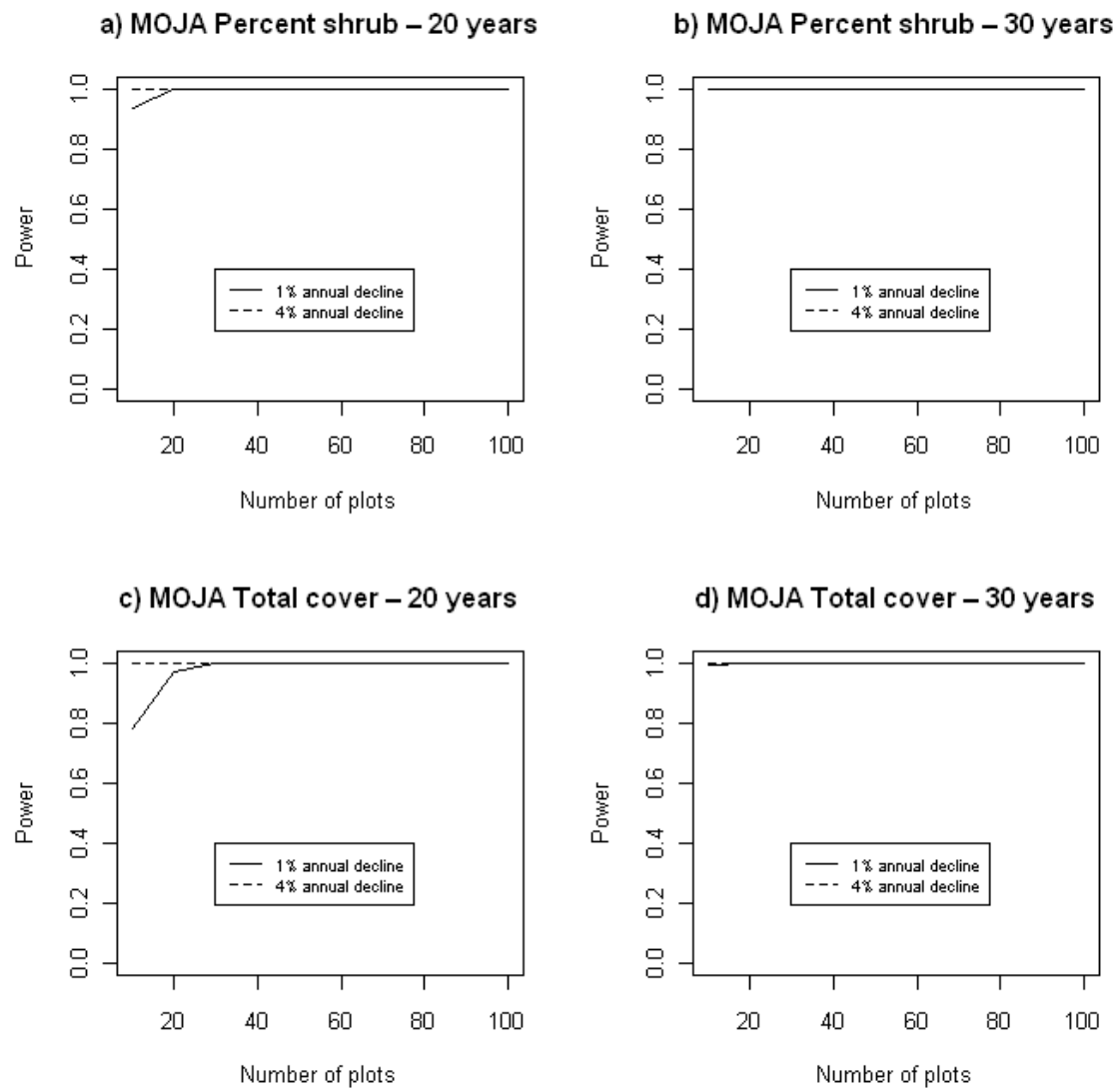


Figure B7. Simulation power for trend testing of cover in MOJA for annual declines of 1% and 4% in log transformed a) percent shrub cover over 20 years, b) percent shrub cover over 30 years, c) percent total cover metrics over 20 years, and d) percent total cover metrics over 30 years for a [1-2] revisit design.

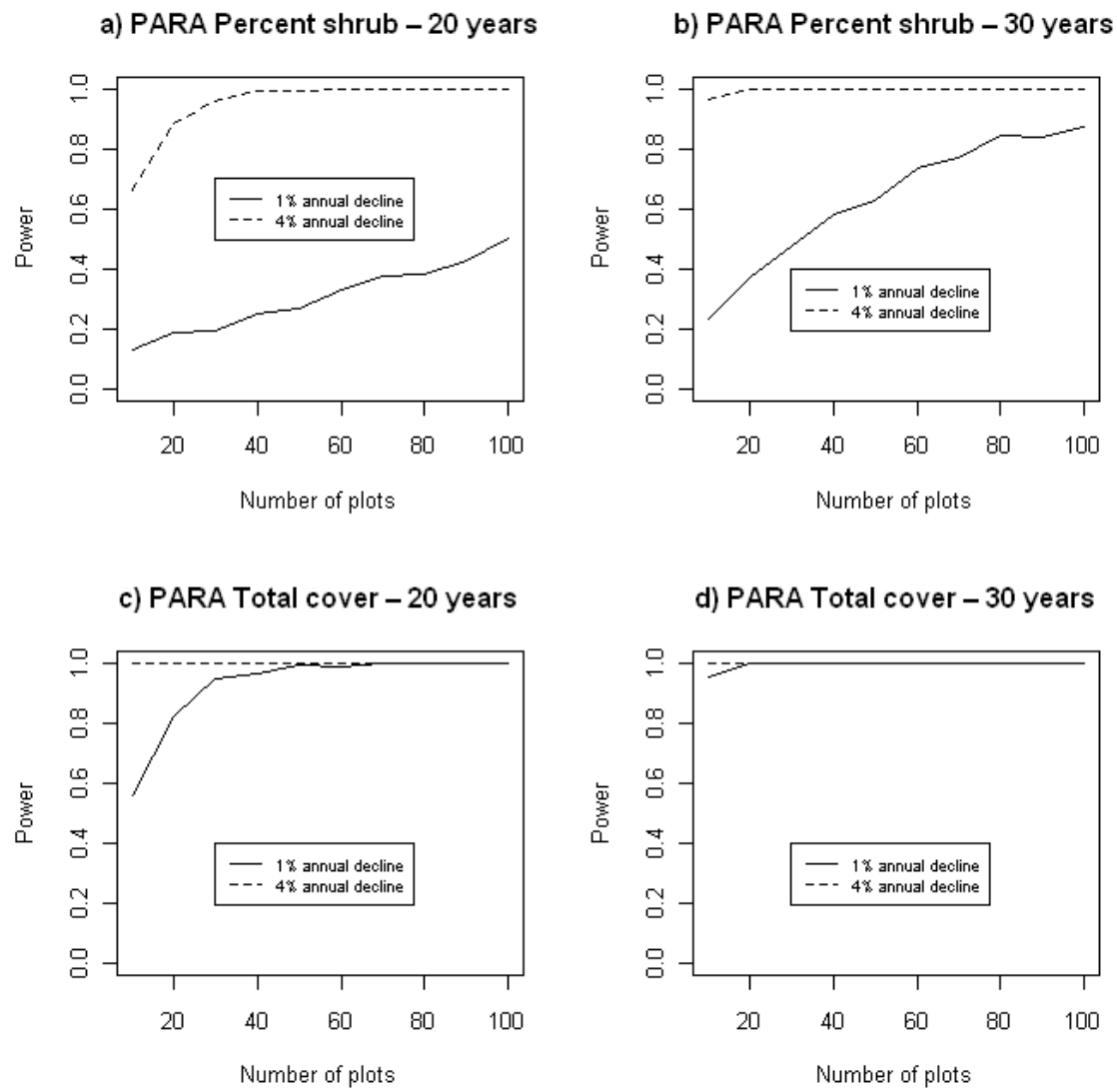


Figure B8. Simulation power for trend testing of cover in PARA for annual declines of 1% and 4% in log transformed a) percent shrub cover over 20 years, b) percent shrub cover over 30 years, c) percent total cover metrics over 20 years, and d) percent total cover metrics over 30 years for a [1-2] revisit design.

Results and Discussion

A 1% annual decline corresponds to a net decline of 18% over 20 years and a net decline of 26% over 30 years. A 4% annual decline corresponds to a net decline of 56% over 20 years and a net decline of 71% over 30 years. As expected, the power to detect a 4% annual change is higher than the power to detect a 1% change, but the trend impacts power differently based on the variability in the pilot data. Power to detect a 4% annual decline is uniformly high ($> 85\%$ for all parks) for an annual sample of at least 20 plots. Power to detect trends in MOJA exceeds 80% for both outcomes and both time frames. Trends in total percent cover in GRBA and PARA are estimated with at least 80% power for all sample sizes when the population declines by at least 4% annually and for annual samples of at least 20 plots when the population exhibits a 1% annual decline.

The power to detect a 1% annual decline over 20 years in LAKE total percent cover and in PARA percent shrub cover were the only scenarios for which 80% power was not obtained with an annual sample of 100 plots. With the exception of percent shrub cover in PARA and LAKE total cover, the power to detect annual declines of 1% over 30 years exceeds 80% for annual samples of 35 *plots* or less. Detecting a similar decline over 20 years requires at least double the number of sites, which is likely cost-prohibitive for long-term monitoring.

Note that this power analysis does not incorporate estimates of year-to-year variation (the variation or random-slope variation (the variation among plot-level trend lines). This variance component can greatly impact the power to detect trend (Urquhart and Kincaid, 1999). When each park has been visited at least three times, the year-to-year variation and random-slope variation can be estimated and used to reassess the power to detect trends in each park.

References

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