

Mojave Inventory and Monitoring Network

Phase I Report/Draft PhaseII Report

September 30, 2005
Version 2

Prepared By: Heister¹, K. M., C. Palmer², D. M. Miller³, T. C. Esque⁴, D. R. Bedford³, R. H. Webb⁵, J. Fenelon⁴, K. M. Schmidt³, and J. R. Nimmo³



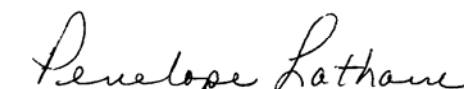
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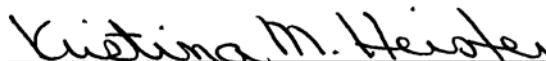
September 30, 2005

Submitted in partial fulfillment of the requirements of the National Inventory and Monitoring Program to develop and implement long-term ecological monitoring within the Mojave Network of parks. Parks within the Mojave Network are: Death Valley National Park, Grand Canyon-Parashant National Monument, Great Basin National Park, Joshua Tree National Park, Lake Mead National Recreation Area, Manzanar National Historic Site, and Mojave National Preserve.

Signature:


William K. Dickinson, Superintendent, Lake Mead NRA


Penelope Latham, Pacific West Region, I&M Coordinator


Kristina M. Heister, Mojave Network Coordinator

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9/29/05
Date 53
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Author Affiliations

¹ Mojave Network, Lake Mead National Recreation Area, 601 Nevada Highway, Boulder City, NV 89005

² Mojave Network, Harry Reid Center for Environmental Studies, University of Nevada, Las Vegas, 4505 Maryland Parkway, Las Vegas, NV 89154-4009

³ United States Geological Survey, Western Region Science Center, 345 Middlefield Road, MS-975, Menlo Park, CA 94025

⁴ United States Geological Survey, Western Ecological Research Center, Las Vegas Field Station, 160 N. Stephanie Street, Henderson, NV 89014

⁵ United States Geological Survey, Arizona District Office, 520 N. Park Avenue, Tucson, AZ 85719

Scope of Phase I Report

In 1999, the National Park Service (NPS) launched the Natural Resource Challenge, a 5-year program designed to strengthen natural resource management in the nation's national parks (National Park Service 1999a). The single biggest undertaking of the Challenge was to expand ongoing park inventory and monitoring efforts into an ambitious comprehensive nationwide program. The Servicewide Inventory and Monitoring (I&M) program was introduced to 270 parks identified as having significant natural resources. Under this program, parks have been organized into 32 networks to conduct long-term vital signs monitoring. Each network links parks that share geographic and natural resource characteristics, allowing for improved efficiency and the sharing of staff and resources. A map of the vital signs networks can be found at the following I&M website: <http://science.nature.nps.gov/im/monitor/networks.htm> (Accessed 30 August 2005). Funding for development and implementation of the I&M program has been allocated to groups of networks with all 32 networks to be fully funded in FY2006. The Mojave Network (MOJN), has already received funds to conduct biological inventories (2000-2004) and received 'start-up' funds in FY2003, FY2004, and FY2005 to conduct planning activities related to the vital signs monitoring program. The network is expected to be fully funded for the monitoring program in FY 2006.

The MOJN Vital Signs Monitoring Plan is being developed over a multi-year period following specific guidance from the NPS Washington Office (WASO) (NPS 2003a). Networks are required to document monitoring planning progress in three distinct phases and to follow a standardized reporting outline. Each phase of the report requires completion of specific portions of the outline.

The Phase I Report includes Chapter One (Introduction and Background) and Chapter Two (Conceptual Models) of the monitoring plan. The Phase II Report includes Chapters 1, 2, and 3 (Vital Signs) of the monitoring plan. Since the MOJN has completed the identification, prioritization, and initial selection of vital signs this information is also presented as a draft version of Chapter 3. Other chapters will be developed for the Phase III Report, the first full version of the MOJN Monitoring Plan. This document presents the MOJN framework and approach to planning for vital signs monitoring and sets the stage upon which the program will be developed. Specifically, this report:

- introduces network monitoring goals and describes the process we will use to select key resources and monitoring questions;
- summarizes existing information concerning park natural resources and identifies the most significant resources and resource threats for each park across the network;
- introduces the ecological context of the Mojave and Great Basin Deserts and provides conceptual models of significant network ecosystems.
- summarizes the process used to identify, prioritize, and initially select network vital signs.

• introduces vital signs identified and initially selected and associated justification, monitoring questions, and/or monitoring objectives.

The schedule for submission of required planning documents and the MOJN Vital Signs Monitoring Plan is as follows:

Planning Phase	Monitoring Plan Chapters	Goals and Tasks	MOJN Deadlines
Phase I	1,2	Program Background, Description of Important Resources and Threats, Data Mining Results and Conceptual Model Development	September 2005
Phase II	1-3	Vital Signs Prioritization, Selection, and Rationale	July 2006
Phase III Initial Draft	1-11	Monitoring Design – Full Monitoring Plan	December 2007
Phase III Peer-review	1-11	Monitoring Design – Full Monitoring Plan	December 2008

Executive Summary

Knowing the condition of natural resources in national parks is fundamental to the Service's ability to manage park resources "unimpaired for the enjoyment of future generations". The National Park Service has implemented a strategy designed to institutionalize natural resource inventory and monitoring on a programmatic basis throughout the agency. The effort was undertaken to ensure that the approximately 270 park units with significant natural resources possess the resource information needed for effective, science-based managerial decision-making and resource protection. The national strategy consists of a framework having three major components: 1) completion of basic resource inventories; 2) creation of experimental prototype monitoring programs; and 3) implementation of ecological monitoring.

Parks with significant natural resources have been grouped into 32 monitoring networks linked by geography and shared natural resource characteristics. The network organization will facilitate collaboration, information sharing, and economies of scale in natural resource monitoring. Parks within each of the 32 networks work together and share funding and professional staff to plan, design, and implement an integrated long-term monitoring program. The Mojave Network (MOJN) is made up of 7 National Park Service units located in Arizona, California and Nevada: Death Valley National Park, Grand Canyon-Parashant National Monument, Great Basin National Park, Joshua Tree National Park, Lake Mead National Recreation Area, Manzanar National Historic Site and Mojave National Preserve.

The complex task of developing ecological monitoring requires a front-end investment in planning and design to ensure that monitoring will meet the most critical information needs and produce ecologically relevant and scientifically credible data that are accessible to managers in a timely manner. Network monitoring programs are being developed over a four-year timeframe with specific objectives and reporting requirements for each of three planning phases. This document is the first of three scheduled reports. Its purpose is to: 1) outline MOJN monitoring goals and the planning process we will use to develop the monitoring program; 2) summarize existing information concerning park natural resources and identify the most significant resources, resource concerns and issues across the network; and 3) introduce the ecological context and provide a conceptual model framework for Mojave-Great Basin ecosystems.

The purpose of the second scheduled report is to: 1) provide completed conceptual models for the Mojave-Great Basin ecosystems; 2) document the MOJN vital signs selection process and results; and 3) provide protocol development summaries for selected vital signs. Although the MOJN has not completed steps 1 and 3 above we have completed the process of identifying, prioritizing and initially selecting a "short list" of high priority vital signs for the network. This information is provided in Chapter 3.

Over the next year, MOJN staff, park managers and scientists, and collaborators from the scientific community will be engaged in the process of final selection of vital signs for monitoring, development of specific, measurable monitoring objectives, continued refinement of conceptual ecological models, writing protocol development summaries, and continued 'mining', documentation and analysis of existing monitoring datasets. The network also hopes to initiate work on aspects of implementation such as sampling design, data management, budget, etc.

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Chapter 1. Introduction and Background

I. Mojave Network Overview

The Mojave Network consists of seven units managed by the National Park Service in Arizona, California and Nevada: Death Valley National Park (DEVA), Grand Canyon-Parashant National Monument (PARA), Great Basin National Park (GRBA), Joshua Tree National Park (JOTR), Lake Mead National Recreation Area (LAME), Manzanar National Historic Site (MANZ), and Mojave National Preserve (MOJA)(Figure 1). Grand Canyon-Parashant National Monument was established on January 11, 2000 by presidential proclamation and is managed jointly by the NPS and Bureau of Land Management (BLM). Total area of the monument is 424,242 hectares (1,048,325 acres). The NPS retains primary management authority over approximately 84,358 ha (208,453 ac) that are still formally within the boundary of Lake Mead National Recreation Area. In September 2002, the network Board of Directors decided to treat PARA as a separate park unit in the MOJN I&M program for the purposes of funding, field efforts and data management. PARA represents the only area of land within the Mojave Network located on the Colorado Plateau. Management documents and basic inventory data are still being developed for PARA and information for this NPS unit has been included where available. As additional information becomes available it will be included in subsequent reports and planning efforts.

MOJN park units include a total of 3,292,732 ha (8,136,519 ac) of land area, span approximately 450 kilometers (280 miles) from east to west, 600 kilometers (373 mi) from north to south, and cover over 4,000 meters (> 13,000 feet) of vertical relief. The majority of network parks are within the Great Basin-Mojave Desert region, which forms a broad wedge between the Sierra Nevada, the Transverse ranges, the Southern Rocky Mountains, and the Columbia and Colorado plateaus (Brussard et al. 1998). The biota of several park units also contains elements of neighboring ecosystems, including the Sonoran Desert (JOTR, MOJA, LAME), the Southern California Mountains (JOTR, MOJA) and the Colorado Plateau (PARA). The size of individual parks varies significantly. Network parks generally exhibit significant topographic relief with elevation ranging from 86 m below sea level to 3981 m above sea level (Table 1). Topographic relief creates powerful elevation gradients that determine temperature regimes (interaction of air density, solar radiation, precipitation, and slope) and influences soil development which in turn strongly influences the distribution of plant and animal communities across the region. Biological diversity across the network is concentrated primarily in riparian habitats (e.g. springs, oases, stream corridors), montane islands, and specialized habitats (e.g. sand dunes)(Brussard et al. 1998). Network parks contain a variety of regionally, nationally, and globally significant resources (Table 2). See Appendix A for a general overview of each network park.

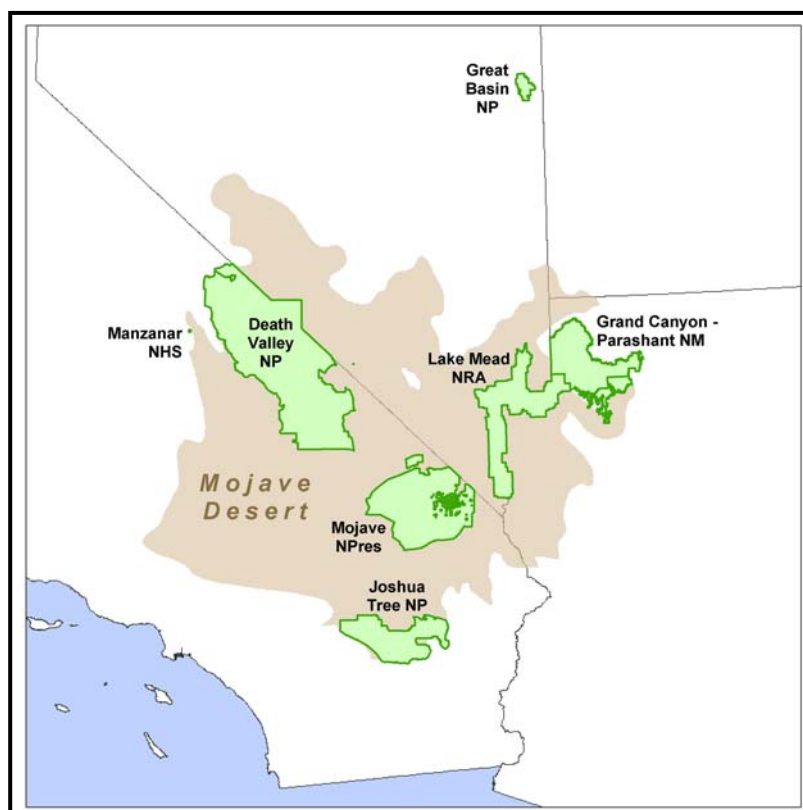


Figure 1. Parks included in the Mojave Inventory and Monitoring Network of the National Park Service.

Table 1. Basic characteristics of Mojave Network park units.

Park Name	Size (Acres)	Size (Hectares)	Elevation Range (m) (Feet Above Sea Level)
Death Valley National Park	3,396,192	1,374,420	-86 to 3,368 (-282 to 11,049)
Grand Canyon-Parashant National Monument	1,048,325 ^a	424,242	366 to 2,447 (1,200 to 8,029)
Great Basin National Park	77,082	31,194	1,615 to 3,981 (5,300 to 13,063)
Joshua Tree National Park	794,000	321,327	0 to 1,772 (Near 0 to 5,814)
Lake Mead National Recreation Area	1,288,274 ^b	521,346	152 to 1,719 (500 to 5,639)
Manzanar National Historical Site	814	329	1,158 (3,800)
Mojave National Preserve	1,531,832	619,923	274 to 2,438 (900 to 8,000)
Total	8,136,519	3,292,732	-86 to 3,981 (-282 to 13,063)

^a Total acreage at PARA includes 208,453 acres of NPS-owned land, 808,747 acres of BLM-owned lands, and 31,125 acres of non-federal lands.

^b Excludes 208,453 acres of NPS-owned land currently within LAME boundary that is now part of PARA; Total park acreage for LAME including NPS-owned land within PARA is 1,496,727 acres.

The landscape of Mojave Network NPS units has been altered significantly through historic patterns of land use and continues to be threatened by competing human interests, particularly related to water use (i.e. water diversion, grazing, development, non-native species, etc.) and urbanization (i.e. pollution, recreation, non-native species, etc.). In 1984, DEVA and JOTR were designated as part of a biosphere reserve program set aside by the United Nations Educational, Scientific, and Cultural Organization under its Man and the Biosphere Program (MAB). MAB is an international program of scientific cooperation dealing with human-environmental interactions throughout all geographic and climatic areas in the world (NPS). The purpose of biosphere reserves is to establish a network of protected samples of the world's major ecosystem types. In 1994, in the face of escalating resource threats and in recognition of the fragility of desert ecosystems, the California Desert (DEVA, JOTR, MANZ, MOJA, and parts of LAME) was designated an official pilot project of the national performance review to demonstrate effective ecosystem management, planning and agency reinvention efforts.

1.1 Purpose of MOJN Parks

The Mojave Network includes 3 National Parks, one National Monument, one National Recreation Area, one National Historic Site, and one National Preserve. In 1970, Congress elaborated on the 1916 NPS Organic Act, saying that all these designations have equal legal standing in the National Park System (NPS 1916).

The enabling legislation of an individual park provides insight into the natural and cultural resources and resource values that it was created to preserve. Along with national legislation, policy and guidance, a park's enabling legislation provides justification and, in some cases, specific guidance for the direction and emphasis of resource management programs, including inventory and monitoring. See Appendix B for a description of the enabling legislation, other related legislation, mission, purpose, and management goals for Mojave Network park units.

One related piece of legislation has significantly affected the entire Mojave Desert region, including 3 network parks, and represents the first comprehensive national statement about the value of the desert. The California Desert Protection Act of 1994 (PL 103-433) was passed due to escalating resource threats and in recognition of the fragility of desert ecosystems. Congress declared that "the public land resources of the California desert now face and are increasingly threatened by adverse pressures which would impair, dilute, and destroy their public and natural values" (PL 103-433). This legislation incorporated the lands of Death Valley National Monument into Death Valley National Park, expanded the park boundary to a total 1.4 million ha (3.37 million acres) and designated approximately 95% of the park as the "Death Valley Wilderness", a component of the National Wilderness Preservation System. At JOTR, the total park acreage was increased to 321,327 ha (794,000 ac), its status changed from National Monument to National Park, and the total area of land designated wilderness expanded to more than 240,165 ha (593,000 ac) (approximately 80% of park). This act also established MOJA to "preserve unrivaled scenic, geologic, and wildlife values" and "perpetuate in their natural state significant and diverse ecosystems of the California Desert" (PL 103-433) with a legislated park boundary encompassing 648,000 ha (1.6 million ac), including 283,500 ha (700,000 ac) of designated wilderness (approximately 44% of park).

Table 2. Significance of Resources Identified in Planning Documents^a for Parks^b Within the Mojave Network.

Park	Resource ^a	Significance Level				Comments
		State	Region	Nation	Global	
DEVA	Geologic Features				X	Complex, exposed geology and tectonics.
	Fossil Record			X		One of the nation's most diverse and significant fossil records.
	Volcanic History			X		One of the nation's most continuous volcanic histories.
	Dune Systems	X			X	Contains five major dune systems representing all dune types and representing one of the only places on earth where this variety of dune types occur in such close proximity. Eureka Dunes, a designated National Natural Landmark at the park's northern end, are the highest dunes in California and the second highest in North America.
	Scenic Landscape			X		One of the most visually dramatic in the United States.
	Water Resources - Devils Hole			X		Subterranean pool of great ecological significance and home to the Federally Endangered, Devils Hole pupfish (<i>Cyprinodon diabolis</i>).
	Weather			X	X	Temperature and precipitation extremes. Valley floor receives the least amount of precipitation in the nation. Highest recorded temperature for the nation and second highest in the world.
	Topography			X		Lowest point in North America
	Rare Species	X		X		Federal and State-listed T&E.
GRBA	Cave Resources	X		X		Lehman Cave is one of the most decorated caves in nation. Park contains the longest cave and highest cave in Nevada.
	Air Quality			X		Cleanest air quality in nation.
	Water Resources		X			Regionally important due to water scarcity.
	Rare species	X				State-listed T&E species.
JOTR	Rare species	X		X		Federal and State listed T&E species
LAME	Water Resources		X			Premier inland water recreation in West; Primary source of drinking water for S. Nevada.
	Rare species	X		X		Federal and State-listed T&E
MOJA	Kelso Dunes			X		Designated National Natural Landmark; Some of highest dunes in the region.
	Cinder Cones			X		Designated National Natural Landmark.
	Cima Dome				X	Joshua tree (<i>Yucca brevifolia</i>) forest on Cima Dome and in Shadow Valley is densest in the world. Internationally known as a place to conduct research.
	Scenic Landscape			X		Rich in visual diversity.
	Rare species	X		X		Federal and State-listed T&E species.

^a Resources and associated level of significance provided in this table were obtained from General Management Plans for network parks (NPS 2001b, 2000, 1999d, 1996, 1995, 1992a) and enabling legislation for PARA.

Table 2. (Con't).

Park	Resource ^a	Significance Level				Comments
		State	Region	Nation	Global	
PARA	Cave resources	X	X			Approximately 20 natural caves, 4 major sinkholes, and numerous other small sinkholes that may potentially contain significant cave features are located on the monument.
	Geologic Features			X	X	Geologic treasure offering a clear view of the geologic history of the Colorado Plateau.
	Fossil Record		X			Significant fossil resources, particularly invertebrates and sponges.
	Volcanic History		X			Plateau capped by 9 million to 1000 year old volcanic cinder cones and basalt flows.
	Scenic Landscape				X	Impressive landscapes. Remote areas of open, undeveloped spaces and engaging scenery located on the edge of one of the most beautiful places on Earth – the Grand Canyon.
	Rare Species	X		X		Federal and State-listed T&E species.

^a Resources and associated level of significance provided in this table were obtained from General Management Plans for network parks (NPS 2001b, 2000, 1999d, 1996, 1995, 1992a) and enabling legislation for PARA.

The purpose of designation for MOJN parks varies from the protection of natural resources, to public recreation, benefit, and use, to preservation of cultural resources. MANZ is the only network park established for the primary purpose of preserving cultural resources (Table 3). The following four categories encompass the network perspective on the purpose of MOJN parks: 1) preservation and protection of the scenic, geologic, and natural resources while perpetuating significant and diverse ecosystems, 2) preserve cultural resources and promote understanding of the cultural heritage of the California Desert and Great Basin physiographic regions, 3) Provide opportunities for scientific research and investigation, and 4) provide compatible public recreation opportunities.

1.2 Regional Context

The quality of the landscape matrix in which national park units are embedded is vital to the long-term integrity of the units themselves. Attributes of the surrounding landscapes contribute to both abiotic and biotic dynamics of remnant areas (Saunders et. al. 1991, Meffe and Carroll 1997) and are major determinants of both short-term and long-term protection effectiveness (Schonewald-Cox 1988). In many cases, it is essential for national park units to work with adjacent landowners simply because their boundaries fail to encompass habitats or interpretive elements of the environment necessary to meet legal mandates and park management goals. In 1963, the National Academy of Sciences Advisory Committee recommended that specific attention should be given to assessing changes in land use, resource use and economic activities on areas adjacent to national parks that likely affect those parks (Robbins et. al. 1963). In 1993, the National Park System Advisory Board recommended that “resource management should be addressed in broader context” and specifically recognized the impact of activities outside park boundaries (NPS 1993).

Table 3. Mission Statement for Mojave Network park units.

Park Name	Park Mission Statement ^a
Death Valley National Park	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.
Grand Canyon-Parashant National Monument	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."
Great Basin National Park	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	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	We provide diverse inland water recreational opportunities in a spectacular desert setting for present and future generations.
Manzanar National Historic Site	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	Mojave National Preserve was established to preserve outstanding natural, cultural, and scenic resources while providing for scientific, educational, and recreational interests.

^a Mission statements obtained from park General Management Plans (NPS 2005a, NPS 2001b, 2000, 1999d, 1996, 1995, 1992a).

Threats or stresses originating from outside park boundaries can, and are, significantly modifying biodiversity and other valued components of park ecosystems (National Parks and Conservation Association 1979, Garratt 1984, Machlis and Tichnell 1985, Sinclair 1998). In 1980, greater than 50% of threats reported across the National Park Service system were from external sources, with development on adjacent lands, air pollution, urban encroachment, roads and railroads most frequently cited (NPS 1980). It has been hypothesized that only protected areas with adequate expanses of surrounding habitat and linkages to other protected areas will be able to support current levels of biodiversity into the future (Hansen et. al. 2001). Specific threats to park resources from within and outside park boundaries are discussed in Section IV.

Parks in the Mojave Network are surrounded by a significant amount of public land. Approximately 93% of the Great Basin National Park boundary abuts other federal lands (78% USDA Forest Service and 15% Bureau of Land Management) and the park is almost completely surrounded by Humboldt National Forest. BLM lands surround the park at lower elevations in the Spring and Snake Valleys. Grand Canyon-Parashant National Monument also is almost completely surrounded by federal lands (NPS and BLM) with only 24 km of the park boundary abutting private lands. Management of these lands is considered critical to the protection of viewsheds and visitor experience at these parks.

Across the California portion of the Mojave Desert (including all parks except GRBA and LAME), a total of 76.84% of land is federally owned and the main federal land administrators are the BLM (34%), NPS (28%) and Department of Defense (14%)(Table 4). Lands in private ownership exist in a checkerboard pattern across the network, “a pattern established in the 19th century as a result of federal policy of land allocation during the homesteading and railroad development period” (Davis et. al. 1998)(Figure 2).

The California Desert Protection Act of 1994 (CDPA) significantly altered not only the size and designation of individual park units within the Mojave Network but the administrative composition of federal land across the region. During the California Gap Analysis project lands across the Mojave Desert region were categorized by management level with status 1 lands being afforded the highest level of protection (e.g. designated wilderness, units of the National Park Service, preserves, ecological reserves, etc.). The CDPA increased the proportion of status 1 lands across the Mojave Desert by approximately 150% (Davis et. al. 1998). Additional information on land management in the Mojave Desert region can be found on-line at: http://www.biogeog.ucsb.edu/projects/gap/gap_rep.html (Accessed 30 August 2005).

Table 4. Land Ownership in the California portions of the Mojave Desert. (From the Mojave Desert Alternative Futures Project at: <http://gis.esri.com/library/userconf/proc00/professional/papers/PAP192/p192.htm>; Accessed 30 August 2005).

Land Owner	Hectares	Percent Total
U.S. Fish and Wildlife Service	1,379	0.02%
Native American	1,584	0.02%
County/City/Regional	2,637	0.04%
USDA Forest Service	18,917	0.26%
State Land	165,890	2.24%
Designated Wilderness	742,617	10.04%
Military	1,066,317	14.42%
Private	1,542,337	20.86%
Bureau of Land Management	1,804,198	24.40%
National Park Service	2,047,635	27.70%
Total	7,393,717	100.00%
Percentage in Federal Ownership		76.84%

The fact that such a significant portion of the Mojave and Great Basin Deserts are publicly owned and managed provides hope for future preservation of park resources in the face of many resource threats and affords unique opportunities for collaboration and partnership and management of resources at multiple scales. These opportunities have been recognized not only through the passage of legislation but in the formation of bodies such as the California Desert Managers Group (DMG). This group was established as a forum for land managers (federal and state) across the Mojave Desert to discuss issues of common concern. The mission of the DMG is compatible with and compliments the goals of the MOJN Vital Signs Monitoring Program

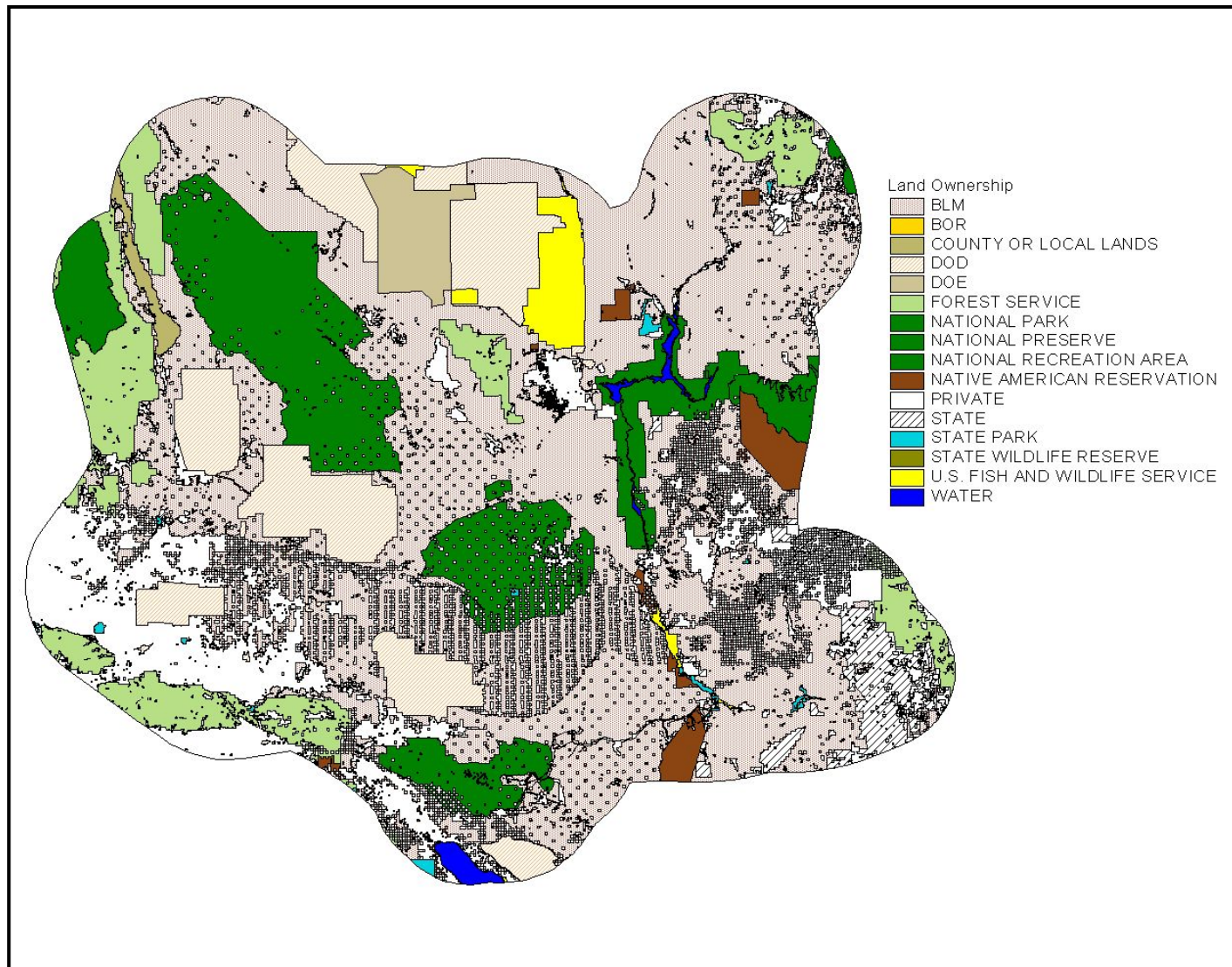


Figure 2. Land ownership across the Mojave Desert Ecoregion (+50 km).

1 including coordinating and integrating efforts to conserve and restore desert resources and
2 development of integrated databases and scientific studies needed for effective resource
3 management (<http://www.dmg.gov/charter.php>; Accessed 30 August 2005). It should also be
4 noted, as significant as the opportunities are for collaboration among federal land managers, that
5 federal land ownership also poses potentially significant challenges related to differences in
6 agency mission, purpose, and management priorities.

7 8 **II. Purpose**

9 10 **2.1 Justification for Monitoring**

11
12 Knowing the condition of natural resources in national parks is fundamental to the Service's
13 ability to manage park resources “unimpaired for the enjoyment of future generations”. NPS
14 managers across the country are confronted with increasingly complex and challenging issues
15 that require a broad-based understanding of the status and trends of park resources as a
16 foundation for making decisions and working with other agencies and the public for the benefit
17 of those resources. For years, managers and scientists have sought a way to characterize and
18 determine trends in the condition of parks and other protected areas to assess the efficacy of
19 management practices and restoration efforts and to provide early warning of impending threats.
20 The challenge of protecting and managing a park’s natural resources requires a multi-agency,
21 ecosystem approach because most parks are open systems, with threats such as air and water
22 pollution, or invasive species, originating outside of the park’s boundaries. An ecosystem
23 approach is further needed because no single spatial or temporal scale is appropriate for all
24 system components and processes; the appropriate scale for understanding and effectively
25 managing a resource might be at the population, species, community, or landscape level, and in
26 some cases may require a regional, national or international effort to understand and manage the
27 resource. National parks are part of larger ecosystems and must be managed in that context.

28
29 Monitoring is a central component of natural resource stewardship in the National Park Service,
30 and in conjunction with natural resource inventories and research, provides the information
31 needed for effective, science-based managerial decision-making and resource protection (Figure
32 3). Ecological monitoring establishes reference conditions for natural resources from which
33 future changes can be detected. Site-specific information provided through natural resource
34 monitoring is needed to understand and identify change in complex, variable, and imperfectly
35 understood ecosystems and to determine whether observed changes are within historic levels of
36 variability or may indicate unwanted human influences. Thus, monitoring data help define the
37 typical limits of variation in park resources and when put into a landscape context, monitoring
38 provides the basis for determining meaningful change in ecosystems. Monitoring results may
39 also be used to determine what constitutes impairment and to identify the need to initiate or
40 change management practices. Understanding the dynamic nature of park ecosystems and the
41 consequences of human activities is essential for management decision-making aimed to
42 maintain, enhance, or restore the ecological integrity of park ecosystems and to avoid, minimize,
43 or mitigate ecological threats to these systems (Roman and Barrett 1999).

The intent of the NPS monitoring program is to track a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values, known as “vital signs.” This subset of resources and processes is part of the total suite of natural resources that park managers are directed to preserve “unimpaired for future generations”. In situations where natural areas have been so highly altered that physical and biological processes no longer operate (e.g., control of fires and floods in developed areas), information obtained through monitoring can help managers understand how to develop the most effective approach to restoration or, in cases where restoration is impossible, ecologically sound management. The broad-based, scientifically sound information obtained through natural resource monitoring will have multiple applications for management decision-making, research, education, and promoting public understanding of park resources.

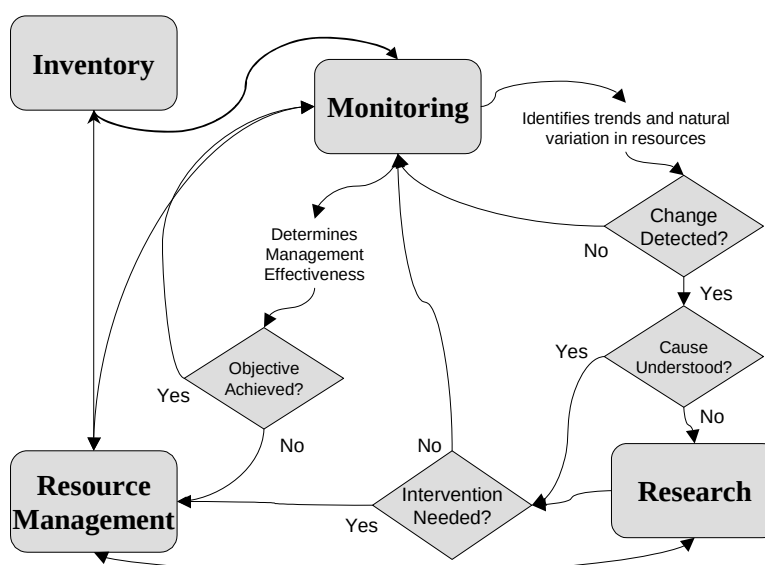


Figure 3. Relationships between monitoring, inventories, research, and natural resource management activities in national parks (modified from Jenkins et al. 2002).

2.2 NPS Framework for Inventory and Monitoring (I&M)

The National Park Service has implemented a strategy designed to institutionalize natural resource inventory and monitoring on a programmatic basis throughout the agency. The effort was undertaken to ensure that the approximately 270 park units with significant natural resources possess the resource information needed for effective, science-based managerial decision-making and resource protection. The national strategy consists of a framework having three major components: (1) completion of basic resource inventories upon which monitoring efforts can be based; (2) creation of experimental Prototype Monitoring Programs to evaluate alternative

1 monitoring designs and strategies; and (3) implementation of operational monitoring of critical
2 parameters ("vital signs") in all natural resource parks (On-line: [http://science.nature.nps.gov/
3 im/monitor/vsmAdmin.htm#Framework](http://science.nature.nps.gov/im/monitor/vsmAdmin.htm#Framework); Accessed 30 August 2005).

4
5 The third component of the NPS national framework for inventory and monitoring consists of
6 approximately 270 parks with significant natural resources that have been grouped into 32
7 monitoring networks linked by geography and shared natural resource characteristics. The
8 network organization will facilitate collaboration, information sharing, and economies of scale in
9 natural resource monitoring. The level of available funding will provide a minimum
10 infrastructure for initiating natural resource monitoring in all parks that can be built upon in the
11 future.

12
13 Parks within each of the 32 networks work together and share funding and professional staff to
14 plan, design, and implement an integrated long-term monitoring program. The complex task of
15 developing a network monitoring program requires a front-end investment in planning and
16 design to ensure that monitoring will meet the most critical information needs of each park and
17 produce scientifically credible data that are accessible to managers and researchers in a timely
18 manner. The investment in planning and design also ensures that monitoring will build upon
19 existing information and understanding of park ecosystems and make maximum use of
20 leveraging and partnerships with other agencies and academia.

21
22 The Mojave Network adopted the recommended 7-step approach to developing a natural
23 resource monitoring program. The approach involves seven steps, incorporated into a 3-phase
24 planning and design process, that has been established for the monitoring program. The seven
25 steps in developing a network monitoring program are (On-line:
26 <http://science.nature.nps.gov/im/monitor/approach.htm>; Accessed 30 August 2005):

- 27 1. Form a network Board of Directors and a Science Advisory committee.
- 28 2. Summarize existing data and understanding.
- 29 3. Prepare for and hold a scoping workshop.
- 30 4. Write a report on the workshop and have it widely reviewed.
- 31 5. Hold meetings to decide on priorities and implementation approaches.
- 32 6. Draft the monitoring strategy.
- 33 7. Have the monitoring strategy reviewed and approved.

34 35 **2.3 Legislation, Policy and Guidance**

36
37 In establishing the first national park in 1872, Congress "dedicated and set apart (nearly
38 1,000,000 acres of land) as a ... pleasuring ground for the benefit and enjoyment of the people"
39 (16 U.S.C. 1 § 21). By 1900, a total of five national parks had been established, along with
40 additional historic sites, scenic rivers, recreation areas, monuments, and other designated units.
41 Each unit was to be administered according to its individual enabling legislation, but had been
42 created with a common purpose of preserving the "precious" resources¹ for people's benefit.
43 Sixteen years later the passage of the National Park Service Organic Act of 1916 (16 U.S.C. 1 §

1) established and defined the mission of the National Park Service, and through it, Congress implied the need to monitor natural resources and guarantee unimpaired park services:

“The service thus established shall promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified ... by such means and measures as conform to the fundamental purpose of the said parks, monuments, and reservations, *which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.*”

Congress reaffirmed the declaration of the Organic Act vis-à-vis the General Authorities Act of 1970 (16 U.S.C. 1a-1a8) and effectively ensured that all park units be united into the ‘National Park System’ by a common purpose of preservation, regardless of title or designation. In 1978, the National Park Service's protective function was further strengthened when Congress again amended the Organic Act to state "...the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established..." thus further endorsing natural resource goals of each park. A decade later, park service management policy again reiterated the importance of this protective function of the NPS to “understand, maintain, restore, and protect the inherent integrity of the natural resources” (NPS 2001a).

More recent and specific requirements for a program of inventory and monitoring park resources are found in the National Parks Omnibus Management Act of 1998 (P.L. 105-391). The intent of the Act is to create an inventory and monitoring program that may be used “to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources” (NPS 1998). Subsequently, in 2001, NPS management updated previous policy and specifically directed the Service to inventory and monitor natural systems in order to inform park management decisions:

“Natural systems in the national park system, and the human influences upon them, will be monitored to detect change. The Service will use the results of monitoring and research to understand the detected change and to develop appropriate management actions” (NPS 2001a).

Legislation and NPS policy related to inventory and monitoring is complemented by a stewardship program for the NPS, approved in 1999, called the Natural Resource Challenge (NRC). The NRC is a budgeted action plan aimed at effectively balancing resource preservation with visitation and facilities development in National Parks. Funding provided by the NRC supports biological inventories, vital signs monitoring, and other resource related programs (e.g. vegetation mapping). The NRC (NPS 1999a) states:

“Clearly, the old management style will be insufficient to conserve our natural resources in the 21st century. ... our lack of information about plants, animals, ecosystems, and their interrelationships is profound. We

1 need to gather more data, expand our natural resource programs, strengthen
 2 partnerships with the scientific community, and share knowledge with
 3 educational institutions and the public.”
 4

5 In addition to the legislation directing the formation and function of the National Park System,
 6 there are several other pieces of legislation intended to not only protect the natural resources
 7 within national parks and other federal lands, but to address general concerns over the
 8 environmental quality of life in the United States. Many of these federal laws also require natural
 9 resource monitoring within national park units. As NPS units are among some of the most secure
 10 areas for numerous threatened, endangered or otherwise compromised natural resources in the
 11 country, the particular guidance offered by federal environmental legislation and policy is an
 12 important component to the development and administration of a natural resource inventory and
 13 monitoring system in the National Parks.
 14

15 Legislation, policy and executive guidance all have an important and direct bearing on the
 16 development and implementation of natural resource monitoring in the National Parks. Relevant
 17 federal legal mandates are therefore summarized in Appendix C. It is particularly important to
 18 note the Government Performance and Results Act (GPRA), because of its central role in agency
 19 operations and its relationship to the monitoring program. The National Park Service has
 20 developed a national strategic plan identifying key goals to be met (NPS 2005). The vital signs
 21 program contributes information needed to understand and measure performance regarding the
 22 condition of park resources that is helpful in achieving or measuring level of achievement toward
 23 these goals. The Vital Signs Monitoring Program reports directly to two GPRA goals identified
 24 for network parks (NPS 2005):
 25

Goal 1b3A - Vital Signs Identified

By September 30, 2008, 100% of 270 parks with significant natural
 resources have identified their vital signs for natural resource monitoring

Goal 1b3B - Vital Signs Monitored

By September 30, 2008, 80% of (216 of 270) parks with significant natural
 resources have implemented natural resource monitoring of key vital signs
 parameters.

37 In addition to the goals above the Vital Signs Monitoring Program provides data and information
 38 systems needed to report to several other GPRA goals. For example, for new Department of
 39 Interior Land Health goals parks will use a combination of quantitative trend information from
 40 vital signs monitoring and other efforts, and qualitative assessments based on the best available
 41 scientific information and expert opinion, to report on the condition of resources within each
 42 land type (e.g. uplands, wetlands) and resource category (e.g. air, water)(On-line:
 43 http://science.nature.nps.gov/im/monitor/docs/Vital_Signs_Overview.doc; Accessed 26
 44 September 2005). A list of the national GPRA goals relevant to MOJN parks is provided in
 45 Table 5. In addition to the national strategic goals, each park unit has a five-year plan that
 46 includes specific park GPRA goals. Many of these park specific goals are directly related to
 47

natural resource monitoring needs. The source for the preceding information on justification for monitoring and legislation, policy and guidance can be located at:
<http://science.nature.nps.gov/im/monitor/vsmAdmin.htm#ProgramAdmin> (Accessed 30 August 2005).

Table 5. GPRA goals specific to parks^a and relevant to development of a monitoring plan for the Mojave Network.

GPRA Goal	Goal #	DEVA	GRBA	JOTR	LAME	MANZ	MOJA
Category 1a: Natural and cultural resources and associated values are protected, restored, and maintained in good condition and managed within their broader ecosystem context.							
Disturbed Lands Restored	Ia1A	X	X	X	X	X	X
Exotic Plant Species	Ia1B	X	X	X	X	X	X
Land Health – Wetlands ^b	Ia1C						
Land Health – Riparian and Stream Areas ^a	Ia1D						
Land Health – Upland ^a	Ia1E						
Land Health – Mined Lands ^a	Ia1G						
Threatened and Endangered Species	Ia2	X	X	X	X		X
Species of Management Concern	Ia(0)2B		X	X	X		X
Exotic Animals	Ia2C	X	X		X		X
Air Quality and Wilderness Values	Ia3	X	X	X		X	
Surface Water Quality	Ia4	X	X	X	X	X	X
Water Quantity	Ia4B						X
Cultural Landscapes on the CLI	Ia7	X	X			X	X
Paleontological Resources	Ia9	X		X	X		X
Category 1b: The National Park Service contributes to knowledge about natural and cultural resources and associated values; management decisions about resources and visitors are based on adequate scholarly and scientific information.							
Park Natural Resource Data Sets	Ib01	X	X	X	X	X	X
Cultural Landscapes Baseline	Ib2B	X	X	X	X	X	X
Vital Signs Identified	Ib3A	X	X	X	X	X	X
Vital Signs Monitored	Ib3B	X	X	X	X	X	X

^a PARA not included because still developing park strategic and planning documents.

^b Goal targets will be established in 2006 after parks have completed baseline and status determinations but it is expected that several MOJN park units will adopt one or more of the land health goals.

2.3.1 National Park Service Mandates for Water Quality

The NPS Water Resources Division provides explicit guidance and funding for the water quality component of a network's monitoring program. Design and implementation of water quality monitoring is fully integrated with the network vital signs monitoring design process (including staffing, planning, design, etc.) to facilitate integration within the context of a comprehensive

network monitoring program. Historically, availability of water quality data for the parks has been inconsistent due to the variety of agency and state efforts and protocols. The NPS goal is to rely on its own uniform monitoring data and use it to protect water resources. Monitoring of water quality also is supported through legislation, policy, and guidance described above, including the 1916 Organic Act (NPS 1916), National Parks Omnibus Management Act (NPS 1998), and Natural Resource Challenge (NPS 1999a).

More explicit direction regarding monitoring and protection of water resources is provided through the NPS Strategic Plan 2005 to 2008 (NPS 2005) which sets the following GPRA goal for the NPS system to meet by September 2008:

- 90% of lake, reservoir, estuarine and marine areas managed by the National Park Service will meet State and Federal water quality standards as defined by the Clean Water Act.

Previous GPRA water quality goals targeted “swimmable beaches.” The strategic plan extended that goal to preventing the deterioration of the highest quality waters and improving the quality of the most degraded NPS waters. Each network, as part of the Vital Signs Monitoring Program, is required to:

1. Determine priorities for impaired water and pristine water monitoring;
2. Define site-specific monitoring objectives; and
3. Develop detailed water quality monitoring plans.

Planning and design for water *quality* monitoring will be addressed as a component of water *resource* monitoring within the MOJN. National GPRA goals related to water resources and relevant to MOJN parks are provided in Table 5. More holistic planning and design for water resource monitoring in the MOJN will include all water-related vital signs and will facilitate integration with the MOJN Vital Signs Monitoring Program. Detailed guidance for water quality monitoring developed by the NPS Water Resources Division is available at: <http://science.nature.nps.gov/im/monitor/vsmTG.htm#TGWater> (Accessed 30 August 2005).

2.4 Goals of Vital Signs Monitoring in the Mojave Network

The goals and objectives we define for monitoring frame our expectations and drive subsequent steps in the conceptual design and protocol development process. Ultimately, 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 indicate a needed change in management practices.

The Servicewide I&M Program has developed long-term goals to comply with legal requirements, fully implement NPS policy and to provide park managers with the data they need to understand and manage park resources. The Servicewide and Mojave Network goals for vital signs monitoring are provided in Table 6. Clear statement of goals and objectives helps define all aspects of a program including the choice of vital signs to be monitored. In the MOJN, monitoring objectives will be developed for each individual vital sign selected for monitoring.

Table 6. Servicewide and Mojave Network vital signs monitoring goals.

- 1. Determine status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources.**
- 2. Provide early warning of abnormal conditions of selected resources to help develop effective mitigation measures and reduce costs of management.**
- 3. Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments.**
- 4. Provide data to meet certain legal and congressional mandates related to natural resource protection and visitor enjoyment.**
- 5. Provide a means of measuring progress toward performance goals.**

Based on network monitoring goals, individual vital signs will be selected that address the most important attributes of ecosystems and/or resources that are of high importance for park management. Following recommendations by Noss (1990) and others, the MOJN aims to select vital signs across a range of spatial and temporal scales and across multiple levels of ecological hierarchy, from the genetic to the landscape level. The program will include effects-oriented monitoring to detect changes in the status or condition of selected resources, stressor-oriented monitoring to meet certain legal mandates (e.g. Clean Air Act), and effectiveness monitoring by parks to measure progress toward meeting performance goals (Noon et. al. 1999, NRC 1995). These goals also acknowledge the importance of seeking an understanding of inherent ecosystem variability in order to interpret human-caused change, and recognize the potential role of NPS ecosystems as reference sites for more impaired systems.

III. General Ecological Overview of the Mojave Network

3.1 Physiographic Provinces

The United States has been divided into physiographic or geomorphic regions based on common topography, rock types and structure and geologic and geomorphic history. Fenneman and Johnson (1946) present a regional geologic classification system based on division, province and section (subdivision). Based on this classification system, parks in the MOJN are primarily contained within the Basin and Range Physiographic Province (Table 7). PARA is located on the Shivwits Plateau, the westernmost plateau of the Colorado Plateau Physiographic Province. Grand Wash Cliffs forms the western boundary of the Shivwits Plateau and also represents the boundary between the Basin and Range and Colorado Plateau provinces.

Table 7. Physiographic provinces and sections within the Mojave Network of parks.

Park Code	Physiographic Province	Physiographic Section(s)
DEVA	Basin and Range	Basin and Range
GRBA	Basin and Range	Basin and Range
JOTR	Basin and Range	Sonoran Desert Salton Trough
LAME	Basin and Range	Basin and Range Sonoran Desert
MANZ	Basin and Range	Basin and Range
MOJA	Basin and Range	Sonoran Desert
PARA	Colorado Plateau	Grand Canyon

The Basin and Range province is the largest in the United States and extends from southeastern Oregon and southern Idaho through Nevada and eastern California, southern Arizona, and New Mexico into western Texas. It is characterized by uplifted and tilted mountain ranges consisting primarily of thick Paleozoic and Mesozoic rocks separated by broad, elongate, alluvium-filled valleys. The overall structure of these mountain ranges and valleys is generally northwest-southeast. Most of the province is characterized by dramatic relief as exhibited at DEVA from the highest point at Telescope Peak (3,368 meters above sea level) to the lowest point at Badwater (86 meters below sea level) (Figure 4). Topographic relief creates powerful elevation gradients that determine temperature regimes (interaction of air density, solar radiation, and precipitation) which in turn strongly influence the distribution of plant and animal communities across the region. The Colorado Plateau province, is bordered to the north and east by the Rocky Mountains and to the south and west by escarpments that divide it from the Basin and Range province. The Colorado Plateau is a high standing crustal block of relatively undeformed rocks and is characterized by large-textured forms developed on a great thickness of nearly horizontal Paleozoic, Mesozoic and Tertiary formations. Extensive areas of bare rock cover the Plateau's surface.



(a)



(b)

Figure 4. Telescope Peak (a) and Badwater Basin (b) at Death Valley National Park. (NPS Photo)

1 MOJN park units are located in 4 physiographic sections: Basin and Range section, Sonoran
2 Desert section, Grand Canyon section, and the Salton Trough section (Table 7). The Basin and
3 Range physiographic section is bounded on the west by the Sierra Nevada Mountains, to the east
4 and south by the Wasatch Mountains and the plateau areas of central and southern Utah, and the
5 Snake River Plain in Oregon and Idaho to the north. It is characterized by alternating, north-
6 south-trending, faulted mountains and flat valley floors.

7
8 There is no uniform geologic characteristic of the Sonoran Desert physiographic section.
9 Although dominated by broad alluvial basins and playas separated by relatively low mountain
10 ranges, there are a large variety of landforms to be found including late Cenozoic cinder cones
11 and lava flows, fault scarps, sand dunes, and playas. The typical geomorphic sequence observed
12 across the region is the mountain upland eroding into bajada or piedmont then sloping down to a
13 dry lake bed (Thomas et. al. 2004). The eastern portion of the section is generally composed of
14 basin and range topography and the northern portion is considered a transitional zone of the
15 Basin and Range physiographic section. The northern portion of the Sonoran Desert section
16 differs from the rest of the section in that the majority of its basins have internal drainage, similar
17 to the Basin and Range section. The southern portion of the Sonoran Desert section (outside the
18 MOJN) contains tributaries to the Gila and Colorado rivers and ultimately drains to the ocean.

19
20 Sections within the Colorado Plateau Physiographic Province were determined based primarily
21 on altitude and dissection extent. The Grand Canyon section is located in the southwestern
22 portion of the province and includes the Grand Canyon and the 2,000 m to 2,700 m block
23 plateaus around it. The Salton Trough physiographic section is a depression that extends from
24 the Gulf of California, in Mexico, to the Transverse Ranges in the northwest and is characterized
25 by desert alluvial slopes and broad deltaic plains. The section is generally divided by the Salton
26 Sea, with the Coachella Valley to the north and Imperial Valley to the South. It is bounded to
27 the east and west by a series of mountain ranges. The Transverse Ranges include the Little San
28 Bernadino, Pinto Mountains, and Eagle Mountains within JOTR and are unusual in that they
29 trend east-west rather than north-south. More information related to the geologic setting for each
30 network park is provided in Appendix D.

31
32 Geologic resources are significant and specifically mentioned in park legislative and/or guidance
33 documents (e.g. enabling legislation, General Management Plan) at DEVA, GRBA, JOTR,
34 MOJA, and PARA. Fifty percent of park significance statements presented in the DEVA
35 General Management Plan relate to geologic resources. The park possesses globally significant
36 geologic resources including the presence of “five major sand dune systems representing all
37 types of dune structures and one of the only places on earth where this variety of dune types
38 occurs in such close proximity” (NPS 2001b)(Figure 5). Eureka Dunes, a designated National
39 Natural Landmark at the park’s northern end, are the highest dunes in California and the second
40 highest in North America. The park also is world renowned for its exposed, complex and diverse
41 geology and tectonics and for its unusual geologic features. At a national level, DEVA contains
42 one of the most diverse and significant fossil records and most continuous volcanic records as
43 well as exhibiting some of the most dramatic visual landscapes in the United States (NPS
44 2001b). Frequently, geologic features such as sand dunes, caves, and playas represent rare,

1 small, and spatially dynamic habitats that support unique species and exhibit a high rate of
2 endemism. These natural areas contribute significantly to the biodiversity of the Mojave-Great
3 Basin Desert region and are discussed in Chapter 2.

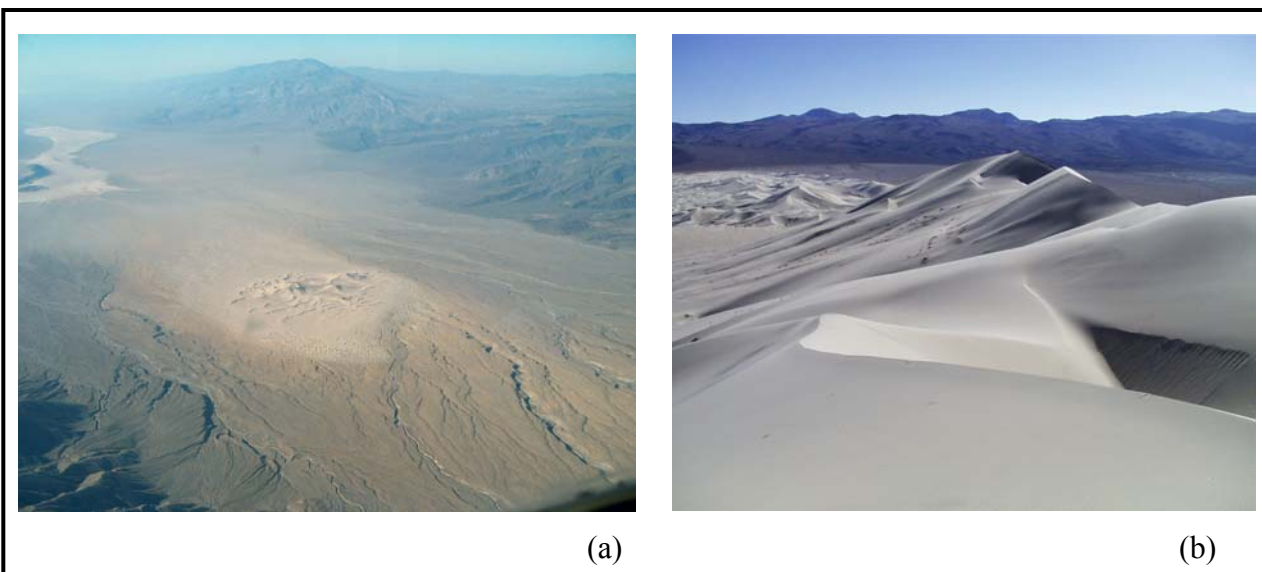


Figure 5. Panamint (a) and Eureka (b) Dunes at Death Valley National Park. (NPS Photo)

3.2 Climate

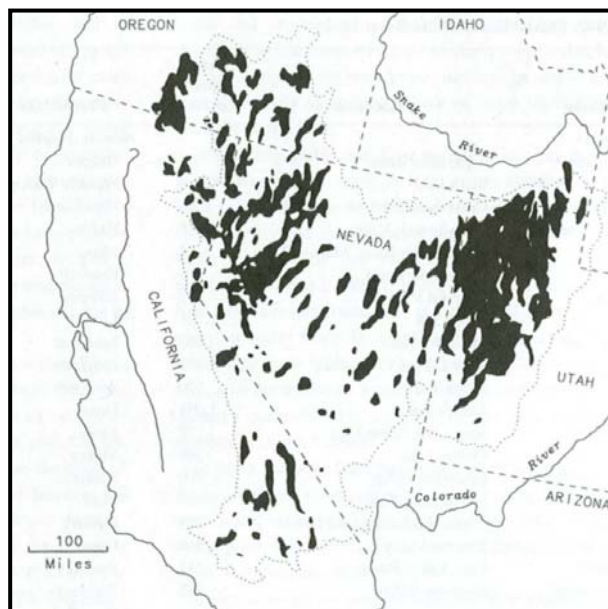
3.2.1 Climatic History

Climate is a primary factor controlling the structure and function of ecosystems in the Mojave Network and an understanding of both current (20th century) climate patterns and climate history is important to understanding and interpreting change and patterns in ecosystem attributes. The modern distribution and ecology of plant and animal communities should be linked at a broad temporal scale to the climatic history of the Great Basin-Mojave Desert region. Tausch et. al. (1995) suggests that in response to climatic changes over time the vegetation in the Great Basin has been in continual geographic and altitudinal movement for thousands of years. Many scientists suggest that we are currently in another interglacial period and to understand how plant and animal communities may respond to future climate change (glaciation or global warming) communities must be examined with history in mind (Gould 1991).

The Pleistocene Epoch ended approximately 11,000 years ago and covered approximately 3 million years during which several glaciation events occurred. Higher snowmelt and precipitation during deglaciation created enormous lakes, such as Lake Bonneville, and wetlands formed in many valleys effectively serving as an isolation mechanism between north-south trending mountain ranges (Figure 6). Glaciers were common in the Great Basin Desert on mountain tops higher than 3000 m (Wagner et. al. 2003), such as Wheeler Peak at GRBA. Generally, as climate changed in the Pleistocene, plant and animal community composition and

1 distribution was altered as species sought more favorable conditions, adapted to existing
2 conditions, were extirpated locally or became globally extinct. During periods of glaciation
3 species were forced down-slope and southward and during warming periods returned up-slope
4 and northward. For example, the diversity of alpine plant species indicates that the alpine zone
5 was greatly expanded during the Pleistocene Epoch but now consists of generally small, isolated
6 communities at the highest elevations (Brussard et. al. 1998). At the end of the Pleistocene
7 Epoch most scientists agree that the area covered and geographic extent of Great Basin shrub-
8 steppe species and Pinyon-Juniper Woodland (*Pinus* spp.-*Juniperus* spp., respectively) habitat
9 was significantly greater than its current distribution, including regions now considered part of
10 the Mojave and Sonoran Deserts (Wagner et. al. 2003) (A listing of species names is provided at
11 the end of this document).

12
13 During the present, Holocene Epoch, glaciers have receded and a warmer, drier climate exists.
14 Heat and drought intolerant species have been forced into the cooler, wetter mountainous regions
15 of the network and drought and heat-tolerant species have spread northward into the region at
16 lower elevations. For example, as pine woodlands receded to higher elevations, the extensive
17 pinyon-juniper zone on lower mountain slopes in the current Great Basin Desert was formed by
18 the northward expansion of single-needle pinyon (*Pinus monophylla*) in combination with
19 expansion of Utah juniper (*Juniperus osteosperma*), a very sparsely distributed species during
20 glacial periods (Wagner et. al. 2003). As pluvial lakes have disappeared, species such as the
21 Bonneville Cutthroat trout (*Oncorhynchus clarki utah*), once abundant in Lake Bonneville, have
22 retreated into mountain streams and have become isolated from similar populations within a
23 single mountain range. Many montane areas are now refugia for species remaining from the



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59 Figure 6. Estimated maximum extent of pluvial lakes in the Great Basin-Mojave Desert Region
60 during the Pleistocene Epoch. (From Brussard et. al. 1998 courtesy of Dr. David Charlet;
61 Available on-line at <http://biology.usgs.gov/s+t/SNT/noframe/gb150.htm>; Accessed 30 August
62 2005).

1 Pleistocene and mountain communities are significantly different from those in the intervening
2 desert valleys. Desert valleys that now also separate montane habitat islands as did pluvial lakes
3 in earlier periods (Brussard et. al. 1998). Isolation of populations for extended periods of time,
4 whether separated on different mountain ranges or in different springs or streams, has
5 contributed to the evolution of genetically unique populations and a high rate of endemism
6 across the Mojave Network.

7
8 Conservation biologists across the Great Basin-Mojave Desert Region are concerned about the
9 potential impact of global warming on species extinctions and the ability of species to re-
10 colonize in suitable locations under current and potential future climate conditions. As
11 temperatures warm and montane habitats shrink, local extinction of some mammalian, avian, and
12 butterfly species is considered likely (Wagner et. al. 2003). Brussard et. al. (1998) reported that
13 populations of 16 montane mammal species are currently isolated on mountains across the Great
14 Basin and that, if extirpated from these areas, are unlikely to re-colonize under current climatic
15 conditions. Recent examination of species composition and distribution of small mammal
16 communities at GRBA revealed that although a relatively large number of species were
17 documented in the park and surrounding areas there were fewer small and medium-sized
18 mammal species occupying the southern Snake Range than would be expected based on
19 available habitat and the pool of potential species occurring within the broader intermountain
20 region. In particular, many species that could occur at higher elevations within the park were
21 absent (e.g. *Tamiasciurus hudsonicus*, *Glaucomys sabrinus*, *Microtus richardsoni*,
22 *Clethrionomys gapperi*, *Zapus princeps*)(Rickart and Robson 2005). Although some of these
23 species may have been present in the past and have yet to be documented from prehistoric sites,
24 they appear to have failed to colonize the Snake Range during the late Pleistocene when
25 conditions would have been the most favorable for immigration across intervening lowlands
26 (Rickart and Heaney 2001). In the absence of many montane mammals, other small mammal
27 species that are normally restricted to low or mid-elevations in mountains with “saturated” local
28 faunas have reportedly expanded upward in distribution in the park (e.g. *Sorex vagrans*, *Lepus*
29 *californicus*, *Spermophilus variegates*, and *Thomomys talpoides*)(Rickart and Robson 2005).

32 3.2.2 20th Century Climate Conditions

34 Climate across the Mojave Network is one of the most extreme and variable in the world with
35 significant diurnal variation in temperature (Bailey 1995). Additionally, the association between
36 topography and climatic factors such as precipitation and temperature creates variable local
37 climatic conditions within parks based on elevation. Death Valley National Park, Joshua Tree
38 National Park, Lake Mead National Recreation Area, Mojave National Preserve and portions of
39 Grand Canyon-Parashant National Monument are located in a hot desert environment. At
40 DEVA, winter temperatures within the park rarely drop below freezing while daytime summer
41 temperatures routinely reach 43-49 °C (110-120 °F). Annual precipitation is approximately 5.08
42 cm (2 in) and there have been years with no recorded rainfall. The valley floor at DEVA
43 receives the least precipitation in the United States and the park can also claim the nation’s
44 highest and world’s second highest recorded temperature (NPS 2001b). At JOTR, winter
45 temperatures are mild, ranging from 4.4-18 °C (40-65 °F) and summer temperatures range from
46 20-41 °C (68-106 °F). Precipitation occurs primarily in the form of rainfall, averaging 10 cm

(4.06 in) per year, although this average varies widely throughout the park. The Pinto Basin average is 0-5 cm (0-2 in) of rain per year while higher elevations areas may receive 15-20 cm (6-8 in) of rain per year (NPS 1995). At LAME, winter temperatures are also mild, averaging 12-19 °C (53-66 °F) and summer temperatures average 32-43 °C (90-110 °F). Precipitation occurs primarily in the form of rainfall, averaging 11 cm (4.5 in) annually (R. Haley *pers. comm.*). At MOJA, winter temperatures are mild, ranging from 1-16 °C (34-61 °F) and summer temperatures range from 25-43 °C (77-109 °F). Precipitation occurs primarily in the form of rainfall, averaging 21.8 cm (8.6 in) per year (NPS 2000).

Great Basin National Park, portions of Grand Canyon-Parashant National Monument, and Manzanar National Historic Site are located in a 'high desert' or cold desert climate. Grand Canyon-Parashant National Monument bridges the Basin and Range Geologic Province with the Colorado Plateau and marks the boundary between the Sonoran/ Mojave/Great Basin floristic provinces indicating highly diverse climatic conditions related to topography. Average summer temperatures in nearby St. George, Utah range from 15-39 °C (59-102 °F) and average winter temperatures range from -3.3-16 °C (26-60 °F). Average total precipitation in St. George is 21 cm (8.3 in) primarily in the form of winter snow and summer rain. At Great Basin National Park, January temperatures at Lehman Caves (6,825 ft/2081 m) vary from -23-4.4 °C (-10 °F to 40+ °F). Average high temperatures during the summer range from 29-35 °C (85-95 °F) in the valleys to 25-28 °C (78-83 °F) at mid-elevations and 13-18 °C (55-65 °F) on the mountain ridges. The corresponding precipitation ranges from an average annual rainfall of 15 cm (6 in) in the valleys to 228+ cm (90+ in) on the mountain ridges (NPS 1992a). Precipitation occurs primarily in the form of winter snows and summer thunderstorms. At MANZ, the Owens Valley is well protected from ocean air masses by the Sierra crest and thus experiences a predominantly high desert type climate. Winter temperatures are often cold dropping below freezing for more than 100 days per year. Winter highs range generally range from the 0-10 °C (30-50 °F). Summer high temperatures often exceed 37 °C (100 °F), followed by evenings ranging from 18-24 °C (65-75 °F). Most precipitation falls as a mix of rain and snow during the months from December through March. A limited amount of precipitation falls from thunderstorms in July and August. Average precipitation totals about 10 cm (5 in) per year (NPS 1996). Information available through the Western Regional Climate Center provides climate data with the longest period of record and data summaries for key meteorological parameters (e.g. temperature and precipitation) in and around Mojave Network parks (Table 8).

Analysis of daily precipitation amounts in the Mojave Desert region between 1893 and 2001 reveal four multi-decadal precipitation regimes that are largely consistent with well-known droughts across the Southwest: 1893-1904 (dry), 1905-1941 (wet), 1942-1975 (dry), and 1976-1998 (wet). The wettest period of the 20th century was between 1976 and 1998 (Hereford et. al. 2004, Hereford et. al. 2002). Events in the tropical Pacific and northern Pacific Ocean are linked to variation in precipitation across the Mojave Network. Interrelated global-scale fluctuations of sea-surface temperature (SST), atmospheric pressure, and atmospheric circulation patterns result in periods of unusually wet or dry climate. Indicators such as the Southern Oscillation Index (SOI) and equatorial SST may be the best predictors of short-term climate variation, associated with El Nino and La Nina activity, in network parks. In the Mojave Desert region, El Nino events produce above normal precipitation more frequently and result in significantly higher precipitation amounts compared to La Nina events. Multi-decadal climate

variation across the desert region follows a pattern best expressed by the Pacific Decadal Oscillation (PDO)(Mantua and Hare 2002, Hereford et. al. 2004, Hereford et. al. 2002). Trend analysis of precipitation across the Mojave Desert and the PDO suggest that for the next 2-3 decades, climate in the region may become drier in a pattern similar to mid-century conditions (Hereford et. al. 2004, Hereford et. al. 2002). Additional information on long-term trends in precipitation and climate across the Mojave Desert and Colorado Plateau regions can be found at <http://pubs.usgs.gov/fs/fs117-03/> and <http://pubs.usgs.gov/fs/2002/fs119-02/> (Accessed 30 August 2005).

Although a comprehensive summary of historic precipitation data has not been completed for the Great Basin region the findings of Hereford et. al. (2004 and 2002) relating to the timing of wet and dry periods and predictors of short-term and multi-decadal variation in climate are generally applicable to most desert regions of the western United States. This statement is strengthened through observation of similar trends in annual precipitation at GRBA between 1952 and 2004 (drier between 1942-1975 and wetter between 1976-1998)(Figure 7)(DuBois and Green 2005).

Long-term trends in ambient temperature are difficult to detect due to the high variability in daily and annual temperatures. Short-term changes can generally be related to El Nino (warming of the sea-surface temperature) and La Nina events (cooling of sea-surface temperature)(Figure 7). At a broader temporal scale, analysis of average maximum and minimum temperatures at GRBA between 1952 and 2004 indicates a significant increasing trend of 0.04 °F per year for annual average minimum temperature (p=0.0002) (Figure 8)(DuBois and Green 2005). Trend toward increasing temperatures is generally reflected in available data from across the Mojave Network and potentially suggests a regional warming trend.

3.3 Air Quality

Air quality across the Mojave Network ranges from the best to the worst in the United States. The most specific direction related to air quality in national parks is provided in the Clean Air Act Amendments of 1977 and 1990, which established the Prevention of Significant Deterioration Program and designated certain areas, generally national parks and wilderness areas, as class I areas. These areas receive special protection from additional pollution and federal land managers have an “affirmative responsibility” to protect class I areas from adverse effects of air pollution. Joshua Tree National Park is the only unit in the network within a class I area. Other park units are considered class II areas, still receiving protection under the Clean Air Act, but to a lesser degree and allowing limited amounts of new emissions. Air quality in the network is affected primarily by pollution sources in California, Arizona, and Nevada, although more distant sources can also affect the area. Los Angeles, the San Joaquin Valley, and Las Vegas are major source areas, with significant emissions from mobile sources (e.g., cars, trucks, off-road vehicles), stationary sources (e.g., power plants and industry), and area sources (e.g., agriculture, fires, and road dust). With south to southwest airflow GRBA is also impacted by the urban plume from Las Vegas and Los Angeles. Infrequently, airflow from the northeast during low pressure periods also may bring pollutants to GRBA from the direction of Salt Lake City, UT (DuBois and Green 2005). Although most of the park units in the network are some distance from cities and pollution sources (Table 9), many experience poor air quality from

Table 8. Period of record climate summaries based on National Weather Service Cooperative Observation (COOP) stations^a in and around Mojave Network park units.

Park Name	Station Elevation (meters asl)	Avg Max Temp. (°C)	Avg. Min. Temp. (°C)	Avg. Total Precip. (cm)	Avg. Total SnowFall (cm)	Avg. Snow Depth (cm)	Period of Record	NWS COOP Station #	Station Name
Death Valley National Park	60	32.6	16.8	5.8	0	0	1961-2005	042319	Death Valley, CA
	1,250	22.3	7.2	17.5	6	0	1969-2000	049671	Wildrose Ranger Stn., CA
Grand Canyon-Parashant National Monument	287-860 ^b	25.4	6.9	21	8.1	0	1892-2005	427516	St. George, UT
Great Basin National Park	2,082	16.0	2.1	33.6	180	2.5	1948-2005	263340	Great Basin Natl. Park, NV
Joshua Tree National Park	604	28.8	11.0	10.8	2.3	0	1948-2005	049099	Twentynine Palms, CA
Lake Mead National Recreation Area	390	29.0	9.9	11.3	0.76	0	1948-2005	265846	Overton, NV
	768	25.4	13.7	14.1	2.5	0	1931-2005	261071	Boulder City, NV
	1,079	24.0	11	19.9	3	0	1914-2005	267369	Searchlight, NV
Manzanar National Historic Site	1,201	23.9	7.1	13.4	8.6	0	1927-2005	044232	Independence, CA
Mojave National Preserve	277	30	15.9	11.7	0.7	0	1948-2005	046118	Needles FAA Airport, CA
	1,326	22.4	11.7	27.3	7.9	0	1958-2005	045721	Mitchell Caverns, CA

^a Period of record monthly climate summaries for the sites listed are available at www.wrcc.dri.edu/summary/climsmca.html (substitute appropriate state abbreviation)(Accessed 30 August 2005).

^b Based on station metadata from St. George, Utah this site has moved on several occasions with reported elevation ranging from 940 feet above sea level to 2,820 feet above sea level.

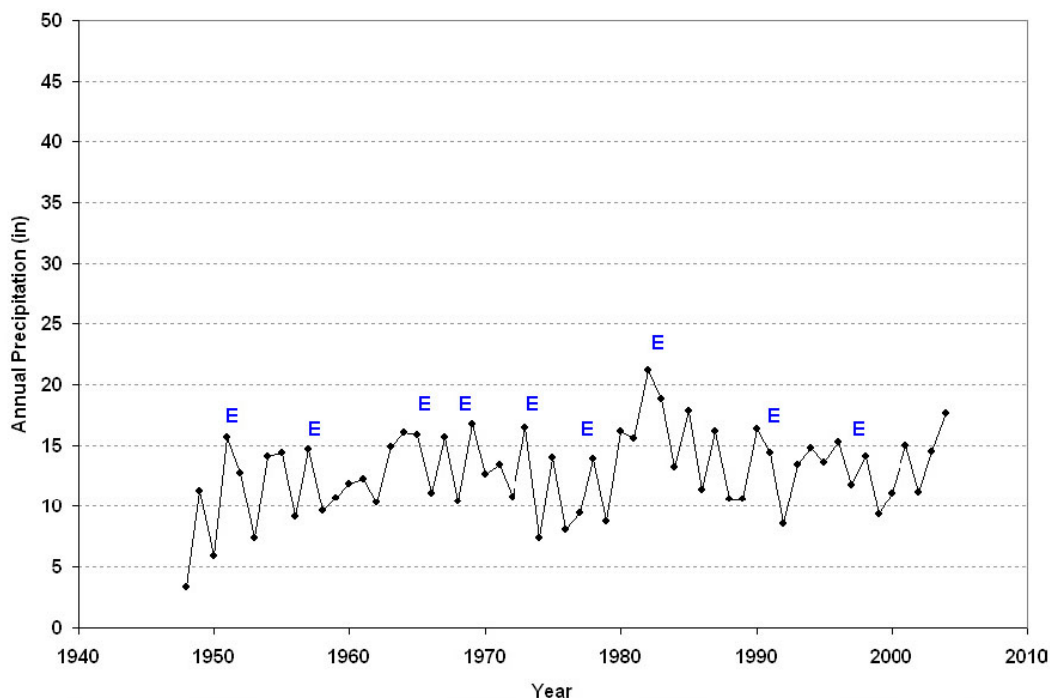


Figure 7. Annual precipitation measured at the National Weather Service Cooperative Observer station located at the Great Basin National Park Visitor Center: 1952-2004 (El Niño years are denoted by a blue “E” above the line)(From DuBois and Green 2005).

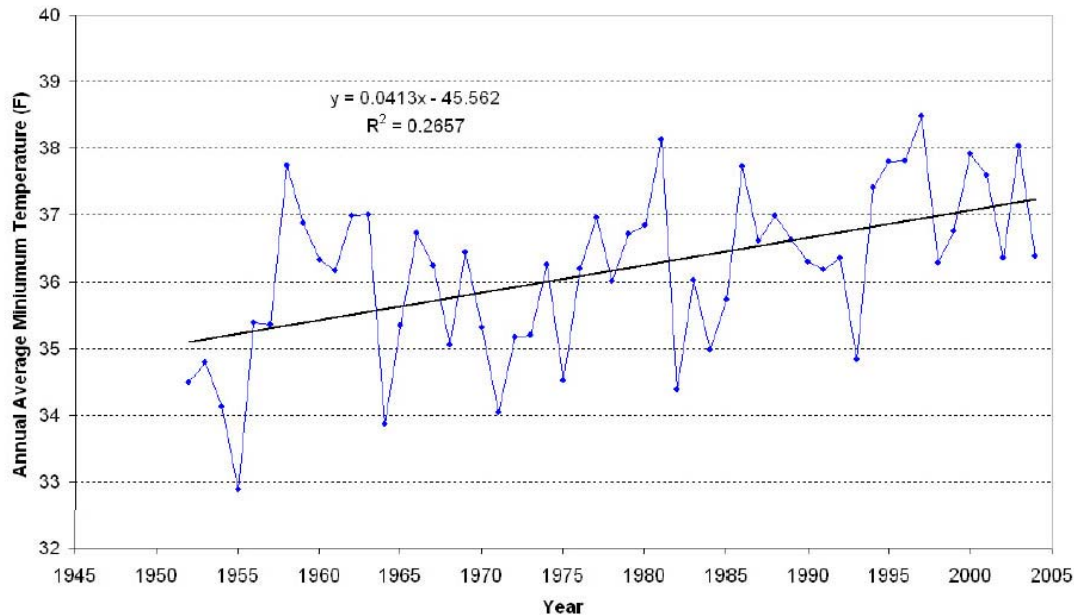


Figure 8. Annual average minimum temperature measured at the National Weather Service Cooperative Observer station located at the Great Basin National Park Visitor Center: 1952-2004 (Note that the vertical scale is one degree F)(From DuBois and Green 2005).

Table 9. Top 10 NO_x sources within 500 kilometers of the Great Basin National Park boundary. (From DuBois and Green 2005)

Facility Name, State	Distance from Park (km)	NO _x (TPY ^a)
Salt River Proj Ag I & P Dist – Navajo, AZ ^b	327.9	35,569
Los Angeles City of - Intermountain, UT ^b	148.8	30,256
Southern California Edison Co - Mohave, NV ^b	407.0	20,267
Pacificorp - Hunter, UT ^b	270.1	19,864
Pacificorp - Huntington, UT ^b	269.2	11,191
Nevada Power Co - Reid Gardner, NV ^b	241.5	10,735
Sierra Pacific Power Co - North Valmy, NV ^b	313.6	7,871
Mine & Copperton Concentrator, UT	242.8	3,881
PacificCorp – Carbon, UT ^b	295.3	3,383
Southern California Gas Co, CA	443.7	2,668
Mean Distance to Emission Source	296	

^a TPY = Tons Per Year

^b Indicates facilities that are also within the top 10 SO₂ sources within 500km of GRBA.

pollutants such as ozone, nitrogen oxides, sulfur dioxide, volatile organic compounds, particulate matter, and toxics (Table 10). Estimates for selected air quality parameters in network parks between 1995 and 1999 are provided in Table 11 (Appendix E).

Table 10. Air quality pollutants in the Mojave Network and associated sources of emission.

Component	Source
Sulfate	coal/oil fired power plants, refining and smelting activities
Nitrate	automobiles, combustion sources
OMC (Organic matter carbon)	biogenics (natural emissions), smoke, industrial solvents
LAC (light-absorbing carbon)	diesel exhaust, smoke
Soil	wind-blown dust, agricultural activities, off-road traffic
CM (coarse particles)	dust, smoke, pollen
Raleigh (Rayleigh scattering)	natural gases in the atmosphere

3.3.1 Ozone

Large areas of the Mojave Desert Network are in or near 8-hour designated non-attainment areas, an indication that they experience ozone concentrations at times harmful to visitor and staff health, and vegetation health. In 2004, the American Lung Association, State of the Air Report declared San Bernadino County, CA (including areas within or adjacent to JOTR and MOJA) to have the unhealthiest air in the nation (ALA 2004). The NPS-Air Resources Division (NPS 2004a) completed a risk assessment of foliar injury to vegetation from ozone in network parks to promote informed decisions on the need to monitor the impacts of ozone on plants. This assessment concluded that JOTR, MANZ, and MOJA are at high risk for foliar injury to plants from elevated ozone levels (Table 12) and identified ozone sensitive and bioindicator plant species at DEVA, GRBA, JOTR, LAME, and MOJA (Appendix F). These species were

identified by cross-referencing NPSpecies with sensitive species identified in “Ozone Sensitive Plant Species on National Park Service and U.S. Fish and Wildlife Service Lands” (Porter 2003) available at <http://www.nature.nps.gov/publications/Pubs2.cfm?ID=6> (Accessed 30 August 2005).

Table 11. Estimates of selected air quality parameters for units of the Mojave Network between 1995 and 1999 (Appendix E).

Park	CLASS ^a	Ozone ^b				NADP (kg/ha/yr) ^c		Visibility - IMPROVE ^d	
		2ndHi1hr	4thHi8hr	#8hr>85	#hrs>100	Wet S	Wet N	Bext Clear	Bext Hazy
DEVA	2	113.3	89.6	18.2	49.1	0.38	1.12	10	66
GRBA	2	97.5	75.8	1.8	3.5	0.54	1.31	5	22
JOTR	1	146.5	102.5	26.2	104.8	0.37	0.89	10	70
LAME	2	103.4	82.2	7.0	19.7	0.41	1.10	8	42
MANZ	2	113.3	89.6	18.2	49.1	0.38	1.12	10	66
MOJA	2	113.3	89.6	18.2	49.1	0.38	1.12	10	66

^a Class: refers to an area's designation under the Clean Air Act.

^b Ozone information represents 5-yr average of annual values from 1995-1999.

- 2nd High 1 hr concentration (ppb): indicates peak values for ozone; old standard of 0.12 ppm (120 ppb) was based on 2nd hi, 1-hr average.
- 4th high 8 hr concentration (ppb): new ozone standard of 0.08 ppm (80 ppb) is based on 4th hi, 8-hr average.
- #8 hours>85 ppb: indicates how often the area would exceed the new 8-hr standard of 0.08 ppb.
- #hours> 100 ppb: high peaks in ozone concentration, as well as cumulative dose, contribute to vegetation injury.

^c NADP deposition (kg/ha/yr): estimate of pollutants deposited to ecosystem by precipitation (NADP-National Atmospheric Deposition Program); NADP information represents 6-yr average of annual values from 1995-2000.

- NADP Total S - sulfur from sulfate deposited by precipitation.
- NADP Total N - inorganic nitrogen (ammonium plus nitrate) deposited by precipitation.

^d Visibility IMPROVE information represents 5-yr average of annual values from 1995-1999.

- bextClear - measure of light scattering and absorption, i.e., extinction, by particles in the air on an average clear day.
- bextHazy - measure of light scattering and absorption, i.e., extinction, by particles in the air on an average hazy day.

Table 12. Risk assessment of foliar injury from ozone for parks in the Mojave Network (NPS 2004a).

Park Code	State	Risk	03 Data
DEVA	CA	Low	Monitored
GRBA	NV	Low	Monitored
JOTR	CA	High ^a	Monitored
LAME	NV	Low	Kriged ^b
MANZ	CA	High	Kriged
MOJA	CA	High	Kriged

^a The threshold for injury is satisfied for both the Sum06 and the W126 indices. Sum06 index is comprised of the 90-day maximum sum of the 0800 through 1959 hourly concentrations of ozone ≥ 60 ppb (0.60 ppm). W126 index is the weighted sum of the 24 one-hour ozone concentrations daily from April through October, and the number of hours of exposure to concentrations ≥ 100 ppb (0.10 ppm) during that period.

^b Technique uses ozone data from near-by monitoring sites to estimate data for the point of interest. The accuracy with which the kriged data represents the actual exposure conditions is likely to vary among the sites.

3.3.2 Wet and Dry Deposition

Atmospheric deposition of nitrogen and sulfur compounds can affect water quality, soils, and vegetation. Both nitrogen and sulfur emissions can form acidic compounds (e.g., nitric or sulfuric acid) that when deposited into ecosystems with low buffering capacity may contribute to acidification of waters and/or soils. Surface waters across the network are generally well-buffered, with sufficient base cations to neutralize acids. However, alpine lakes at GRBA have very low buffering capacities and are considered to be “sensitive” to “ultrasensitive” to acidification (NPS 1999b). Deposition of nitrogen compounds can also have a fertilization effect on waters and soils, particularly in systems such as the Mojave Network adapted to low nitrogen conditions. Even small increases in soil nitrogen may have significant impacts on desert resources because the ratio of increased nitrogen to plant biomass is higher compared to other ecosystems. Significant evidence exists linking increased levels of soil nitrogen to alien annual plant dominance, particularly invasive annual grasses such as *Bromus* spp. and *Schismus* spp., and suggests soil nitrogen as a determinant of habitat invasibility by invasive plants in the Mojave Desert (Brooks 1999a). Major sources of nitrogen oxides and sulfur are provided in Table 10. Research being conducted cooperatively with the University of California, Riverside and U.S. Forest Service, is currently examining the impacts of anthropogenic nitrogen deposition on weed invasion, biodiversity, and the fire cycle at JOTR.

Trend analysis of sulfate in precipitation illustrates that sulfate is decreasing at Great Basin National Park and other western parks, while increasing at others. Nitrate in precipitation is increasing at some western sites, including Mojave Network park units, while decreasing at others. Monitoring of wet and dry deposition at DEVA and JOTR was started in 2000, so trend data are not yet available for those sites. There are insufficient long-term dry deposition data available to do a trend analysis similar to that described for wet deposition however trends in dry deposition are likely to generally follow trends in wet deposition. When assessing ecosystem impacts from atmospheric deposition it is desirable to have estimates of total deposition, that is, wet plus dry deposition. Estimates of total deposition for the three Mojave Desert Network sites with wet and dry deposition sampling are given in Table 13.

Table 13. Estimates of total (wet+dry) deposition (kg/ha/yr) based on data from the Clean Air Status and Trends Network (1995-1999) at Death Valley National Park, Great Basin National Park, and Joshua Tree National Park (NPS 2004b).

Park Name	Total Nitrogen (kg/ha/yr)	Total Sulfur (kg/ha/yr)
Death Valley National Park	2.92	0.88
Great Basin National Park	2.43	0.88
Joshua Tree National Park	5.26	1.16

These estimates indicate that deposition of both nitrogen and sulfur are elevated above natural levels of deposition in these 3 park units. Estimates of natural deposition for either sulfur or nitrogen in the West are approximately 0.25 kg/ha/yr (NPS 2004b)(Appendix E).

3.3.3 Particulate Matter and Visibility

Pollutant particles in the air reduce visibility and affect visitor experience. Visibility, ‘visual quality’ and/or ‘far-reaching vistas’ (including night skies) are specifically mentioned as important park resources in primary planning documents for DEVA, GRBA, JOTR, and MOJA (NPS 2001b, 2000, 1999b, 1999c, 1995, 1992a). The best visibility in the contiguous United States occurs in an area centered near GRBA. Visibility also is considered a critical element of the cultural landscape at MANZ. Visibility has been degraded from natural conditions in all network units and trend analysis between 1990 and 1999, indicates that visibility in network parks is improving slightly on the 20 percent clearest days and worsening on the 20 percent haziest days. States are now required to develop plans to make progress towards the national goal of preventing future impairment and improving existing impairment of visibility resulting from manmade air pollution in class I airsheds. Information related to this planning effort for JOTR can be found through the Western Regional Air Partnership (WRAP) at <http://www.wrapair.org> (Accessed 30 August 2005).

Particulate matter is another type of air pollution of special concern in the Mojave Network. Eolian transport of sand, silt and/or clay by wind, at various spatial and temporal scales, is one of the dominant processes in arid environments (Breshears et. al. 2003) and is critical in the maintenance of key ecosystem processes such as pedogenesis. Some scientists estimate that as much as 50% of the fine soils on the Colorado Plateau, that add nutrients and trace metals essential for plant life, originate in the Mojave Desert. Finer silts and clays can rise up to 15,000 feet and travel thousands of miles arriving in the Mojave Desert from different continents such as the Sahara Desert in Africa (Wright 2005). At a regional scale, the sparsely vegetated landscape, characteristic of network parks, in combination with factors that stabilize surface soils (rocks, biological and physical soil crusts) that are easily disturbed by vehicles, livestock, and other human activities makes this ecosystem highly susceptible to significant changes in dust transport in response to a variety of ecosystem stressors. In addition to contributing to altered visitor experience (e.g. visibility, human health) change in dust transport has significant implications for ecosystem function via effects on soil texture and chemistry (Reynolds et. al. 2001), which affects soil infiltration rates and nutrient concentrations (Breshears et. al. 2003) with possible feedback mechanisms to the overall ecosystem. Concerns related to change in dust transport on a global scale relate to the potential transport and deposition of pollutants (e.g. acidic gases, soot, heavy metals, herbicides, pesticides), pathogens, etc. that may be harmful to plant, animal, and human health. Approximately 33% of the more than 100 species of bacteria, viruses, and fungi that have been cultured from airborne dust are considered plant, animal, or human pathogens (Wright 2005).

3.4 Ecoregion Classification

Land classification is a process of arranging information about land units to better understand their similarities and relationships. In recent years, the idea of ecoregions has emerged as the most useful land classification system for supporting sustainable resource management practices (Bailey 1998, 1995). The ecosystem concept underlies the ecoregion system of land classification because it effectively brings together the biological and physical worlds into a framework by which natural systems can be described, evaluated, and managed (Rowe 1992).

1 The National Hierarchical Framework of Ecological Units developed by the USDA Forest
2 Service (Bailey 1995, McNab and Avers 1994, ECOMAP 1993) provides a useful means of
3 integrating factors such as regional physiography and climate to assess broad-scale differences
4 and similarities among MOJN parks. Ecological types are defined and combined into ecological
5 units, then described and mapped based on the National Hierarchical Framework of Terrestrial
6 Ecological Units (ECOMAP Framework). The ECOMAP Framework is a regionalization,
7 classification and mapping system for stratifying the Earth into progressively smaller areas of
8 increasingly uniform ecological potential. There are four levels of ecological units delineated in
9 the hierarchical framework for understanding MOJN park resources ranging from *domain* with
10 its broad applicability to management on an ecoregion scale to the *section* unit, which is more
11 pertinent for the strategic, sub-regional effort of monitoring park resources. All MOJN parks are
12 located within the Dry Domain of the National Hierarchical Framework. An essential attribute of
13 the “Dry” climate distinction is that annual losses of water through evaporation exceed annual
14 water gained through precipitation. Units in the hierarchy are designed on the basis of similarity
15 for: 1) potential natural communities, 2) soils, 3) hydrologic function, 4) topography and
16 landforms, 5) lithology, 6) climate, 7) air quality, and 8) ecological processes such as nutrient
17 cycling and natural disturbance regimes (Cleland et. al. 1997). A general ecological comparison
18 of network parks within the broad categories of the Mojave Desert region and Great Basin Desert
19 region is presented in Table 14.

20
21 Bailey (1998, 1995) describes climate as a source of energy and water to operate at the broadest
22 spatial and temporal scales, and thus to serve as a major controlling factor for ecosystem
23 distribution. The major controls on climate are latitude and topography, along with continental
24 position for terrestrial regions. Continental position is important because it is related to
25 prevailing winds and moisture regimes largely determined by global atmospheric conditions.
26 Therefore, oceanic conditions must be taken into account when trying to understand
27 macroclimates of the continental landscape.

28
29 Climate strongly affects landforms and erosion cycles. Therefore, at the next level of controlling
30 factors (for terrestrial regions) we find landform and geomorphic processes, which relate to
31 geological substrate, surface shape and relief. At the meso- and macroscales, soil and vegetation
32 patterns derive from landform, because landform controls key factors affecting soil development
33 and plant growth. Within this context, slight differences in slope and aspect determine soil
34 moisture availability that in turn determines vegetation community. In the Mojave Network
35 climate dominates the rate, direction, and timing of many physical and biotic processes (Davis et.
36 al. 1998).

37
38 Mountainous regions with their great altitudinal range and topographic complexity, present a
39 special case in ecoregion definition. Altitudinal zonation occurs because increasing altitude
40 affects climate in a manner similar to increasing latitude. Altitudinal variation tends to form
41 definable ecological units whose character depends on the climate zone in which the unit lies.
42 The presence of mountains, especially large mountains such as Wheeler Peak at GRBA, modifies
43 macroclimate and determines mesoscale ecoregions. Much like large mountains, deep canyons
44 have a range of altitudes and topographic character and can also pose a special case in
45 determination of the distribution of vegetation and animal communities. Terrestrial and aquatic
46 components of landscapes are not independent and should not be considered separately.

1 Table 14. Ecological Comparison of the Mojave and Great Basin Deserts^a

Classification	Description	D E V A	G R B A	J O T R	L A M E	M A N Z	M O J A	P A R A	Descriptive Comments
Ecosystem Domain	Dry Domain	X	X	X	X	X	X	X	Annual losses of water through evapotranspiration at the Earth's surface exceed annual water gains from precipitation.
Ecosystem Division	Mediterranean Regime Mountains			X					
	Temperate Desert Regime Mountains		X						
	Temperate Desert	X				X			
	Tropical/Subtropical Desert	X		X	X		X		
	Tropical/Subtropical Steppe							X	
Ecosystem Province	American Semidesert and Desert	X		X	X		X		
	California Coastal Range Open Woodland-Shrub-Coniferous Forest-Meadow			X					
	Colorado Plateau Semi-Desert Province							X	
	Intermountain Semi-Desert and Desert	X				X			
	Nevada-Utah Mountains-Semi-Desert-Coniferous Forest-Alpine Meadow		X						
Floristic Region	California Floristic Province	X							
	Colorado Plateau Province							X	
	Great Basin Province		X						Creosotebush (<i>Larrea tridentata</i>) absent.
	Sonoran Province	X		X	X		X		DEVA, JOTR, LAME, MANZ, and MOJA are within the Mojavean Subprovince; portions of JOTR and LAME also are within the Sonoran Subprovince; Creosotebush present.
Climate	Hot desert - Average annual temperature = 60-75 degrees F.	X		X	X		X		One of the most extreme and variable in the world with significant diurnal variation in temperature. DEVA is the site of the nation's highest and the world's second highest recorded temperature (134 degrees Fahrenheit or 57 degrees Celsius)
	Cold desert – Average annual temperature = 38-50 degrees F.		X			X		X	

^a Based on Bailey 1998, 1995.

2
3
4

Table 10. (Con't)

Classification	Description	D E V A	G R B A	J O T R	L A M E	M A N Z	M O J A	P A R A	Descriptive Comments
Precipitation	Rain - Average annual precipitation is 2-10" in the valleys; may reach 25 in on mountains. Generally in form of winter and summer rains.	X		X	X	X	X		A strong east-west gradient across the network allows more summer rains from the Gulf of Mexico to reach the eastern regions of the Great Basin and Mojave Deserts than western portions.
	Snow - Average annual precipitation is 5-8" in valleys; up to 25-35" at higher elevations. Generally in form of winter snows and summer thunderstorms.		X					X	
Elevation	Low	X		X	X	X	X		Elevation ranges from 280 ft below sea level to 4,000 ft in valleys and basins with some mountain ranges reaching as high as 11,000 ft above sea level (e.g. DEVA)
	High		X					X	At GRBA, elevation ranges from approximately 5,000 ft above sea level in valleys and basins to >13,000 feet above sea level. The majority of the park is above 7,000 ft.
Soils	Aridisols. Entisols along older alluvial fans and terraces. Gravel or bare rock prevalent at the base of mountains and on steep slopes.	X		X	X	X	X		
	Aridisols. Entisols along stream floodplains. Mollisols, alfisols, and gravel or bare rock at higher elevations.		X					X	

^a Based on Bailey 1998, 1995.

Ecosystems are linked with other ecosystems through the flow of materials, energy and organisms in spatially-structured landscape mosaics (Turner et. al. 2001). Integral to this ecoregion concept is that larger ecosystems encompasses smaller systems and control the operation of the smaller systems (Bailey 1998, 1995). Thus landscape-level considerations are encompassed in the approach utilized in the MOJN monitoring program.

3.5 Ecosystem Provinces

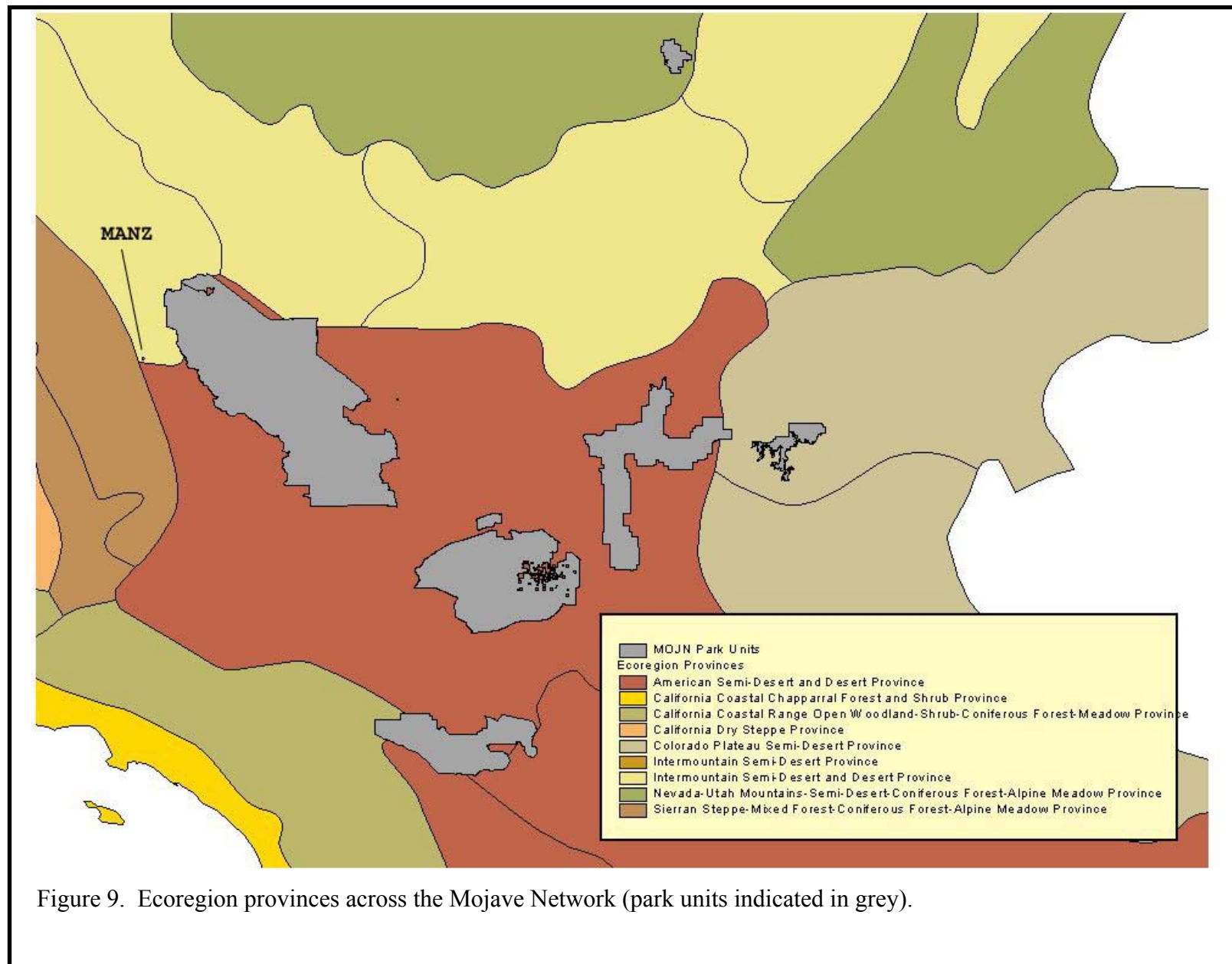
Park units within the MOJN are located within five ecoregion provinces: American Semi-Desert and Desert Province, California Coastal Range Open Woodland-Shrub-Coniferous Forest-Meadow Province (JOTR), Colorado Plateau Semi-Desert Province, Intermountain Semi-Desert and Desert Province, and Nevada-Utah Mountains-Semi-Desert-Coniferous Forest-Alpine Meadow Province (Figure 9)(Table 14). Only a very small portion of the MOJN (< 5%) is contained within the California Coastal Range and Intermountain Semi-Desert and Desert Provinces and these will not be addressed separately. Ecoregion sections across the network are provided in Figure 10 and section descriptions can be found at <http://www.fs.fed.us/land/pubs/ecoregions/> (Accessed 30 August 2005).

3.5.1 American Semi-Desert and Desert Province

This province represents the majority of network parks including DEVA, LAME, MOJA, and JOTR and includes the Mojave, Colorado, and Sonoran Deserts. Although MANZ appears to be within the Intermountain Semi-Desert and Desert Province, vegetation and other characteristics are more similar to the American Semi-Desert and Desert Province. Climatically, this region is considered a 'hot' desert. Province climate is characterized by long, hot summers with the highest temperature ever recorded in the United States at DEVA (134 °F/57 °C) in 1913. Precipitation generally occurs in the form of gentle winter rains and summer thunderstorms although some portions (Colorado and Mojave Deserts) may experience no summer rains.

Soils are primarily aridisols with mollisols and alfisols found at higher elevations in the mountains and entisols on older alluvial fans and terraces. Gravel or bare rock occurs extensively at the base of some mountains and on steep slopes (Figure 11). Aridisols and entisols occur in combination with thermic or hyperthermic soil temperature regimes and aridic soil moisture regimes on foothills and valleys. On mountains, aridisols and entisols occur in combination with thermic or mesic soil temperature regimes, and aridic or xeric soil moisture regimes (Appendix G).

Hydrologically, most of this province drains to the sea through underground seepage and washes (dry most of the year) although there are some areas of internal drainage (e.g. Salton Trough). Permanent streams are considered rare with the Colorado River the only sizeable stream in the eastern portion of the province. Spring resources are ecologically significant in all network parks and across the province due to the scarcity of surface water resources.



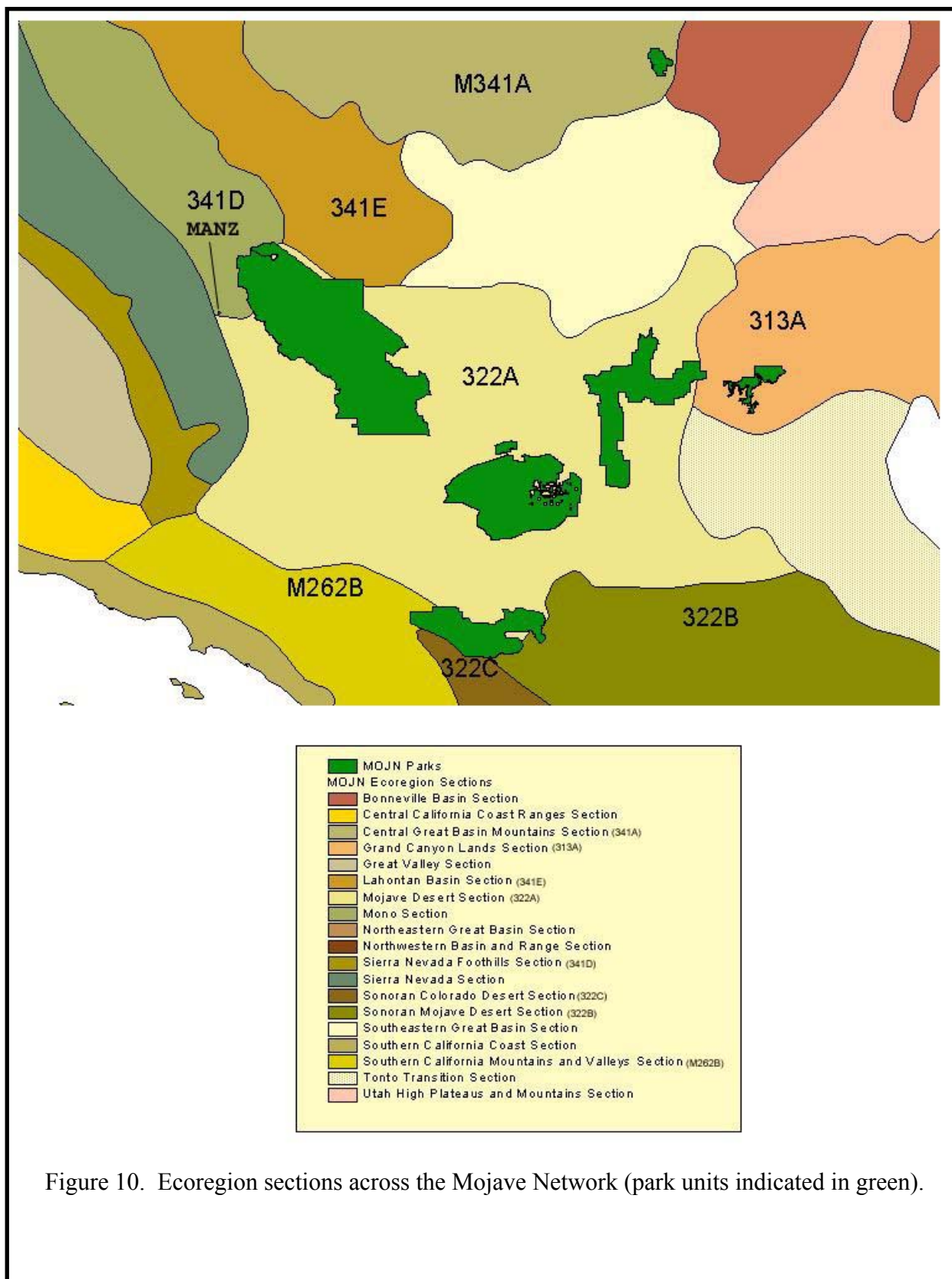


Figure 10. Ecoregion sections across the Mojave Network (park units indicated in green).



Figure 11. Gravel and bare rock accumulating at the base of mountains, referred to as an alluvial fan, at Death Valley National Park. (NPS Photo)

Three vegetation communities contribute approximately 75% of the land cover across the Mojave Desert: Mojave Creosote Bush Scrub (57%), Mojave Mixed Woody Scrub (13%), and Desert Saltbush Scrub (5%) (Davis et. al. 1998). At slightly higher elevations a belt dominated by the Joshua tree (*Yucca brevifolia*) is present and at even high elevations a belt of pinyon-juniper exists. Some mountain ranges are high enough to have a montane zone dominated by ponderosa pine (*Pinus ponderosa*), Douglas fir (*Pseudotsuga menziesii*), and Engelmann spruce (*Picea engelmannii*). DEVA possesses an alpine belt at elevations between 3,048 and 3,353 meters above sea level. Two distinct floristic subregions, eastern and western, occur in the Mojave Desert related to a strong east-west precipitation gradient.

Plant communities that cover a significantly greater area in the east Mojave include Desert Dunes, Mojave Mixed Steppe, Big Sagebrush Scrub, Shadscale Scrub, and Desert Native Grassland. Mojave Mixed Woody and Succulent Scrub was the only community type to occur only in the east Mojave (Davis et. al. 1998). Plant communities more widely represented in the west Mojave include Mojave Creosote Bush Scrub, Blackbrush Scrub, Desert Saltbush Scrub, and Alkali Playa (Davis et. al. 1998).

JOTR represents a transition zone between the Mojave and Sonoran Deserts and in the southern half of the park species such as ocotillo (*Fouquieria splendens*) and smoke tree (*Psoralea argemone*) occur in conjunction with creosote bush (*Larrea tridentata*). A listing of the existing vegetation alliances and associations within the Mojave-Great Basin Desert region compiled for the Mojave Network by the Association for Biodiversity Information (2001) is provided in Appendix H. Additional information on plant alliances and associations is provided in Chapter 2.

3.5.2 Nevada-Utah Mountains Semidesert-Coniferous Forest-Alpine Meadow Province and Colorado Plateau Semi-Desert Province

These provinces are generally similar climatically and floristically and similarities are presented here together. Parks represented in these provinces are GRBA and PARA portion. PARA represents a transition zone between the Great Basin, Colorado Plateau, and Mojave Deserts. Climatically, this region is considered a 'cold' desert. Climate varies with altitude but is generally characterized by long, cold winters and relatively short summers with significant variation in diurnal temperature. Precipitation occurs primarily in the form of winter snow/rain with some arriving with summer thunderstorms (particularly on the Colorado Plateau).

Soils are primarily aridisols with mollisols and alfisols found at higher elevations in the mountains and entisols along the floodplains of major streams. Alpine areas at GRBA are covered primarily by gravel or bare rock (Figure 12). Soils occur in combination with thermic, mesic or frigid soil temperature regimes and aridic, xeric or aquic soil moisture regimes (Appendix G).

Drainage divides define the boundaries of the Great Basin hydrographic region, an approximately 518,135 km² area of internal drainage. Surface water leaves the Great Basin only by evaporation and precipitation in the region evaporates, sinks underground, or flows into lakes (e.g. Great Salt Lake). Although permanent streams are considered rare, 10 permanent streams originate within GRBA. Spring resources are considered extremely important ecologically at all network parks. Portions of LAME (including PARA) drain to the sea through the Colorado River, the only significant permanent stream in the province.



Figure 12. Wheeler Peak rock glacier within alpine habitat at Great Basin National Park. (Photo courtesy of Dr. J. Arnott)

Vegetation exhibits altitudinal zonation with lower elevations dominated by large expanses of sagebrush-grass. The sagebrush-grass community is the largest and most continuous in the region. A woodland belt above the sagebrush zone is dominated by pinyon-juniper complex very similar to the Colorado Plateau. At GRBA, pinyon-juniper woodland covers 17% of the park land base and also is the dominant vegetation cover type at PARA. The Montane zone, including subalpine woodlands, is dominated by mountain mahogany (*Cercocarpus* spp.), ponderosa pine, Douglas fir, Engelmann spruce, limber pine (*Pinus flexilis*) and bristlecone pine (*Pinus longaeva*). The presence of quaking aspen (*Populus tremuloides*) and interspersed patches of sagebrush-grass habitat also is a common feature of the montane zone (Brussard et. al. 1998). At the highest elevations, the alpine zone begins at the treeline and has an extremely limited distribution across the Great Basin-Mojave Desert region although it covers 8% (2,554 ha) of the total land base at GRBA. Most alpine area contains talus, steep slopes, and rocky ridges but these areas are interspersed with alpine tundra, alpine meadow and, at GRBA, several stands of ancient bristlecone pine ($\geq 5,000$ years old). With approximately 600 alpine plant species documented in the Great Basin region, this zone “is as diverse as that of either the Rocky Mountains or the Sierra Nevada at equivalent latitudes and adds greatly to the biological diversity of the region and to the potential resilience of the region in response to climatic change” (Brussard et. al. 1998). At GRBA, 55% of rare and sensitive plant species documented within the park occur in alpine or subalpine habitats.

Portions of the network on the Colorado Plateau are dominated by pinyon-juniper woodland with ponderosa pine forest communities at higher elevations (Figure 13). A listing of the existing vegetation alliances and associations within the Mojave-Great Basin Desert region compiled for the Mojave Network by the Association for Biodiversity Information (2001) is provided in Appendix H. Additional information on plant alliances and associations is provided in Chapter 2.



Figure 13. Chaining pattern in pinyon-juniper woodlands at Grand Canyon-Parashant National Monument on the Colorado Plateau. (NPS Photo)

3.6 Hydrology

Aquatic and associated riparian resources represent a very small portion of total land cover in the Mojave Network, except at LAME, however they are disproportionately important ecologically (e.g. biodiversity, biological productivity, etc.). Infrequent precipitation and long periods of drought are defining characteristics of the Mojave and Sonoran Deserts and water availability is the primary factor limiting plant productivity in deserts (Whitford 2002). Precipitation events recharge desert basin aquifers at a slow rate and this recharge feeds scattered springs and wetland habitats. Surface waters are fed by groundwater and surface run-off (e.g. snow melt, rain events) and changes in groundwater flow systems, climatic change and climate variability may have significant impacts on the availability of surface water. Pumping a relatively small fraction of groundwater out of these basins can lower the water table and potentially dry up critical surface water resources. Subsidence of the Mojave Desert by as much as four inches between 1992 and 1999 also has been linked to water-level declines of more than 30 m (100 ft) between the 1950's and 1990's. In places around Las Vegas, Nevada groundwater levels have declined 90 m (300 ft) since the first flowing artesian well was drilled in 1907 (Bawden et. al. 2003).

Surface water resources present across network parks include both lotic and lentic environments. Lotic (flowing water) environments include rivers (e.g. Colorado, Virgin, and Muddy rivers), perennial streams and springs and seasonal and ephemeral springs, streams, and seeps. Lentic (non-flowing water) environments in the Mojave Network include lakes and ponds, playas, and oases/springs as well as floodplains. LAME encompasses two reservoirs formed by the Colorado River: Lake Mead and Lake Mojave. These two reservoirs contain 77,490 ha (191,477 ac) of water surface and are responsible for providing 90% of Southern Nevada's water supply. Due primarily to recent drought conditions, lake levels dropped 18 m (60 ft) between 2000 and 2003 (Figure 14). Water management officials predict further drops in the future, if weather and water use predictions are correct (Allen 2003). Additionally, a variety of man-made structures exist across the desert landscape to provide artificial sources of surface water (e.g. guzzlers) for domestic livestock and wildlife. Surface waters in parks are important for a variety of reasons including ecological significance, importance as a supply of drinking water, and association with important cultural sites. Additional information on water resources in individual network parks is provided in Appendix I.

Due to the isolated nature of surface water resources across the network (Figure 15) these sites, particularly springs, tend to exhibit a high rate of endemism. A diverse crenobiotic (obligate spring-dwelling) fauna is now known to occupy isolated habitats throughout much of the western U.S. These



Figure 14. Recently exposed shoreline at Lake Mead. (NPS Photo)

1 species represent relict populations that have persisted in isolated habitats for thousands of years.
2 They are unable to live outside of an aquatic environment for long periods and most of them are
3 restricted to springs with good water quality. They never inhabit springs that periodically dry.
4 The Great Basin supports a particularly extensive aquatic fauna that includes approximately 125
5 endemic species (two amphibians, 28 fish, eight insects, one fairy shrimp, 85 mollusks, and two
6 amphipods) and 45 subspecies (one aquatic insect and 44 fish)(Sada and Vinyard 2002).
7

8 A significant number of species of special concern also are associated with aquatic and riparian
9 habitat within network parks. Sixty-seven percent of Federally endangered species in the
10 network are desert fishes (Appendix J) including the Devils Hole pupfish (*Cyprinodon diabolis*),
11 Mohave tui chub (*Siphateles bicolor mojavensis*), bonytail chub (*Gila elegans*), and razorback
12 sucker (*Xyrauchen texanus*). In the majority of cases, desert fish populations are small and
13 isolated from each other. The potential impacts to small, isolated native fish populations from
14 changes in water quantity or quality, disease, etc. are potentially significant, including local and
15 global extinction.
16
17



18
19
20 Figure 15. Typical, isolated spring complex at Death Valley National Park. (NPS Photo)
21

22 3.6.1 Hydrologic Regions

23
24 The hydrologic unit system divides and subdivides the United States into four nested levels of
25 units. The largest units are called regions and represent either the drainage area of a major river
26 or the combined drainage areas of a series of rivers. The successively smaller units within
27 regions are subregions, accounting units, and cataloging units or watersheds. Network parks are
28 located within the Great Basin, California, and Lower Colorado hydrologic regions of the United

States. Hydrologic units are used for collecting and organizing hydrologic data within hydrologic regions. These units are land areas that catch rain or snow and drain to marshes, streams, rivers, lakes, or groundwater. Under the 1998 Presidential Clean Water Action Plan (CWAP), each state was required to prepare Unified Watershed Assessments for watersheds at the 8-digit Hydrologic Unit Code (HUC) level. The 8-digit HUC signifies the smallest geographical drainage division used currently by the United States Geological Survey (USGS) to divide the nation into water basins (Ledder 2003). Table 15 lists the MOJN park units, their major hydrologic region, and HUC code(s).

Table 15. Hydrologic region, major watershed(s), and hydrologic unit code(s) for Mojave Network parks.

Park Name	Hydrologic Region (s)	Major Watershed	HUC Code
Death Valley National Park	Great Basin	Cactus-Sarcobatus Flats	16060013
	California	Eureka-Saline Valleys	18090201
		Upper Amargosa	18090202
		Death Valley-Lower Amargosa	18090203
		Panamint Valley	18090204
Great Basin National Park	Great Basin	Hamlin-Snake Valleys	16020301
		Spring-Steptoe Valleys	16060008
Joshua Tree National Park	California	Southern Mojave	18100100
		Salton Sea	18100200
Lake Mead National Recreation Area	Lower Colorado	Grand Canyon	15010002
		Lake Mead	15010005
		Grand Wash	15010006
		Hualapai Wash	15010007
		Lower Virgin	15010010
		Muddy	15010012
		Detrital Wash	15010014
		Las Vegas Wash	15010015
		Havasui-Mojave Lakes	15030101
	Great Basin	Ivanpah-Pahrump Valleys	16060015
Grand Canyon-Parashant National Monument	Lower Colorado	Grand Canyon	15010002
		Lake Mead	15010005
		Grand Wash	15010006
		Fort Pierce Wash	15010009
		Lower Virgin	15010010
Manzanar National Historic Site	California	Owens Lake	18090103
Mojave National Preserve	Great Basin	Ivanpah-Pahrump Valleys	16060015
	California	Death Valley-Lower Amargosa	18090203
		Mojave	18090208
		Southern Mojave	18100100
	Lower Colorado	Piute Wash	15030102

3.6.2 Impaired Waters

Under the Water Quality Act of 1965, each state is required to develop water quality standards to achieve water quality goals for interstate waters. The Federal Water Pollution Control Act Amendments of 1972 (also known as the Clean Water Act) established the National Pollutant

1 Discharge Elimination System (NPDES), which requires each point source discharger to waters
2 of the United States to obtain a discharge permit. These amendments also extended the water
3 quality standards program to intrastate waters, required the establishment of technology-based
4 effluent limitations for NPDES permits, and required permits to be consistent with applicable
5 state water quality standards. The original intent of this legislation was to protect water quality
6 and improve polluted United States waters to at least “fishable and swimmable” quality.

7
8 Water quality standards are the basis for a water quality-based approach to pollution control and
9 are a fundamental part of watershed management. The basic components of water quality
10 standards are the designated uses defining the goals for a water body, numeric criteria adopted or
11 established to protect the uses, anti-degradation policy to protect existing uses and high quality
12 waters, and implementation policy. States must consider public drinking supply, fish and aquatic
13 life, agriculture, industrial and navigation uses, and other needs when designating water body
14 uses. The federal guidelines provide policy and implementation guidance to protect uses that
15 states must meet. Section 303(c) of the Clean Water Act established the basis for the current
16 water quality standards program, including oversight of state standards by the Environmental
17 Protection Agency (EPA) (Appendix I).

18
19 Concern that states were relying too much on narrative criteria for control of toxics (e.g. “no
20 toxics in toxic amounts”) led to the Water Quality Act of 1987. These amendments to the Water
21 Quality Act required states to identify waters that do not meet water quality standards, adopt
22 numeric criteria for pollutants in such waters, and establish effluent limitations for individual
23 discharges to such water bodies. These amendments also explicitly recognized the EPA’s
24 antidegradation policy to protect the level of water quality necessary to sustain existing uses and
25 provide a means for assessing the need for developments that may lower water quality in high
26 quality waters.

27
28 Under Section 305(b) of the Clean Water Act, each state is required to conduct water quality
29 surveys to determine the overall health of the waters of the state, including whether or not
30 designated uses are being met. States report to the EPA every two years. When impaired water
31 bodies are identified through 305(b) assessments, they are included in 303(d) lists for ranking of
32 priority sites and Total Maximum Daily Load (TMDL) development in order to limit discharges
33 of specific pollutants to that water body (Ledder 2003). Lake Mead National Recreation Area is
34 the only network park that contains waters designated as 303(d) or “impaired”. (Table 16,
35 Figure 16)

36 37 **3.6.3 Outstanding National Resource Waters**

38
39 The Clean Water Act includes a provision for the identification of Outstanding National
40 Resource Waters (ONRW) to provide protection to the Nation’s most treasured water bodies.
41 ONRW designation by a state is an anti-degradation policy determination, which signifies that no
42 lowering of water quality is allowed for that specific high quality water body and provides the
43 maximum amount of protection under the Clean Water Act.

Table 16. California and Nevada 303(d) Listed Water Bodies Within and Adjacent to Parks in the Mojave Network.

Waterbody ID	Waterbody Name	Reach Description	Size	Units	Existing TMDL's	Pollutant/ Stressor of Concern	In Park (See Figure 16)
Nevada's 303(d) List of Impaired Waterbodies							
NV13-CL-06	Las Vegas Wash	Telephone Line Rd to Lake Mead	5.12	miles	Total ammonia, total phosphorus	Iron (total) Total suspended solids	Yes (portions)
NV13-CL-09	Virgin River	Mesquite to Lake Mead	25.7	miles	Draft TMDL Boron	Boron (total) Iron (total) Temperature Total phosphorus	Yes (portions)
NV13-CL-12	Muddy River	Glendale to Lake Mead	25.1	miles	None	Boron (total) Iron (total) Temperature	Yes (portions)
Nevada's List of Waterbodies with Exceedances of RMHQs (Requirements to Maintain Higher Quality Water)							
NV13-CL-04	Lake Mead/Las Vegas Bay	Las Vegas Bay	3,840	acres		chlorophyll <u>a</u>	Yes; Data collected by Las Vegas Wash Discharger Monitoring Network
Nevada's List of Waterbodies Warranting Further Investigation							
NV13-CL-01	Colorado River	Lake Mohave Inlet to CA stateline				Temperature	Yes (portions)
NV13-CL-02	Colorado River	Hoover Dam to Lake Mohave Inlet				Temperature	Yes
NV13-CL-06	Las Vegas Wash	Telephone Line Rd to Lake Mead				Selenium (total)	Yes (portions)
NV13-CL-09	Virgin River	Mesquite to Lake Mead				Selenium (total)	Yes (portions)
California's 303(d) List of Impaired Water Bodies: None exist in or adjacent to Mojave network parks.							

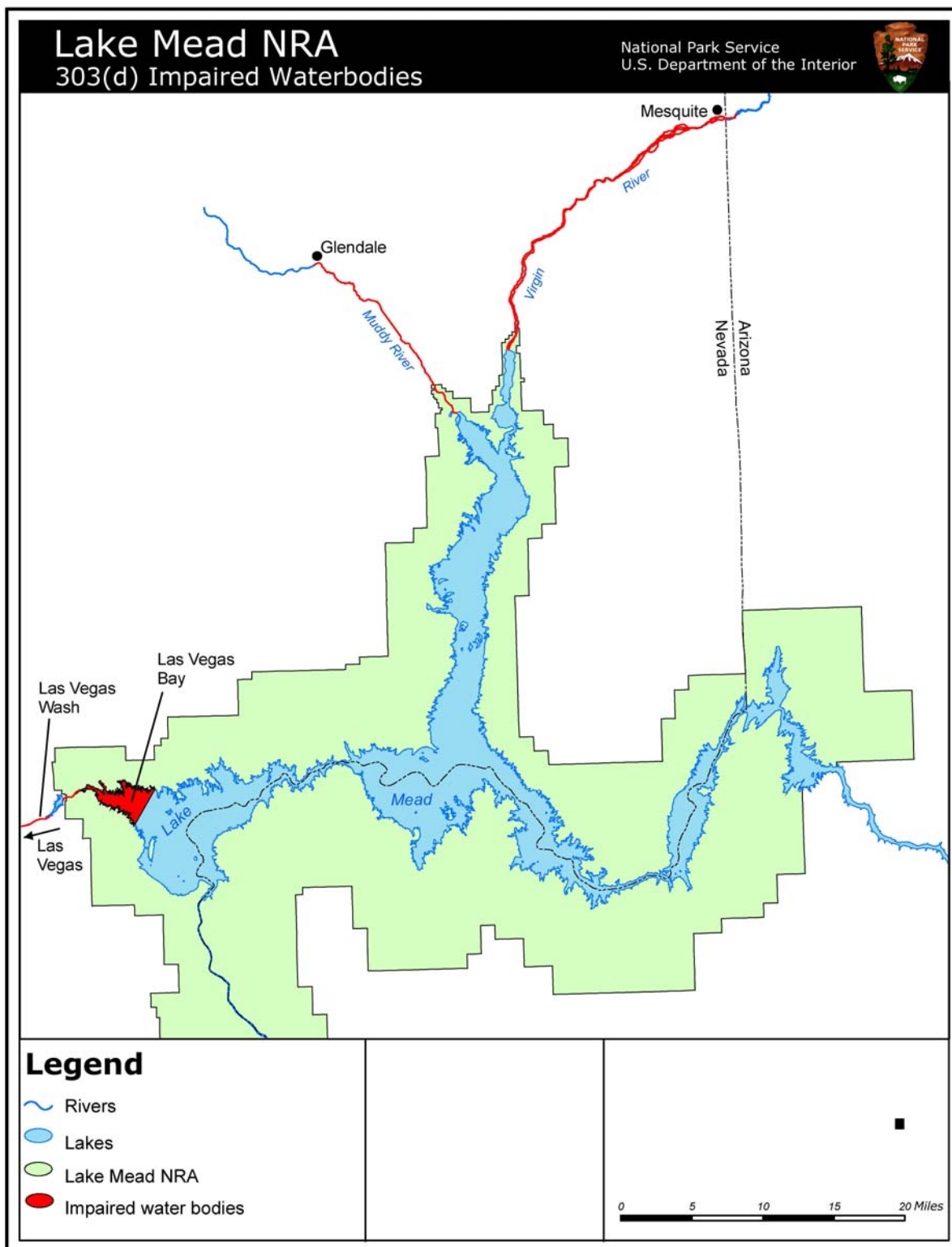


Figure 16. Impaired water bodies (303d-listed) at Lake Mead National Recreation Area.

Each state has developed its own list of ONRW waters. For the Parks in the Mojave Network, only GBRA has water bodies that have received a designation that could be interpreted as ONRW (Table 17, Figure 17). In the State of Nevada, the Nevada Administrative Code (NAC 445A.124; On-line: <http://www.ndep.nv.gov/>; Accessed 30 August 2005) identifies waters defined as Class A waters. Class A waters include waters or portions of waters located in areas of little human habitation, no industrial development or intensive agriculture and where the watershed is relatively undisturbed by man's activity.

Table 17. Class A waters (Outstanding National Resource Waters) within the Mojave Network.

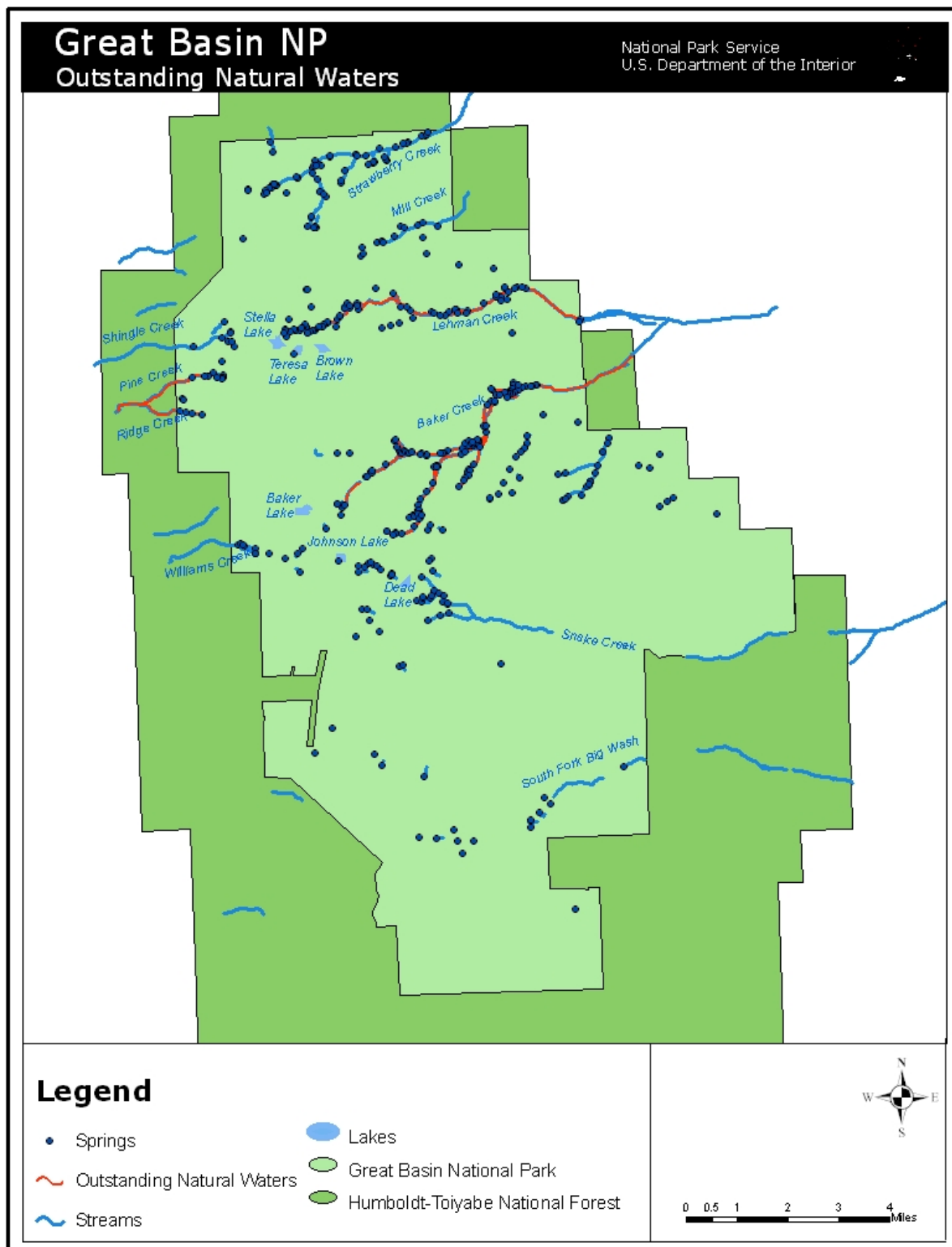
Park	Water Body Name	Description
GRBA	Baker Creek	From its origin to the national forest boundary.
	Lehman Creek	From its origin to the national forest boundary.
	Pine Creek	From its origin to the first point of diversion, near the west line of section 17, T. 13 N., R. 68 E.
	Ridge Creek	From its origin to the first point of diversion, near the west line of section 17, T. 13 N., R. 68 E.

3.7 Flora

3.7.1 Desert Plant Communities

Description and discussion of extant Mojave Desert vegetation and Sonoran Desert vegetation relevant to the Mojave Networks, either in terms of spatial distribution, functional groups, or biotic communities, are given in Vasek and Barbour (1977), Rowlands et. al. (1982), Sawyer and Keeler-Wolf (1995), and Thomas et. al. (2004). Delineations and descriptions of Great Basin vegetation are provided in Beatley (1976), Billings (1951), and Holmgren (1972). The Mojave Desert has the highest frequency of endemic species in the western United States (McLaughlin 1986), which is indicative of its high value within the national park system. Vegetation in this region may be separated among several functional groups and between riparian and xerophytic species (Johnson 1976). Riparian species occur in the relatively rare situation with perennial surface water and (or) high ground water. Xerophytic species occur on uplands and can be separated into annual, biennial, and perennial species. Most desert plants exhibit general adaptations to hot environments such as small leaf size and reduced stomata number and size. Adaptive specializations that further improve the probability of survival include rooting patterns, stem photosynthesis, succulence, seed production and germination strategies, and different photosynthetic pathways (Whitford 2002). Annual, perennial, and biennial species tend to exhibit different adaptive specializations such as fine, shallow root systems in annual species and deep root systems frequently with some root near the soil surface exhibited by many perennial species. Understanding these functional differences between annual, perennial, and biennial species can help in predicting and interpreting plant response to stressors such as climate change.

It should be noted that functionally, most hot desert (Sonoran and Mojave deserts) and Great Basin species utilize the C_3 photosynthetic pathway (Johnson 1976); implying that they predominantly respond to cool-season precipitation. However, significant numbers of C_4 species



1 Figure 17. Class A (Outstanding National Resource Waters) waters at Great Basin National
2 Park.

(chenopods, some perennial grasses, some woody shrubs and trees) including CAM species (cacti and other succulents) are also present. CAM plants are considered to use a modified C_4 photosynthetic pathway but instead of segregating the C_4 and C_3 pathways in different parts of the leaf, they separate them in time by taking in CO_2 at night. Generally, cactus-like plants exhibit low evapotranspiration rates and are highly water efficient and tolerant of higher temperatures compared to other plants. However, they are also very susceptible to extended drought periods and exposure to below-freezing temperatures (Whitford 2002). C_3 plants are considered generally to be less water efficient, have lower optimum temperatures, and have a lower rate of photosynthesis compared to C_4 plants and should logically be the least adapted to hot desert environments. These properties of C_3 plants affect the growth and morphological characteristics of plants that are successful in hot deserts such as leaf growth and production, pattern of stem elongation, root growth and distribution, and canopy shape (Whitford 2002). Because C_3 plants can be considered potentially less adapted to hot desert environments they also may be more susceptible to changes in water availability (timing and amount) and temperature regimes over time.

3.7.2 Plant Functional Groups

Functional groups of species are considered to have similar effects on ecosystem processes (Chapin et al. 1996) although our understanding of the relationship between individual species, functional groups, and ecosystem function is poorly understood. It can be argued that within functional groups some species may be lost with little to no effect on ecosystem processes. In contrast, loss of a significant number of species within a functional group may have significant and long-term impacts on ecosystem processes (Whitford 2002). Therefore, monitoring of functional groups or functional types may be more useful from a management perspective in maintaining ecosystem services and measuring performance in achieving desired future conditions in parks based on ecological processes and function.

Annual Vegetation: Annual vegetation consists of plant species that may reside in the soil for many years as dormant seeds, but germinate under favorable conditions, establish, grow to reproduction and die within one year (Baskin and Baskin 1998). Annual species may be herbs or grasses, but rarely develop a woody stem. The Mojave Desert is known for panoramas of color that consist almost entirely of annual plant flowers during years of above average precipitation (Figure 18). Annual plant species in the deserts are tremendously speciose, thus discussions will mostly be very general and not include particular species. Rundel and Gibson (1996) estimated that there are at least 400 annual plant species in the Mojave Desert. Annual vegetation exists as either winter or summer annuals (Went 1948, Juhren et. al. 1956, Beatley 1974) depending on their requirements for seedling germination and growth. The two floras are discrete in the timing of their phenologies and this separation in time is maintained by different temperature, moisture, and stratification requirements for germination.

Stratification refers to conditions that seeds require for germination that may include but are not limited to physically breaking the seed coat by scarification from a variety of sources, high or low temperature exposure, exposure to nutrient pulses, or leaching of inhibitors that suspend germination (Baskin and Baskin 1998). The two functional types of annuals are separated by different requirements for scarification. For example, winter and summer annuals germinate in

1 discrete temperature ranges, with winter annuals germinating during cooler temperatures (e.g.
2 15-20 °C) and summer annuals requiring relatively warmer temperatures (e.g., 25-35 °C). Winter
3 annual plant populations may be expressed in response to greater than 25 mm (1 inch) of
4 precipitation by October (Beatley 1974), but may partially express populations with adequate
5 precipitation between October and April. Summer annual germination coincides with summer
6 monsoon storms and establish during July through September and usually going to seed by
7 November.

8
9 In addition to seasonal variation between the two annual plant floras, the survival of many native
10 annual plant populations depends on a persistent seed bank that may lie dormant in the soil for
11 years until specific conditions are met for germination. Persistence of the seed bank depends on
12 seeds from each species being triggered to germinate by a range of conditions such that the entire
13 population of each species does not germinate in any single year. Thus those remaining in the
14 seed “bank” remain dormant in the soil as insurance against a total failure to reproduce in a
15 single year. Adult plants may produce seeds that respond to germination triggers differently such
16 that they maximize fitness by having successful offspring across multiple years.

17
18 Although seed banks are important for many species, at least some species of annual plants do
19 not possess a persistent seed bank. A notable exception to the persistent seed bank dynamics
20 described here include annual plant species that do not appear to maintain a seed bank for
21 population survival such as red brome (*Bromus madritensis* var. *rubens*) and cheatgrass (*Bromus*
22 *tectorum*). Interestingly, both of these species are non-native species from the Mediterranean
23



26 Figure 18. Floral display of winter annual vegetation at Lake Mead National Recreation Area
27 near mile post 7 on the east side of Boulder Dam in 2001. (Photo courtesy T. Esque, USGS.)
28
29
30

1 region of Europe and Asia. These species produce prodigious amounts of seed which apparently
2 is a very different yet successful approach to population persistence. Although super-abundant as
3 invasive species in North America, these species are not as numerically dominant where they are
4 native (Jackson 1985).

5
6 Annual plant populations are affected by climate fluctuations; air quality and nutrient deposition,
7 particularly associated with air pollution; introduction and spread of non-native species; and fires
8 (Hunter 1991, Brooks 2000, Fenn et. al. 2003). Production of annual plants can be measured as
9 biomass, cover or the density of plants per unit area. Native annual plant production may range
10 from virtually zero in many years to as much as 120 grams per square meter with over 15 species
11 of plants found in 0.1 of a square meter (L. DeFalco, Unpublished Data, 2005). Production is tied
12 closely to the amount of precipitation during seasonal storms (Beatley 1969). Climatic
13 fluctuations involving temperature shifts and change in seasonal precipitation could substantially
14 affect the growing season and annual plant production. Interactions between atmospheric
15 deposition of nutrients (e.g., nitrogen), invasive plants, and fire form complex relations and could
16 have a negative influence on native annual plants from changed nutrient cycling, changed
17 disturbance regime, and added competition from non-native species. Because some non-native
18 species may increase fire frequency to their benefit and exclusion or suppression of other
19 annuals, the introduction and spread of non-native species may be the largest threat to annual
20 plant populations in the Mojave Desert.

21
22 **Biennial Species:** Biennial species generally live for no more than two years, and their ability to
23 survive through the summer drought with its high temperatures distinguish these species from
24 annuals. Typical biennial species include globe mallow (*Sphaeralcea ambigua*) and locoweed
25 (*Astragalus* sp.). Although this group spans the difference between annuals and perennials, their
26 characteristics and responses are similar enough to annuals to be considered partially within that
27 group.

28
29 **Perennial Species:** Perennial plants live for several years to thousands of years in our desert
30 environments. The bristlecone pine, found on windswept mountain tops of Death Valley and
31 Great Basin National Parks, is distinguished as the oldest known tree species on earth – known to
32 live over 4,000 y. Although shrublands (or desert scrub; Turner 1994) are the predominant
33 vegetation type throughout much of the Mojave Desert, perennial vegetation occurs in many life
34 forms. Creosote bush, which purportedly can live more than 12,000 years (Vasek and Barbour
35 1977), is a classic example of a Mojave Desert perennial shrub, although perennials also include
36 grasses (*Achnatherum* spp.), herbaceous perennials (e.g. *Stanleya elata*), cacti (e.g., *Opuntia*
37 *basilaris*), geophytes such as bulbs and corymbs (e.g. *Calochortus kennedyi*), semi-succulents
38 (e.g. *Yucca brevifolia*, *Fouquieria splendens*), and salt-tolerant succulents (e.g. *Allenrolfea*
39 *occidentalis*). Perennial species usually have a woody stem with woody or deciduous branches,
40 or, in a few species, possess a persistent underground caudex with deciduous above-ground
41 stems (e.g. *Cucurbita palmata*).

42
43 Perennial plants provide a great number of services in ecosystems and are components of many
44 processes. Perennial plants provide most of the habitat structure that is important to animals as
45 cover, nest sites and perches to fulfill many aspects of making a living in the desert. In addition

1 to structure, perennial plants are a tremendous source of nutrients whether simply as foliage, or
2 as pollen, nectar, and underground nutrient storage components.

3
4 Despite this diversity in perennial life forms, the species considered most characteristic of the
5 Mojave Desert are creosote bush and Joshua tree. At Mojave National Preserve, Great Basin
6 National Park and Parashant National Monument, sagebrush (*Artemisia* spp.) and pinyon-juniper
7 communities grade into coniferous woodlands and eventually forests dominated by different
8 species with increasing elevation including lodgepole pine (*Pinus contorta*), limber pine, white
9 fir (*Abies concolor*), Engelmann spruce, bristlecone pine, and sub-alpine fir. Coniferous forests
10 give way to alpine tundra habitats with their dwarf willows (*Salix* spp.), and representative
11 krummholz and cushion plant growth forms on tops of the highest desert peaks.

12
13 In addition to a variety of life forms, there is an equally great variety of characteristics that
14 provide plants with the ability to survive the rigors of desert environments such as drought,
15 herbivory, both high and low temperature extremes, highly variable soil water availability, and
16 high insolation. Above-ground structure plays a significant role in life history; for example,
17 creosote bush is shaped like an inverted cone, which is ideal for stem transmission of rainwater
18 directly to a central root crown. Other species form hemispheric mounds that may optimize leaf
19 exposure to sunlight. Many leaf, cuticle, flower and seed characteristics appear to have
20 developed in response to severe desert conditions.

21 22 **3.7.3 Riparian Plant Communities**

23
24 Riparian communities in the MOJN are supported along water major watercourses (including
25 lakeshores) and in association with isolated springs, seeps, ponds, and streams. Riparian areas
26 comprise one of the most dramatically altered community types over the last 150 years in the
27 western United States, however they remain the most biologically diverse. More than 75% of
28 the species in the Mojave-Great Basin region are strongly associated with riparian vegetation,
29 including 80% of birds and 70% of butterflies (Brussard et al. 1998). Additionally, a significant
30 number of species of special concern are associated with riparian habitat (e.g. Southwest willow
31 flycatcher and Least Bell's Vireo) and because of the isolated nature of surface water resources in
32 the MOJN these sites, particularly springs, tend to exhibit a high rate of endemism. Plant and
33 animal communities associated with surface water, have been significantly altered across
34 network parks due to the effects of past and current human use including water diversions,
35 agricultural development, and livestock grazing. In many areas, riparian communities are now
36 dominated by non-native tamarisk species that access water more easily and tolerate saline soils
37 better than native plant species. This habitat is potentially the most significant to maintaining
38 biological diversity and the most threatened across parks in the Mojave Network.

39
40 Vegetation associated with either surface water or high ground-water levels can be categorized
41 as obligate riparian species, facultative riparian species, or opportunistic xerophytic species.
42 Obligate riparian species are also known as phreatophytes because of their dependence on high
43 ground-water levels (Meinzer 1927). In the Mojave Desert, Frémont cottonwood (*Populus*
44 *fremontii*), desert willow (*Chilopsis linearis*), and mesquite (*Prosopis velutina*) are the iconic
45 obligate riparian species. Although the desert willow and mesquite are widespread in the Mojave
46 and Sonoran desert parks, the cottonwoods are generally quite rare, except along large river

1 systems where shallow ground water is available. Great Basin systems have a greater elevational
2 range, more abundant precipitation in the form of rainfall, snow and ice and thus more obligate
3 species of riparian plants. Riparian vegetation in the Great Basin can be delimited by the grass-
4 like sedges and rushes (*Carex* spp., *Scirpus* spp. and *Juncus* spp.) from the valley bottoms to
5 alpine habitats. At low elevations the same cottonwood trees that are riparian indicators in the
6 Mojave Desert also occur in the Great Basin. True willows (*Salix* sp.) may form small thickets
7 along watercourses opportunistically. At middle elevations (1400 – 2000 m) the cottonwoods are
8 accompanied by a maple (*Acer glabrum*), more willows, and rose thickets (*Rosa woodsii*).
9 Higher up (2000-2900 m) the Frémont cottonwood is replaced by the narrowleaf cottonwood (*P.*
10 *angustifolia*) which are also accompanied by willows and roses. In alpine and subalpine habitats
11 (>2900 m), primarily willows are accompanied by several facultative species from the
12 surrounding upland habitats such as subalpine fir (*Abies lasiocarpa*) and Englemann spruce. In
13 contrast to obligate species, facultative riparian species can also live in more xeric sites, but these
14 species remain dependent upon at least some available water, either through seasonal surface-
15 water recharge of perched alluvial aquifers (species of the genus *Chrysothamnus*) or water
16 storage in sand dunes (e.g. mesquite). Non-native species, such as tamarisk (*Tamarix* spp.), may
17 take the role of either obligate or facultative riparian species and dominate some riparian
18 systems. Finally, many xerophytic species ordinarily associated with uplands thrive with extra
19 water associated with washes, including creosote bush, salt bushes (*Atriplex* spp.), desert broom
20 (*Lepidospartum squamatum* in the western Mojave, *Baccharis sarathroides* in the eastern
21 Mojave), and catclaw (*Acacia greggii*, normally found as an upland species in the Sonoran
22 Desert).

23
24 Some unique annual, biennial, and perennial floras exist around springs in the Mojave Desert.
25 Many of these species are endemics with limited distribution and considered either threatened or
26 endangered. In some settings, particularly in Death Valley National Park and Lake Mead
27 National Recreation Area, aquatic plant species are also highly important indicators of ecosystem
28 status and health.

3.8 Fauna

3.8.1 Terrestrial Invertebrates

34 Invertebrates and microorganisms are important inhabitants in desert ecosystems because of their
35 roles in functional groups including predators, parasites, granivores, herbivores, pollinators and
36 decomposers. Invertebrate comprise approximately 95% of all animals on earth (Mason 1995)
37 and similarly comprise most of the animal biomass in deserts. The invertebrates considered here
38 include all arthropods and mollusks. When asked about the types of invertebrates that occur in
39 deserts, many people describe the stuff of nightmares including tarantulas (*Aphonopelma*
40 *chalcodes*), scorpions (e.g., *Centruroids exilicauda*, *Hadrurus arizonensis*), and black widows
41 (*Latrodectus hesperus*). Other common invertebrates that contribute greatly to ecosystem
42 processes in the desert include the white-lined sphinx caterpillar (*Hyles lineata*), termites (Order
43 *Isoptera*), grasshoppers (Family *Acrididae*), ants (Order *Hymenoptera*), and yucca moths or their
44 caterpillars (*Tegeticula* spp).

1 Microorganisms play an often unnoticed role in the function of desert ecosystems. They must
2 also be adapted to the harsh desert environment. Cyanobacteria are exclusively the endolithic
3 primary producers in the desert due to their ability to adjust to extreme temperatures and low
4 amounts of moisture (Atlas and Bartha 1998). Cyanobacteria fix atmospheric nitrogen into
5 amino acids, helping to enrich the soil with nitrogen for plant growth. Fungi facilitate the
6 decomposition of dead organic material, also making nutrients available for plants. Lichens are a
7 composite plant of an algae and fungus in a mutually beneficial relationship. The fungus provide
8 the necessary water and support structure, while the algae provide food through photosynthesis.
9 Lichens are dependent on the uptake of nutrients from the atmosphere, making them sensitive to
10 air pollutants (Sweat et. al. 2004). Desert varnish is very common in the desert and can be found
11 on entire mountain sides of rock. Desert varnish is a thin coating of manganese, iron and clays on
12 the surface of rocks. These elements are “cemented” to the rock by bacteria. One microorganism
13 that does not go unnoticed is the salt loving halobacteria found in many salt lakes and playas.
14 The halobacteria give the salt lakes and playas a pink or red tint. Perhaps one of the most well
15 known microorganisms are those comprising the gut flora of termites as symbionts that facilitate
16 the decomposition of cellulose, which is mechanically decomposed by the termites.

17
18 Ants are represented by a variety of functional groups including the well known granivores,
19 nectarivores, predators, and even species that enslave colonies of other ant species as their
20 workers. Ants are the primary soil workers of the desert, aerating the soil, mixing nutrients in the
21 soil, consuming and re-distributing seeds potentially affecting plant species both directly and
22 indirectly by their activities. Species diversity of ants was found to be highly correlated with
23 mean annual precipitation, which is also an index of productivity in dry regions (Davidson
24 1977). With an increase in annual plant production in high precipitation years, more seed will
25 become available. Competition for limited resources such as seeds may encourage ant
26 communities to seek out different niches in time, space, and thermal regimes (Bernstein 1974,
27 Whitford 1978, Davidson 1977, Mehlhop and Scott 1983). Competition for food indicates that
28 ants may have an impact on seed resources and, thus, the plant community. Harvester ants have
29 been observed to collect from 33% to 86% of the seeds from certain plant species, 9 to 26% of
30 all available seeds and found that as much as 100% of some plant species were removed within
31 ant foraging areas (Crist and MacMahon 1992). In one study it was found that ants ultimately
32 increased the diversity of seed banks and plant production by harvesting the most common seeds
33 (Brown et. al. 1979). Even though they may be very efficient at gleaning seeds, ants are not
34 always seed predators: worker ants may disperse seeds by carrying them to the nest, and not
35 consuming them (Carroll and Janzen 1973, Hölldobler and Wilson 1994). Irrespective of how the
36 seeds arrive on ant nests, plant community composition can be changed and reproduction can
37 increase for plants that germinate and establish near ant nests in desert environments (Rissing
38 1986, Brown and Human 1997, Esque 2004).

39
40 Besides providing sustenance for many small insectivores, termites function as primary
41 decomposers of plant fiber in deserts (Aber and Melillo 2001) and function secondarily in the
42 decomposition waste from large herbivores (e.g. feral horses, livestock). Termites provide a
43 platform for symbiotic microorganisms that live in termite guts, and both speed the decay of
44 woody substances and fix atmospheric nitrogen.

1 Some yucca moths (*Tegeticula* spp.) and yucca species (e.g. *Yucca brevifolia*, *Yucca schidigera*)
2 exist in obligate symbiotic relationships. In these relationships, yucca plant species rely on yucca
3 moths for pollination. The moth depends on the plant for nourishment for their larvae. The
4 emergence of moth pupae is timed with the emergence of yucca flowers. After the female moth
5 emerges from pupae in the ground, they mate with a male in a yucca flower. The female then
6 flies, nocturnally, to a freshly opened flower where it removes the pollen. She proceeds to
7 another flower where she oviposits her egg into a locule, then she pollinates the flower. The
8 larvae that form consume the seeds in the same seed pod where they hatch, unless interrupted by
9 the activities of animals or the decomposition of the seed pod as a result of poor weather
10 conditions (Baker 1986). The classic example of obligate symbiosis reflected in many text books
11 (e.g. Ricklefs 1990) was recently complicated by the discovery that some yucca moths are
12 cheaters and actually prey on seeds without benefiting the plants (Marr et. al. 2001).

13
14 Although many of the species described here are generalists, such as termites that can consume a
15 wide variety of woody plant fiber, many invertebrates are obligates of particular plant species
16 that are required to fulfill aspects of their complex life histories. These types of obligate
17 relationships are sensitive to disruptions in the availability of the host plant. Therefore,
18 disturbances such as fire, or pollution that extirpate certain species are likely to affect many
19 invertebrate species as well.

20 21 **3.8.2 Aquatic Invertebrates**

22
23 Until recently aquatic invertebrates were mostly overlooked due to the low amounts of free
24 surface water in the Mojave and Great Basin Deserts. Unfortunately, significant numbers of
25 aquatic invertebrates most likely exist in this region, but have not been described. As with
26 terrestrial invertebrates, aquatic invertebrate communities experience the environment on a much
27 smaller temporal and spatial scale than larger animals. Due to this characteristic, aquatic
28 invertebrates can function as water quality monitors or indicators (Brussard et. al. 1998). Many
29 aquatic invertebrates can be found in arid land springs that are scattered across the Mojave and
30 Great Basin desert region. Springs are small wetlands supported by ground water that discharges
31 onto the land and each is distinctive because of water chemistry, discharge, temperature,
32 elevation, morphology, and disturbance. Springs are becoming increasingly important and are
33 referred to as biodiversity hotspots as they support a large proportion of the aquatic and riparian
34 species in desert regions (Desert Research Institute 2005).

35 36 **3.8.3 Vertebrates**

37
38 A fascinating variety of vertebrate species are found in the Mojave Desert, Sonoran Desert and
39 Great Basin regions. Vertebrates may be categorized taxonomically or by functional categories
40 broken into how animals consume their required nutrients and/or the ecosystem services they
41 provide/processes that they participate in. Based on foraging types animals are characterized as
42 herbivores, granivores, carnivores, omnivores, and scavengers. Among these groups, more
43 precise descriptors include frugivores, nectarivores, insectivores, but mostly very general classes
44 will be considered here. Functional groups that focus on process orientation or services include
45 but are not limited to: pollination, bioturbation (i.e. those that move soil) and decomposition.

3.8.3.1 Vertebrate Functional Groups

Herbivores: Large herbivores are some of the most readily apparent desert inhabitants are represented broadly by cervids, equids and artiodactyls. Although they do not comprise a large portion of the total animal mass in Mojave Network parks, large herbivores can affect vegetation and sensitive habitats either individually, or by nature of their herding behavior. Large herbivores can be separated into grazers (primarily consume grass), browsers (primarily consume shrubs), or both types. Of the Cervidae: mule deer (*Odocoileus hemionus*), desert bighorn sheep (*Ovis canadensis nelsoni*), are widespread in the network. Domestic sheep do not currently inhabit the parks, and are discussed in the invasives section. Elk (*Cervus elaphus*) may be found at Manzanar, where they cause some destruction to vegetation (F. Hays pers. comm.), and Great Basin National Park. The Artiodactyls: pronghorn (*Antilocapra Americana*) are recorded from Great Basin National Park. Mule deer inhabit mostly moderate elevations in desert mountain ranges across network parks where they are present in pinyon-juniper stands which probably provide cover year round. Pinyon-juniper stands play an important role as winter cover for mule deer further north in the Great Basin. Bighorn sheep inhabit open rugged terrain and require steep cliff faces for escape terrain from predators. They may be encountered from valley floors to the tops of the highest peaks if appropriate escape terrain is available. Thick vegetation provides too much cover for predators and may inhibit bighorn sheep populations (K. Longshore pers. comm.).

As large herbivore populations grow they have the capacity to affect the abundance and availability of vegetation that they eat. Large herbivores provide food for large carnivores such as the mountain lion (*Felis concolor*), and as such are susceptible to the presence of these large and successful predators. These large animals have the capacity to move great distances from one mountain range to others, but are highly susceptible to habitat fragmentation and encroachment by humans.

Small fossorial herbivores are a group that is particularly important for their roles in the movement and aeration of soil, effects on plant communities and resulting effects on nutrient cycling. Vole (*Microtus* spp., or *Lagurus* spp.) populations are represented by a large number of isolated populations occupying some low elevation wetlands in desert habitats, wet meadows at higher elevations, and shrub lands in higher latitudes throughout the Mojave Network. As other herbivores listed here, voles disarticulate, consume, and decompose a large amount of fresh vegetation. They maintain runways that are clipped free of vegetation wherever they live and these runways are probably used by other small animals and invertebrates. They also burrow and by so doing increase nutrient cycling during the redistribution of vegetative material and maintain the friability of soils. Gophers (*Thomomys* spp.) are mostly solitary and mostly fossorial in their movements. Although gophers may be observed during an occasional above-ground foray, they spend a great deal of their time underground in fossorial activities. Since they conduct most of their life cycle underground, the result is that gophers move tremendous amounts of soil.

Granivores: Granivores are those that consume seeds for a significant portion of their diet and include rodents such as kangaroo rats and many small birds (Reichman 1977, Pulliam and Brand 1975). Kangaroo rats and related animals specialize in finding and handling seeds. Many of them

1 survive by caching multitudes of seed when they are abundant, and then living off of cached
2 seeds during more lean times. Although granivorous rodents consume prodigious amounts of
3 seeds, they may also be responsible for placing large numbers of seeds in sites for germination.
4 Birds may be primarily granivorous on a seasonal basis because most of them require insects or
5 fruits during growth periods. Granivorous birds include many finches, and large birds such as
6 quail and introduced chukar. Rather than caching seed for future use, birds generally must
7 continue moving as more seed are required.

8
9 **Frugivores and Seed Dispersers:** Frugivores and seed dispersers are not particularly abundant
10 in hot desert habitats, but more types are found in the Great Basin Desert because of the greater
11 availability of fruits. One interesting hot desert frugivore is a small bird known as the silky
12 flycatcher or phainopepla. *Phainopepla* spp. spend part of their lives feeding on the viscous fruit
13 of a parasitic plant known as mistletoe (*Phoradendron* spp.). Interestingly, in a symbiotic
14 relationship, the mistletoe seeds consumed by phainopeplas are ultimately deposited (through
15 feces) on the trees that are the mistletoe host plant.

16
17 **Nectarivores and Pollinators:** Nectarivores and pollinators include several types of birds that
18 glean a large portion of their sustenance by gathering nectar from flowers. Nectaring activities
19 inadvertently result in pollination of some of the flowers when nectaring occurs. These species
20 are largely summer residents in the Great Basin, but may inhabit the desert year round in the
21 Sonoran and Mojave Deserts. For example, the verdin (*Auriparus flaviceps*) gleans at least part
22 of its sustenance by nectaring. More specialized are the hummingbirds which are primarily
23 seasonal visitors, but have become year-round residents in some areas, partially due to continued
24 year-long sustenance from cultivated gardens. Even the hot desert environment of the Mojave
25 Desert is mostly devoid of flowers for nectaring during winter months

26
27 **Carnivores:** Carnivores are vertebrates that consume animal matter in large part of their diets.
28 Carnivores include the felines (mountain lion, bobcats), canines (coyote and foxes), mustelids
29 (short-tailed weasels), raptors (hawks, owls and eagles), and rapacious songbirds such as the
30 loggerhead shrike. The special case of insectivores is included in this group including many birds
31 – especially seasonally, and the specialists such as shrews and bats. Many reptiles are
32 insectivores including the ant-specialist the horned lizard (*Phrynosoma deserti*), and all
33 amphibians are insectivores as adults. Other than reptilian insectivores, they typically have high
34 metabolisms and eat many times their own mass in insects. Avian insectivores must adapt to the
35 variability in the availability of their prey. This can be done by migrating seasonally, switching
36 food types, or in rare instances by entering a state of torpor during inclement weather or even
37 seasons. One of the most interesting avian desert insectivores is the white throated swift which
38 catches great numbers of insects at high speed while on the wing. The swifts nest and roost in
39 cracks on inaccessible cliff faces and during cold weather can enter a state of torpor with
40 depressed body temperatures. Another bird that may enter torpor during inclement weather or
41 seasonally is the poor will and it may winter at Joshua Tree National Park

42
43 **Omnivores and Scavengers:** Omnivores and scavengers include an interesting group of animals
44 that are largely generalists and includes some mustelids (striped and spotted skunks), the ringtail
45 (*Bassariscus* spp.) and avian species such as ravens. The classic scavenger of the desert is the
46 turkey vulture (*Cathartes aura*).

3.8.3.2 Riparian Bird Communities

Obligate riparian bird species may be particularly good indicators of change in riparian communities, the most threatened habitat in the MOJN. These are species that place >90% of their nests in riparian vegetation or for which >90% of their abundance occurs in riparian vegetation during the breeding season, such as the Least bell's vireo. Almost all birds in the Mojave Network depend on wetland and riparian habitats during at least some phase of their annual cycle. More than half of the breeding birds in the Great Basin are associated primarily with riparian habitat. Birds rely on these areas for food, water, protection from predators, and for breeding. Of the southwestern bird species that are dependent upon riparian areas, half are specifically restricted to these areas for breeding (Knopf and Samson 1994). Riparian areas in this region also provide habitat for migrating passerines. Only three of many birds of this region are listed as endangered or threatened. The species are, the bald eagle (*Haliaeetus leucocephalus*), peregrine falcon (*Falco peregrinus*), and southwestern willow flycatcher (*Empidonax trailii*). However, an additional twenty are candidates for federal listing or are considered sensitive species (Brussard et. al. 1998).

The largest concern for these birds is loss of habitat due to degradation and destruction of riparian areas. Declines in habitat have been attributed to many factors, one being livestock grazing (Fleischner 1994). Breeding bird surveys have been established and conducted to assess changes in bird abundance. Although the data are not entirely reliable due to limited sampling, a downward trend in population size has been associated with loss of riparian habitats. Fragmentation of habitat is another concern and is thought to lead to change in distribution of some species (Brussard et al 1998). Wildfires could be an important factor in bird species declines due to their ability to cause habitat fragmentation. When riparian habitat is fragmented due to wildfire or other degrading factors, the wildlife that uses those areas tends to disperse and a decline in population could occur. If this fragmentation occurs during breeding season, the riparian obligates would be forced to disperse to smaller patches of habitat potentially leading to increased competition for suitable habitat, increased risk of predation, and delayed or lost breeding opportunities (Finch and Stoleson 2000).

Another concern is encroachment of nonnative plant species. Encroachment of nonnative plant species is especially of concern at Lake Mead National Recreation Area. Due to flood control and irrigation projects, riparian areas within LAME have been altered and saltcedar (*Tamarix ramosissima*) has displaced large areas of valuable native riparian plant communities. Saltcedar is also known to increase soil salinity and wildfires, and use great quantities of groundwater critically needed for the riparian areas and other communities that depend on it (DeLoach 2004).

3.9 Biological Soil Crusts

The terms biotic soil crusts, microbiotic crusts, cryptobiotic crusts or cryptogamic soils (cryptogams) all refer to a diverse community of cyanobacteria, bacteria, lichen, mosses and metabolic by-products that are cemented into a semi-permeable soil surface. The biomass and species richness of biological soil crusts increases as the amount of precipitation increases and the temperature at which it falls decreases. The lichen and moss components of the crusts are most prevalent at locations dominated by winter precipitation, whereas warm season

precipitation seems to be a limiting factor for the distribution of these organisms (J. Belnap *pers. com.*). Ongoing studies by Belnap and colleagues in the Mojave Desert indicate that biological soil crusts exhibit a marked preference for younger piedmont deposits with weaker pedogenic soils, and they are relatively rare on active and very old deposits. In addition, biological soil crust cover tends to be denser on substrates rich in granitic or limestone detritus and sparse on those with >85% eolian sand. Therefore, potential biological soil crust cover is predictable and these relations can be used to manage lands that have reduced crust cover.

Intact biological soil crusts (Figure 19) protect soils from both wind and water erosion, relative to bare soil, thus providing soil stabilization (Belnap 2003a, Warren 2003). Biological soil crusts contribute to the nutrient regime of soils by capturing fine particles from erosional processes and atmospheric deposition. In addition to passive participants in soil formation, some components of biological soil crusts fix carbon and nitrogen (Evans and Ehleringer 1993, Belnap 2003b). More developed biological soil crusts also support a more diverse and abundant suite of subsurface soil organisms important in decomposition and nutrient cycling (Belnap 2003c). Disturbances to crusts may result in changes in ecosystem processes (Harper and Marble 1988, Belnap 2003a).



Figure 19. Biological soil crust at Mojave National Preserve. (NPS Photo)

Biological soil crusts are susceptible to trampling from large animals including feral equids, livestock and recreationists, as well as disturbances from vehicles.

3.10 Cultural Landscapes

The Mojave Network has a rich and fascinating cultural history. Cultural landscapes are important in maintaining our national, regional, and local identity by revealing human origins and development through their form, features, and the way they were used. A cultural landscape is defined as “a geographic area, including both cultural and natural resources and the wildlife and domestic animals therein, associated with a historic event, activity, or person or exhibiting other cultural or aesthetic values.” Types of cultural landscapes found within Mojave Network parks are historic vernacular landscapes, historic sites, and ethnographic landscapes (Table 18). Most cultural landscapes are dependent on natural resources and it is interconnected natural systems with dynamic properties that differentiate cultural landscapes from other cultural resources (On-line: www.cr.nps.gov/hps/tps/briefs/brief36.htm; Accessed 30 August 2005).

Table 18. Cultural landscape types found within the Mojave Network.

Cultural Landscape Type	Description	Mojave Network Examples (Park Code)
Historic Vernacular	A landscape that evolved through use by the people whose activities or occupancy shaped that landscape. Through social or cultural attitudes often individual, family or a community, the landscape reflects the physical, biological, and cultural character of those everyday lives. Function plays a significant role in vernacular landscapes. They can be a single property such as a farm or a collection of properties such as a district of historic farms along a river valley.	• Scotty's Castle (DEVA) • Lower Vine Ranch (DEVA) • CCC-era national monument administration structures (DEVA) • Osceola ditch (GRBA) • Lehman Orchard (GRBA) • Keys Ranch Area (JOTR) • Lost Horse Mine Ranch Area (JOTR) • Kelso Depot Historic District (MOJA) • Zzyzx Depot Historic District (MOJA) • Mojave Road (MOJA) • Greater Waring Ranch (PARA) • Tassi Ranch (PARA)
Historic Site	A landscape significant for its association with a historic event, activity, or person.	• Internment camp associated with the relocation of Japanese- Americans during World War II (MANZ)
Ethnographic	A landscape containing a variety of natural and cultural resources that associated people define as heritage resources.	• Contemporary Timbisha Shoshone Village (DEVA) • Prehistoric burial grounds and burial caves (GRBA) • Spirit Mountain Traditional Cultural Property (LAME) • Sugarloaf Mountain Goldstrike Canyon Traditional Cultural Property (LAME)

Cultural landscapes within MOJN parks reflect a diverse human history ranging from the Pleistocene Era to present day. Prehistoric occupation of network parks dates from the Paleo Indian period (12,000 B.C. to 9,000 B.C.) through the Shoshonean period (A.D. 1300 to present) (NPS 1995, NPS 2001a). Prehistoric inhabitants were hunters and gatherers and included the Pinto Culture in southern portions of the network and Fremont Culture in northern portions of the network. The Timbisha Shoshone Tribe continues, in the present day, to inhabit portions of DEVA and works collaboratively with the NPS to manage resources. The first Euro-American exploration of the Great Basin-Mojave Desert Region began in the late 1700's and is evidenced by the presence of wagon roads, railroads, and other early transportation routes. Lands within MOJA served as an east-west transportation corridor across the eastern Mojave Desert since prehistoric times. Variants of the Mojave Indian Trail, used by Native Americans for centuries, were followed by explorers, mountain men, and traders beginning in the late 1820's, establishing what would become the Old Spanish Trail (NPS 2000).

Euro-American settlement in the network occurred in the mid-late 1800's and the primary 'industries' of early, and in many cases current, settlements were associated with ranching, agriculture and mining. In the 1920's and 1930's, construction of new roads and the advancement of the automobile brought homesteaders to the Great Basin-Mojave Desert area. The location of early settlements was generally directly related to the availability of water resources. The post-World War II era brought the greatest changes to the Mojave Desert landscape with establishment of military training and testing sites (e.g. Edwards Air Force Base,

Nellis Air Force Base) encompassing over 10,000 mi². Initiation of military training exercises began in the 1940's and above ground testing of nuclear weapons occurred between 1951 and 1963 (Wilkerson 2004).

MANZ represents the only historic site within the MOJN. Between 1942 and 1945, this 329 ha site was occupied by 10,000 Japanese American internees (during World War II). Prior to their arrival the site had been largely denuded of vegetation, except a few fruit orchards, and during



the period of confinement internees engaged in extensive landscaping and development of “victory gardens” in available space. Additionally, this site contained significant support facilities including a hospital complex, auditorium, residential barracks, schools, stores, road network, agricultural plots, etc. Of 10 centers established during World War II for similar purpose, MANZ is the best preserved (NPS 1996). This entire site is considered a cultural landscape and principles for managing the area as a landscape are being established. Today thousands of visitors come to see and recreate in these landscapes, preserved and memorialized in MOJN parks.

Cultural landscapes are an important component of the parks of the Mojave Network. While cultural landscapes represent a relatively small proportion of total land area in the network, they are disproportionately important to park mission and visitor experience. These landscapes are affected by natural forces (Figure 20), development (e.g. commercial, residential), vandalism, and neglect. Few cultural landscapes in network parks have

Figure 20. Damage to cultural resources due to erosion at MANZ. (NPS Photo)

been formally designated or nominated through the regional inventory and assessment process coordinated out of the NPS Pacific West regional office and the majority of parks lack baseline data and planning documents related to important cultural and ethnographic resources. As the regional inventory and assessment process continues, many of these landscapes, sites, and features will be formally designated in the future.

Cultural landscapes are important to the MOJN monitoring program in a number of ways. First, these landscapes and features are highly influential on park ecosystems. It is in these cultural landscapes where much of the visitation and NPS management is concentrated, particularly those landscapes associated with surface water resources. Spring sites associated with cultural landscapes tend to be highly altered areas that frequently serve as a source of non-native plant and animal invasion (e.g. bullfrogs) thus affecting the structure and function of surrounding ecosystems. Additionally, natural forces such as floods and wind that may alter or destroy important elements of the cultural landscape also pose a significant threat to preservation of natural resources. Lastly, cultural landscapes function as discreet ecosystems in and of

1 themselves and therefore represent an important focus for monitoring. The MOJN monitoring
2 program distinguishes cultural landscapes as distinct systems that exhibit unique and important
3 ecosystem processes and interacts with surrounding ecosystems in profoundly important ways.
4 It is within this context that the MOJN seeks to explicitly incorporate cultural landscapes into the
5 vital signs monitoring program.

7 **IV. Natural Resource Threats and Management Concerns**

9 Parks in the Mojave Network share many similar natural resource threats and issues originating
10 from both inside and outside park boundaries. Threats or stresses originating from outside park
11 boundaries can, and are, significantly modifying biodiversity and other valued components of
12 park ecosystems (National Parks Conservation Association 1979, Garratt 1984, Machlis and
13 Tichnell 1985, Sinclair 1998). In 1980, greater than 50% of threats reported across the National
14 Park Service system were from external sources, with development on adjacent lands, air
15 pollution, urban encroachment, roads, and railroads most frequently cited (NPS 1980). More
16 recently, land use change (Hansen and Rotella 2002), fragmentation (Ambrose and Bratton
17 1990), and human population density (Newmark et. al. 1994) have been documented as threats to
18 individual parks. It has been hypothesized that only protected areas with adequate expanses of
19 surrounding habitat and linkages to other protected areas will be able to support current levels of
20 biodiversity into the future (Hansen et. al. 2001).

22 An essential step in the process of selecting vital signs is the gathering of park specific
23 information on key natural resources, natural resource threats, and the significant concerns and
24 issues facing parks in the management of those resources. In order to narrow the focus, ensure
25 relevance to network parks, and increase efficiencies in the planning process, priorities must be
26 established among focal resources and resource concerns. Network staff used several sources of
27 information to summarize priority resource threats and management concerns in network parks
28 including General Management Plans, Resource Management Plans, Strategic Plans, and
29 interviews with park staff. Resource managers identified stressors/threats to park resources and
30 those considered a high priority at the network-level were: invasive species, water quantity
31 alteration, land use change/development, and air quality degradation. Additional threats
32 considered a high priority in at least 2 individual parks but not at a network-level were altered
33 disturbance regime, recreation/visitation, and soil alteration. Livestock grazing also is briefly
34 discussed due the significant and broad scale historic impacts of this activity within network
35 parks and relevance to present day species composition and distribution. A summary of threats
36 and management concerns for all Level 2 vital signs is provided in Appendix K.

38 **4.1 Network-wide Threat and Management Concerns**

40 **4.1.1 Invasive Species**

42 Deserts are considered one of the least invaded ecosystems by plants, possibly related to
43 naturally low levels of soil nitrogen (Brooks and Esque 2003). However, at least 66 non-native
44 plant species have been identified in two or more park units within the Mojave Network
45 (Appendix L). Of most concern across the network are invasive annual grasses (e.g. genera
46 *Bromus* and *Schismus*) and *Tamarix* spp. Invasive annual grasses are widespread and abundant

in the Mojave Desert. By one estimate, alien annuals comprised 9-13% of all annual plant species but 4 species (*Bromus madritensis rubens*, *Schismus barbatus*, *S. arabicus*, *Erodium cicutarium*) comprised 66% of all annual plant biomass in one wet year (Brooks 1998, 2000). Only 7 non-native vertebrate species have been identified in two or more park units, representing several common bird species (e.g. *Sturnus vulgaris*, brown-headed cowbird, house sparrow), wild burro (*Equus asinus*), and wild horse (*Equus caballus*) (Appendix L). Although non-native fauna was considered less important compared to non-native, invasive plants a significant amount of staff time has been and continues to be dedicated to the management of some of these species (e.g. wild burro) (Figure 21).

Park management concerns are primarily related to invasive, non-native plant species and include: (1) the ability of invasive, non-native plant species to compete with native plant communities for limited resources, reducing native plant density, biomass, and diversity (Brooks 2000); (2) potential impacts on associated faunal communities, particularly special status species (e.g. desert tortoise, *Gopherus agassizii*), of alteration of native plant communities (e.g. food source, shelter); (3) potential for permanent alteration of ecosystem processes such as fire, critical to maintaining ecosystem structure and function; and (4) potential impacts on groundwater and surface water resources associated with selected invasive species such as tamarisk. As an example, change in fire regime in some network parks has been directly linked to the spread of invasive grasses which form a continuous layer of fine fuels in an environment characterized by few fine fuels and patchy fuel distribution. In 1999, nearly 5,666 ha (14,000 ac) at JOTR burned including many large Joshua tree stands. It has been suggested that repeated burning in the future and the inability of desert plant communities to recover from repeated burns may result in a permanent shift from shrubland habitats to alien annual grasslands in some network parks (Brooks 1999b). Permanent alteration of the fire process and native shrubland plant communities has significant implications for the desert tortoise (*Gopherus agassizii*). Increased fire frequency and intensity may cause direct tortoise mortality through burning or smoke inhalation (in or out of burrow), particularly during the spring (active season for tortoises), and may alter the nutritional quality of available forage (Boarman 2002). *Schismus* spp. is an invasive grass species often eaten by tortoises (Esque 1994) and nutritional analyses indicate that consumption results in depletion of nitrogen, phosphorus, and water in tortoises ultimately leading to weight losses (Avery 1998, Nagy et. al. 1998, Hazard et. al. 2001).



Figure 21. Burro round-up in the Black Mountains at Lake Mead National Recreation Area, 1993. (NPS Photo)

Tamarisk has invaded almost all watercourses and other wetland habitats throughout the Southwest, taking over more than one million acres of wetland habitat. These habitats in the Mojave Network are considered hotspots of biodiversity and support a significant number of special status species as well as frequently being culturally significant. A single, large tamarisk can transpire up to 300 gallons of water per day and in areas where watercourses are small or intermittent this species can severely limit the available water, or even dry up a water source. Reduction in water quantity at critical desert springs poses a significant threat to biotic communities (Eastman 2002; On-line: <http://www.riverparkway.org/html/newstam.html>; Accessed 30 August 2005).

4.1.2 Water Quantity Alteration

Water is the lifeblood of the desert. Available water is critical for desert survival and areas associated with surface waters are often focal points for biodiversity and important in the management of special status species as evidenced by the fact the 67% of Federally Endangered species in the network are desert fishes (Figure 22). The availability of surface water is directly related to the availability of subsurface or groundwater (although this relationship is poorly understood) which is slowly recharged through precipitation events and feeds scattered springs and wetland habitats across network parks. In places around Las Vegas, groundwater levels have declined 90 m (300 ft) since the first flowing artesian well was drilled in 1907 due to the demands of the human population (Bawden et. al. 2003). Continued up-gradient pumping of groundwater may potentially lower the water table and dry up critical surface water resources within network parks. Primary threats to water quantity, surface and subsurface, identified by park managers are groundwater withdrawal by surrounding communities/ commercial use, diversion of surface waters (e.g. through pipeline), and hydrophyllic, non-native plant species such as tamarisk (*Tamarix ramosissima*).

Park management concerns related to alteration of water quantity are primarily focused on the future ability of parks to protect this critical resource in the face of burgeoning population growth and poor understanding of the relationship between groundwater withdrawal and available surface water, loss of biodiversity, potential extinction of aquatic and riparian dependent species, and impacts to other faunal species (e.g. bighorn sheep) if already scarce water resources begin to disappear.



Figure 22. Groundwater monitoring at Devils Hole in Death Valley National Park. (NPS Photo)

4.1.3 Land Use Change/Development

The landscape of the Mojave Network NPS units has been altered significantly through historic and current patterns of land use and continues to be threatened by competing human interests (e.g. obtaining drinking water for a burgeoning population versus preservation of desert spring systems) with possibly the most significant alterations in areas associated with water. The landscape at MANZ has been most intensely altered through human activities due to the density of the human population over a short time period and the nature of land use during occupation of the site (e.g. agriculture, high density housing). Land use in its broadest sense encompasses a myriad of human activities occurring within and outside park boundaries such as: 1) physical alteration of the landscape surface (e.g. road-building, construction of buildings, agriculture and grazing; 2) modifications of plant and animal communities (e.g. introduction of predators such as cats and dogs, introduction of invasive plants and animals, and habitat fragmentation); and 3) multiplicative effects such as enhanced dust generation from gravel roads, and effects of visitation. As human population continues to increase in areas surrounding parks the associated impacts of urbanization such as air pollution, increased groundwater withdrawal, nitrogen deposition, noise pollution, introduction of invasive species, etc. on fragile desert resources are expected to increase. Since WWII, human population across the desert southwest has increased from approximately 8 million people to over 40 million human inhabitants today (Wilkerson 2004). In Clark County, Nevada, human population has increased from 16,414 individuals in 1940 (U. S. Census Bureau 1995; On-line: <http://www.census.gov/population/cencounts/nv190090.txt>; Accessed 30 August 2005) to 1,357,765 individuals in 2000 (U. S. Census Bureau 2000; On-line: <http://www.census.gov/census2000/states/nv.html>; Accessed 30 August 2005).

4.1.4 Air Quality Degradation

Air quality in the Mojave Network ranges from the best to the worst in the United States with Joshua Tree National Park being the only park unit within a class I area. In 2004, the American Lung Association State of the Air Report declared San Bernadino County, CA (including areas within or adjacent to JOTR and MOJA) to have the unhealthiest air in the nation (ALA 2004). Recent data indicates that JOTR, MANZ, and MOJA are at high risk for foliar injury to plants from elevated ozone levels (NPS 2004a). In contrast, the best visibility in the contiguous United States occurs in an area centered near GRBA.

Threats to air quality in and around network parks are primarily associated with urbanization adjacent to park units and include both point and non-point sources of pollution. Air quality in the network is affected primarily by pollution sources in California, Arizona, and Nevada, although more distant sources can also affect the area. Network parks experience poor air quality primarily from pollutants such as ozone, nitrogen oxides, sulfur dioxide, volatile organic compounds, particulate matter, and toxics. Specific sources of air quality degradation identified by park managers within and outside park boundaries included increased fire frequency, off-road vehicular traffic, mining activities (particulates), congeneration power plants, landfills, vehicular emissions, and watercraft emissions (nitrogen and sulfur deposition, ozone, toxins). Potential future threats to air quality primarily related to proposed commercial development on lands adjacent to parks (e.g. Eagle Mountain Landfill).

Park management concerns related to declining air quality are associated with potential or actual negative impacts to visitor experience and human health, impacts on selected park resources (e.g. petroglyphs), and alteration of ecological processes (e.g. nutrient cycling) critical to maintaining ecosystem structure and function and achieving park management goals. Maintenance of viewsheds and night sky vistas is a key management goal for several network parks and visibility impairment may have a significant negative impact on the quality of visitor experience. Some park resources are sensitive to specific pollutants such as alpine lakes at Great Basin National Park, which have a very low buffering capability and whose ecology (e.g. soil and water chemistry, species composition, predator-prey relations, etc.) could be significantly altered through deposition of 'acid rain', a by-product of emission of sulfur and nitrogen compounds into the atmosphere (Figure 23).

The greatest concern among network parks relates to the potential landscape-scale changes in abiotic and biotic resources associated with increasing levels of nitrogen deposition in and around network parks. Stable isotope studies near Joshua Tree National Park indicate that soil nitrogen increases in and around the park are due to increased atmospheric deposition and that these changes have occurred rapidly, since the 1950's (NPS 2004b). Nitrogen is a limiting factor in desert soils and widespread deposition of nitrogen compounds acts to fertilize desert soils and alter key ecosystem processes such as nutrient cycling and competitive relationships between native and non-native plant species. Soil nutrients (particularly soil nitrogen) are one of the determinants of habitat invasibility in the Mojave Network (Brooks 1999a) and there is evidence to suggest that invasive plant species benefit from increased soil nitrogen and are likely to continue to spread and thrive in areas subject to increased atmospheric nitrogen deposition.



Figure 23. Alpine lake at Great Basin National Park. (NPS Photo)

4.2 Additional Park-Level Threats and Management Concerns

4.2.1 Recreation/Visitation

Increased human population (described under section 4.1.3) surrounding parks is reflected in an increasing trend in park visitation. The longest period of record for visitation exists at DEVA and indicates an increase from 9,970 visitors in 1933 to 890,375 visitors in 2003 (Figure 22). In 2003, four of six network parks (DEVA, JOTR, LAME, MOJA) were in the top 30% of NPS units (N=353) with the highest percent of total visitors. LAME experiences the highest visitation in the network and, in 2003, ranked 5th in the nation with 7,915,581 recreation visits. The highest visitation was 9,838,702 total recreation visits at LAME, in 1995 (On-line: www2.nature.nps.gov/stats/; Accessed 30 August 2005)(Appendix M). In addition to direct impacts on natural resources within parks from changes in land use and development outside park boundaries are the direct and indirect impact of increased visitation within parks. Direct effects of increased park visitation include soil compaction in sensitive riparian habitats, light

pollution (e.g. headlights), illegal collecting, and introduction and spread of invasive plant and animal species, etc. Indirect effects are related to the potential need for additional park infrastructure, staff, etc. to manage visitation and provide a quality visitor experience. Ultimately, the need to provide high quality visitor services may lead to changes in land use and possible development within park boundaries and negative impacts to park resources (e.g. increased number of developed roads, increased number of bathrooms, interpretive buildings, and increased water consumption).

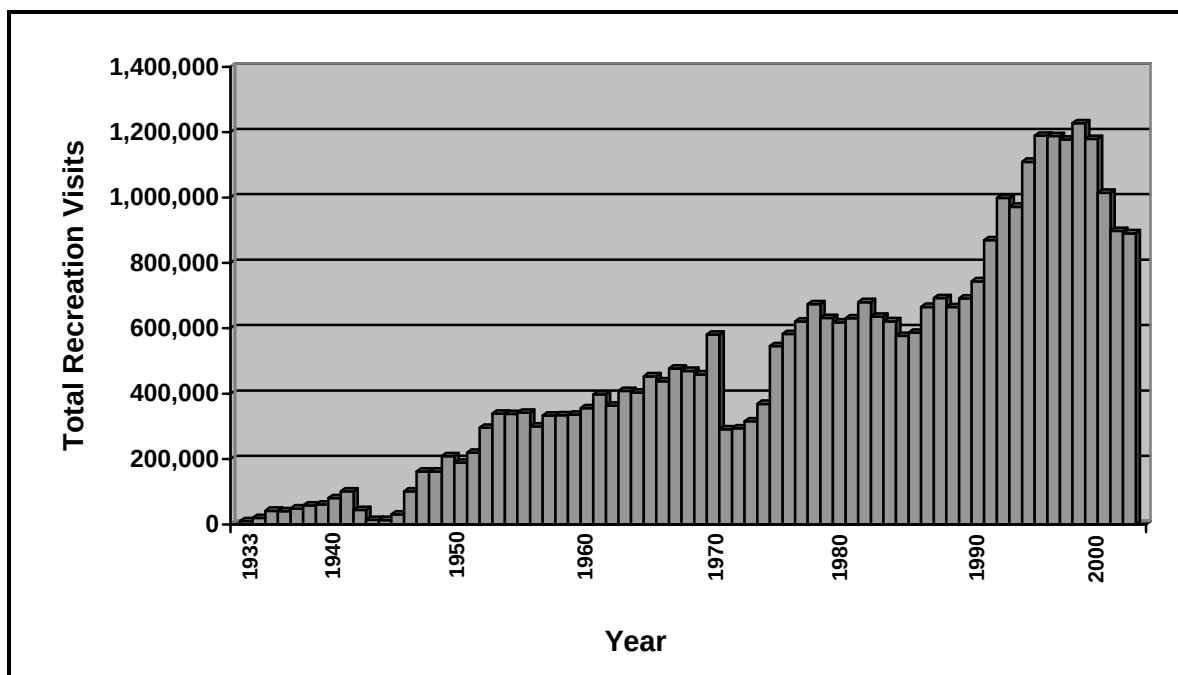


Figure 24. Trend in visitation (total number of recreation visits) at Death Valley National Park between 1933 and 2003.

4.2.2 Soil Alteration

Soil is the basic element affecting the structure and processes of arid and most terrestrial ecosystems (Whitford 2002). In arid systems, any disturbance or other alteration to the top soil layer (top 3-20 mm) where nutrients and living organisms are concentrated is of particular concern. Generally, threats to soil resources in the Mojave Network include any change that may unnaturally accelerate geomorphic processes (e.g. change in rate of erosion and deposition, rate of stabilization, sand/dust mobilization) or significantly alter the physical or chemical properties of soils (e.g. compaction, contamination) and ability of soils to function. Specific threats to soils identified in network parks include atmospheric deposition of nutrients, accelerated climate change, grazing, altered fire regime, mining activities, roads, road maintenance, commercial operations (e.g. railroad) and recreational activities. Concerns expressed by park managers vary depending on the specific threat but relate primarily to the potential impacts of degraded soil quality on desert ecosystems. Specific concerns identified include: (1) the potential for altered soil nutrient cycling leading to broad scale changes in plant communities (e.g. spread of invasive annual grasses); (2) increased atmospheric particulates (e.g.

dust) leading to alteration of soil pedogenesis processes; (3) compaction of soils in high visitor use areas (e.g. trails, riparian habitats) and in association with activities such as grazing and off-highway vehicle use leading to long-term changes in soil-water-plant interactions, runoff, and rate of soil erosion; (4) alteration in the location and/or rate of soil erosion leading to changes in surface hydrology, loss of cultural resources, alteration in plant distribution, etc.; (5) destruction of biological soil crusts and associated changes in soil stability and rate of erosion; (6) development of hydrophobic soils in association with more intense, stand replacing fires (altered fire regime); and (7) potential contamination of soils and water (e.g. cyanide, lead, mercury, arsenic, uranium) associated with mining and other commercial activities in parks.

The need for information related to soils and changes to this resource over time is directly related to the need for park management to focus on prevention rather than restoration of soils over the long-term. Preventing damage is critical because of the sensitivity of desert soils to disturbance and time required for recovery. A single footprint may have long-lasting impacts in desert environments that are not easily repaired because living organisms and nutrients are only in the soil surface. For example, biological soil crust recovery after a single footstep is estimated to take up to 20 years in areas of higher rainfall and up to 250 years on dryer sites, assuming the area is not disturbed again (Belnap 2001). Recovery time for plant communities on sites that have been repeatedly disturbed may be much longer. Webb et al. (1983) estimated recovery of plant communities in the Western Mojave Desert to potentially take centuries in areas subject to off-road vehicle use. Soils are further discussed in Chapter 2.

4.2.3 Altered Disturbance Regime

Natural disturbance regimes that are of primary interest in the MOJN related to drought, fire, and flood events. Although these disturbances are considered part of and critical to the maintenance of natural ecological processes they may also be considered ecosystem stressors or threats when the natural disturbance regime is altered due to human activities. Changes in disturbance regime that concern park managers generally involve change in frequency (e.g. fire frequency), change in intensity (e.g. flood events), or change in duration (e.g. drought events). Examples of specific threats to natural disturbance regimes in network parks include: (1) spread of invasive annual grasses leading to increased fuel continuity and increasing fire frequency and intensity; (2) historic and current fire suppression activities (in and around parks) leading to increased fuel loading and changes in plant community structure and composition that increase the frequency and intensity of fires; and (3) climate change that may alter the amount or pattern of precipitation leading to extended drought periods or increased frequency and intensity of floods.

It should be noted that across the Mojave and Great Basin Deserts and Colorado Plateau, the impacts and importance of change in, for example, fire regimes may be very different. The goal of management in the Great Basin and Colorado Plateau has been to restore the natural fire regime after 100 years of fire suppression as a means of maintaining the species composition and distribution of native plant communities. In contrast, the Mojave Desert is poorly adapted to fire and fires of any size have been historically infrequent. Prevention of fires and/or fire suppression is the goal of management in this system where increased fire frequency may move natural systems beyond their ability to recover naturally. Park managers also are concerned that the paucity of information available to them regarding natural disturbance regimes and the

1 response of park ecosystems to disturbance is insufficient to guide future management and
2 determine thresholds for management action. Disturbance and variability is further discussed in
3 Chapter 2.

4 5 **4.2.5 Grazing**

6
7 Livestock grazing is a common use of lands throughout western states including the majority of
8 federal lands (Fleischner 1994) and has occurred at a broad scale and varied intensity for over
9 150 years in the Mojave Network. Limited livestock grazing continues presently in DEVA,
10 GRBA, LAME, MOJA, and PARA although several parks are in the process of removing this
11 activity from NPS lands. Few studies have extensively documented the impacts of grazing on
12 park ecosystems or natural recovery time after removal of grazing in the Mojave Desert and
13 Colorado Plateau. However, research from other areas of the Southwest indicates that livestock
14 grazing can impact the species composition, function, and structure of ecosystems (Fleischner
15 1994). Grazing directly alters the composition of plant communities through differential
16 selection of species by grazing animals and the sensitivity of those species to grazing and
17 trampling. These changes combined with soil disturbance and seed dissemination by livestock
18 further modify species composition by facilitating the invasion of exotic species.

19
20 Ecosystem functions that are disrupted by livestock grazing include nutrient cycling and
21 succession (Fleischner 1994). In arid systems, such as on the Colorado Plateau and adjacent
22 ecoregions, soils contribute a vital role in nutrient cycling (Rychert and Skujine 1974) as well as
23 soil stability (Harper and Marble 1988, Bailey et al. 1973), water infiltration (Brotherson and
24 Rushforth 1983, Loope and Gifford 1972), and water retention (Lange et al. 1998). Fragile
25 desert soils, particularly biological soil crusts are highly sensitive to trampling impacts. Studies
26 have found that surface disturbances such as trampling can decrease biological soil crust cover
27 (Jeffries and Klopatek 1987) and reduce or eliminate nutrient cycling (Belnap et al. 1994). The
28 loss of nitrogen cycling can have a corresponding impact on the nitrogen content of dominant
29 plant species (Harper and Pendleton 1993). Livestock grazing patterns and surface disturbance
30 may arrest succession or irreversibly shift a habitat to another state (Fleischner 1994). Two
31 studies of riparian habitat in Arizona found that cottonwoods were not regenerating on grazed
32 sites (Glinski 1977, Carothers et al. 1974). Under a continuous grazing regime, this could
33 ultimately impact canopy cover and stand replacement (Glinski 1977).

34
35 Grazing impacts are of particular concern to park managers relative to riparian habitat. As stated
36 previously, riparian habitat in the MOJN supports a high level of biotic diversity (Snyder and
37 Miller 1992, Carothers et al. 1974) and is potentially the most threatened habitat across network
38 parks. Livestock grazing has been identified as a primary threat to this ecosystem (Chaney et al.
39 1990, Szaro 1989, Mosconi and Hutto 1982, Carothers 1977, Leopold 1924) in part because the
40 animals actively seek riparian zones for water and shelter (Windell et al. 1986, Roath and
41 Krueger 1982, Van Vuren 1982). As summarized by Fleischner (1994), "Riparian vegetation is
42 altered by livestock in several ways: (1) compaction of soil, which increases runoff and
43 decreases water availability to plants; (2) herbage removal, which allows soil temperatures to
44 rise, thereby increasing evaporation; (3) physical damage to vegetation by rubbing, trampling,
45 and browsing; and (4) altering the growth form of plants by removing terminal buds and
46 stimulating lateral branching". Bahre (1991) found that the legacy impacts of grazing included

1 degradation of riparian habitat from erosion, loss of palatable plant species, spread of exotic
2 species, and altered age structure of tree species. Although some studies concluded that complete
3 removal of grazing from riparian systems can result in relatively rapid recovery (2+ years) of
4 aquatic components (Fleischer 1994, Warren and Anderson 1987), the wooded component may
5 require extended recovery times (Szaro and Pase 1983, Knopf and Cannon 1982).

6
7 At the local and regional level, grazing and trampling also has long-term, moderate to major
8 adverse effects on water quality by increasing erosion within stream corridors and around
9 springs, which then increases sedimentation. Increased sedimentation with accumulations of
10 urine and fecal matter changes water chemistry. Over a long period of time, changes in water
11 chemistry in combination with trampling (livestock, hikers, and motorized vehicles) can destroy
12 the micro- and macrobiotic communities that help define a healthy riparian system (Cole and
13 Bayfield 1993, Marion and Merriam 1985). The impacts discussed above collectively contribute
14 to the degradation of ecosystems at a local and regional scale thus impairing systems on adjacent
15 NPS lands.

18 **V. Summary of Past and Current Monitoring**

19
20 An understanding of current and previous monitoring in and around network parks is an
21 important foundation for development of the MOJN vital signs monitoring program.
22 Documentation and review of existing work allows the network to identify where monitoring is
23 adequate, where additional inventory, monitoring or protocol development is needed, which
24 monitoring studies can be built upon and expanded, and what studies to abandon. Monitoring
25 activities within network parks falls into 2 general categories: 1) monitoring being conducted
26 only within park boundaries; and 2) monitoring being conducted within parks that is part of a
27 larger (e.g. state-wide, regional, national) monitoring program attempting to make inferences
28 beyond park boundaries. Regional or broader-scale monitoring within parks may or may not
29 significantly involve park staff. Current and historic monitoring activities within network parks
30 is described in Appendix N. Monitoring that is occurring at a larger regional to national scale in
31 and around network parks is described in Appendix O.

33 **5.1 Past and Current Monitoring in and around Mojave Network Parks**

34
35 Park Resource Management Plans and the NPS Natural Resource Inventory and Monitoring
36 Guidelines (NPS-75) guide current monitoring activities at the network parks (NPS 1992b).
37 Monitoring of vital signs identified through park and network level vital signs scoping
38 workshops should be complementary to existing monitoring programs already in place in
39 network parks. The existence of current and past monitoring or data that may serve as the basis
40 for long-term monitoring in parks related to high priority or initially 'selected' MOJN vital signs
41 is indicated in Table 19. Historic and current monitoring activities occurring within network
42 parks have been initially documented in the NPS I&M program Dataset Catalog database.

Table 19. Availability of historic (H)(≥ 5 years ago) or current (C) monitoring data related to high priority vitals signs for Mojave Network park units.

MOJN Vital Sign	DEVA	GRBA	JOTR	LAME	MANZ	MOJA	PARA
Groundwater dynamics and chemistry	H/C		H/C				
Surface water dynamics	H/C	C		C			
Surface water chemistry	H/C	C		H/C			
Occurrence of invasive plants – status and trends ^a				C			
Occurrence of invasive plants – early detection				C			
Air chemistry – ozone	H/C	H/C	H/C	H/C			
Air chemistry – visibility and particulates	H/C	H/C	H/C				
Air chemistry – wet and dry deposition	H/C	H/C	H/C				
Weather – basic meteorology	H/C	H/C	H/C	C		H/C	
Riparian communities		C		C ^b			
[Riparian] bird communities	C ^c	C ^c	H/C ^c	H/C ^c		C ^c	
Visitor use, visitor satisfaction, visitation	H/C	H/C	H/C	H/C	C	H/C	
Soil chemistry and nutrient cycling			C				
Soil hydrologic function							
Soil erosion and deposition				C ^d			
Soil disturbance				C ^d			
Biological soil crust dynamics							
Vegetation change	C ^e	C	C ^e	C ^e		C ^e	
At-risk populations				C			
Federal T&E species	H/C		H	H/C		C	
Cave and karst processes		C					
Land use, land cover, and landscape pattern							
Bighorn sheep	H	H/C	H/C	H/C		H/C	
Fire and fuel dynamics	H/C	H/C	H/C	H/C		H/C	H/C
Cultural landscape condition							
Reptile communities							
Small mammal communities							

^a All parks report the number of acres of invasive species ‘contained’ related to GPRA Goal Ia1B.

^b Associated with spring restoration.

^c Landbird monitoring primarily conducted in parks through the Great Basin Bird Observatory, Point Reyes Bird Observatory, U. S. Geological Survey (N. Am. Breeding Bird Survey), or state wildlife agencies (NV raptor surveys) – some focus on riparian habitats. LAME is the only network park with a MAPS (Monitoring Avian Productivity and Survivorship Program) station.

^d Represents a project approved for funding titled, “Monitoring protocols for soil stability at Lake Mead National Recreation Area” – see description below.

^e A total of 921 long-term vegetation monitoring plots associated with the U. S. Forest Service, Forest Inventory and Analysis program are contained within DEVA (N=553), JOTR (N=127), and MOJA (N=241) and it is assumed some plots are located within LAME. It is unknown how many of these plots have associated data.

In addition, network staff worked with Lake Mead National Recreation Area to provide assistance in their on-going effort to document a large body of resource data including, but not limited to, species monitoring, natural resources, cultural resources, and infrastructure. As in many park units, available data are in many forms and formats which don't lend themselves to efficient querying or summarizing and assembling these data into organized bodies that provide useful information requires several steps. The process varies depending on the state of the data, the history of its management, and its source media types. The general process that has been followed at LAME is provided in Figure 25. To date, resource/monitoring projects that have been fully documented and organized at LAME are springs (fifteen sources of spatial and tabular data relating to area of interest), annual bald eagle population surveys (1981-2005), and desert tortoise monitoring and research projects (13). Time required by one individual to complete documentation and organization of data related to a particular resource is estimated to be approximately three months (M. Sappington *pers. comm.*). Park staff are currently working on data related to wild horses and burros and plan to initiate work on peregrine falcon, desert bighorn sheep, abandoned mines, botany and cultural resource data.

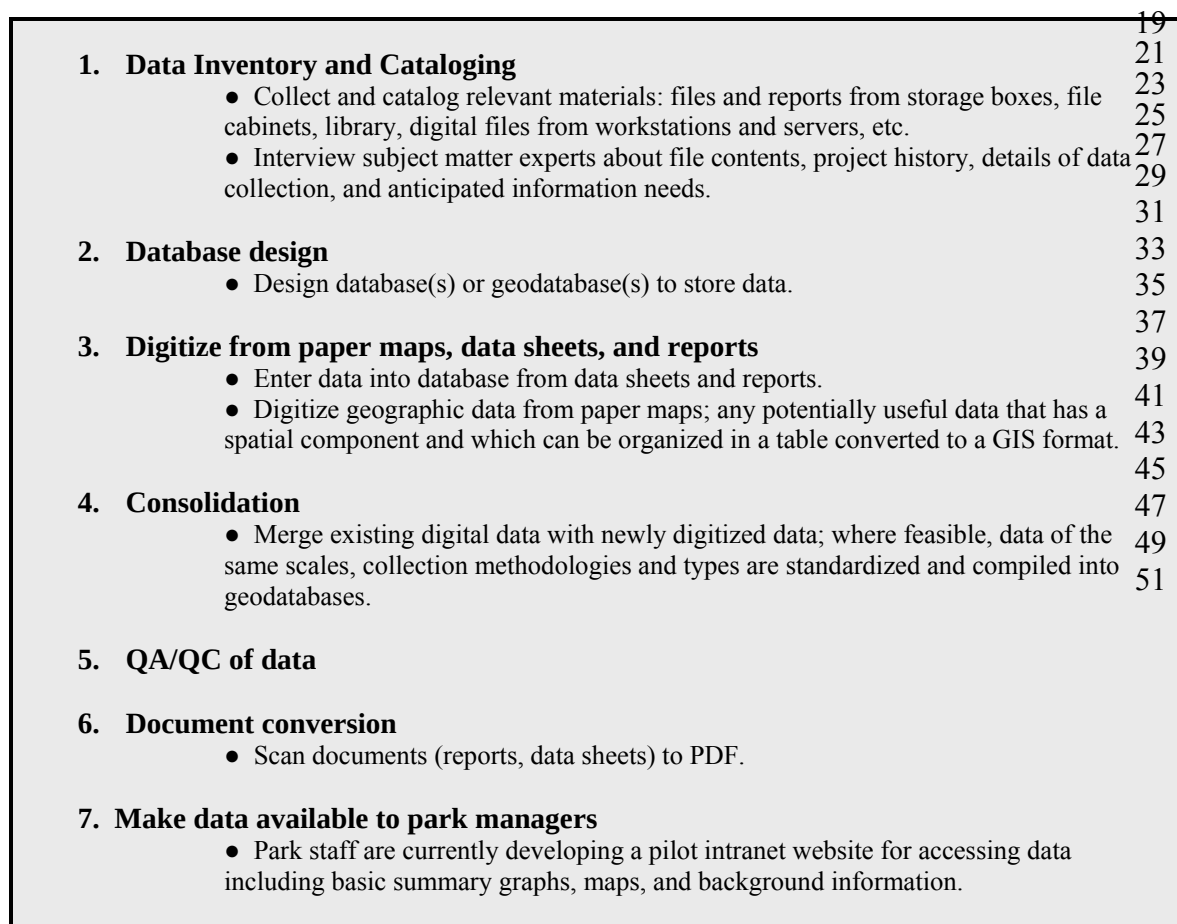


Figure 25. Data mining and documentation process followed at Lake Mead National Recreation Area, 2005.

The most significant network-wide monitoring being conducted is related to air quality and weather. DEVA, GRBA and JOTR have long-term, on-site, air quality monitoring stations supported by the NPS. Types of monitoring at these sites include ozone monitoring through the NPS Gaseous Pollutant Monitoring Network (GPMN), wet deposition monitoring of atmospheric pollutants by the National Atmospheric Deposition Program (NADP), dry deposition monitoring of atmospheric pollutants by the Clean Air Status and Trends Network (CASTNet), and visibility monitoring through the Interagency Monitoring of Protected Visual Environments (IMPROVE) Program (Figure 26). Additional information related to air quality monitoring and the monitoring history associated with NPS-administered sites in individual network park is available in Appendix E.

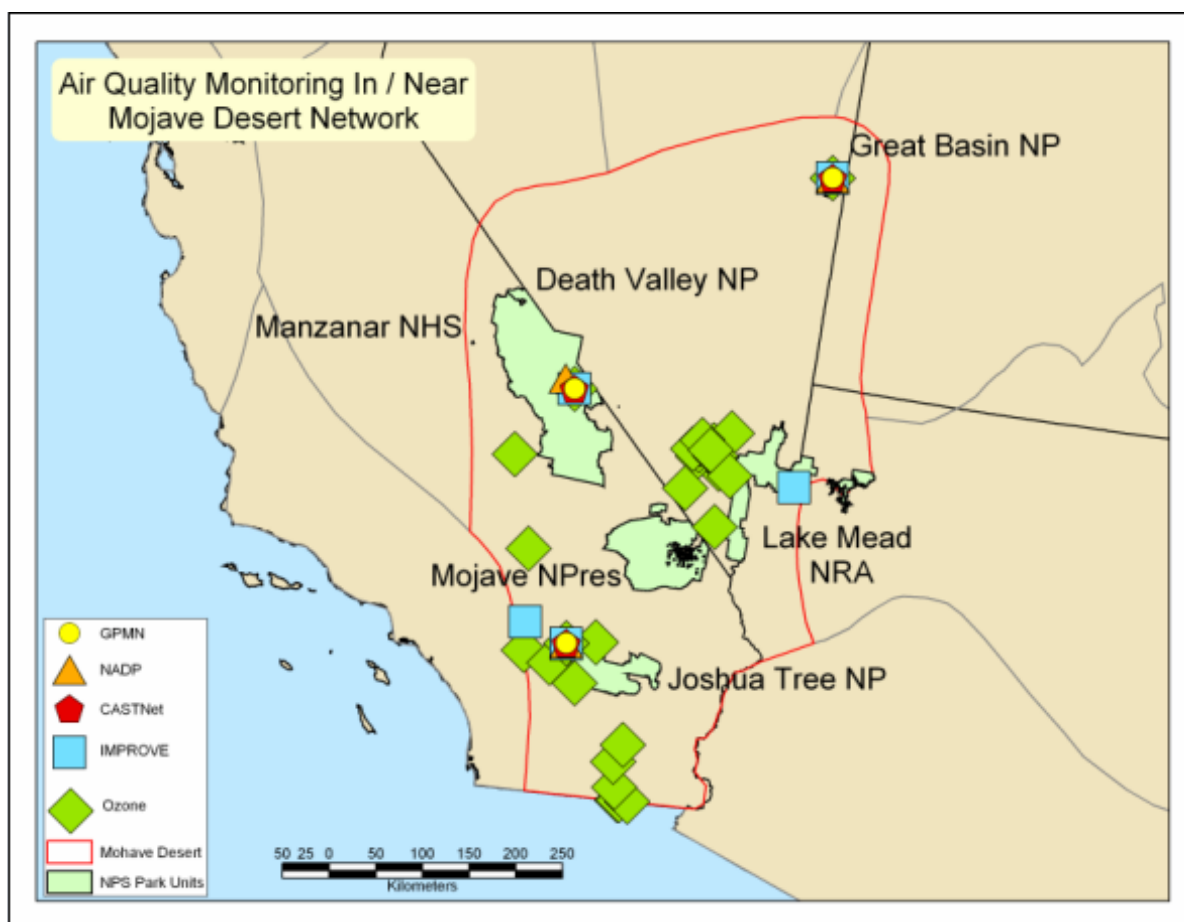


Figure 26. Air quality monitoring in the Mojave Desert Network (GPMN=NPS Gaseous Pollutant Monitoring Network for ozone; NADP= National Atmospheric Deposition Program; CASTNet= Clean Air Status and Trends Network; IMPROVE=Interagency Monitoring of Protected Visual Environments; Ozone=ozone monitoring by States).

Weather data (daily minimum and maximum temperature, 24-hour precipitation total, and snowfall) collected in and around network parks with the longest period of record is available through the National Weather Service Cooperative Observer (COOP) Program. The goal of this nationwide volunteer program is to provide observational meteorological data required to define the climate of the United States and to help measure long-term climate changes. Data collection

1 is conducted by NPS staff at DEVA and GRBA. The period of record for COOP sites in and
2 around park units ranges from 31 to 113 years (Refer to Table 8). Additionally, DEVA and
3 GRBA have recently become long-term monitoring sites for climate with the U.S. Climate
4 Reference Network, a program administered by the National Oceanic and Atmospheric
5 Administration.

6
7 No significant monitoring of soils or other geologic features has occurred in network parks.
8 Some monitoring of selected parameters (e.g. radon, visitation) in caves at GRBA occurs and
9 some monitoring of fault movements is underway at DEVA. At the LAME vital signs workshop
10 in 1999, the parameter most highly recommended for monitoring related to ecosystem health and
11 sustainability was the condition of desert soils and ground disturbances. During 2000 and 2001,
12 the U. S. Department of Agriculture, Jornada Experimental Range Station took soils
13 measurements at over 30 locations within areas of existing disturbances related to burro grazing
14 and illegal off-road vehicle tracks. The purpose of this work was to evaluate the use of soils
15 indicators developed in other locations for their potential use as indicators within LAME. These
16 included: soil stability, chlorophyll content (a microbiotic crust indicator), penetrometer
17 resistance, and gravel cover. Soil particle size analysis was also completed for each location.

18
19 Initial results provided information on the relevance of possible indicators of overall soils
20 condition and some indication of the relative sensitivity of different soils to disturbance.
21 Additional funding has been received by LAME to expand this initial work, titled "Monitoring
22 protocols for soil stability at Lake Mead National Recreation Area" with the following
23 objectives:

- 24
25 1. Develop a cost-effective, soils-based monitoring framework that is compatible with local and
26 national protocols (ESI and TEUI), and can be scaled up from the plot to the landscape level.
 - 27 a. Develop state and transition conceptual models for each Ecological Site or equivalent
28 unit in the county.
 - 29 b. Use these models to identify critical processes and properties for monitoring.
 - 30
31 2. Develop soil indicators of these processes and properties that builds upon soil indicator work
32 already complete by NPS, Geologic Resources Division.
 - 33 a. Determine how disturbance and climate change modifies and/or maintains soil
34 characteristics or processes, and which of these characteristics/processes need to be
35 monitored.
 - 36 b. Develop cost-effective methods to measure the selected soil characteristics.
 - 37 c. Determine the extent to which soil indicators can be used to predict plant responses.
 - 38
39 3. Develop a monitoring program for a pilot area that addresses a suite of management options.
 - 40 a. Revise the state and transition models based on research in objective 2.
 - 41 b. Complete an assessment using the national interagency protocols.
 - 42 c. Select and apply indicators based on the assessment and models for each ecological
43 site occurring in the pilot area.
- 44
45
46

4. Develop a “schoolyard” ecological monitoring program based on the soil indicators generated by this project.
 - a. Develop and adapt a minimum of 15 environmental science education modules that directly address Nevada State education standards.
 - b. Fund and train a local environmental science educator to establish pilot schoolyard monitoring programs at a minimum of 12 schools.
 - c. Provide ongoing scientific and curriculum support for the educator for the duration of the project (NPS 2002).

Existing monitoring involving park staff related to focal species and communities varies by park unit. Generally monitoring conducted by or in cooperation with park staff is geared toward reporting to various [GPRA] management goals and often is focused on special status species (Appendix Q), non-native plant and animal species (Appendix R), and riparian communities. Frequently, data collection efforts have been sporadic and documentation is inadequate. The most significant monitoring occurring in network parks relates to desert fish populations (DEVA, GRBA, LAME), and the desert tortoise (LAME, MOJA). Monitoring of vertebrate species and communities outside of selected special status species is generally focused on birds, selected big-game species, and non-native species. Bighorn sheep populations (e.g. population size, movements) are monitored in almost all network parks either by park staff (GRBA), state wildlife agencies (LAME and MOJA), or other cooperators (JOTR). Additionally, significant time and effort has been spent by parks managers and others to quantify wild horse and burro population size within parks and track progress toward target population goals (e.g. zero in some park units). Monitoring of bird populations within parks is generally conducted by non-NPS organizations such as the Point Reyes Bird Observatory and Great Basin Bird Observatory each of which has bird point-count stations within network parks. Often these sites are associated with riparian habitats (Figure 27).

Some monitoring of native plant communities is conducted in association with the NPS fire program but generally represents monitoring of ≤ 3 years in duration (post-fire), is limited in scope, and parameters measured are not standardized across parks. In 2003, Lake Mead National Recreation Area initiated the “Weed Sentry Program”, a monitoring program whose goal is the early detection and eradication of invasive plant species. The program includes systematic survey of areas, such as riparian zones, rights of way and other disturbed areas with a high probability of invasion by high priority invasive plant species, mapping and characterizing any existing stands of non-native plants, and early treatment of incipient populations. Data collected includes location, date, species present, number of individuals, patch size, cover classification, treatment, and weather data. Also worthy of note is a recent evaluation of riparian plant communities at GRBA relative to potential future monitoring considerations (e.g. baseline data and mapping, ability of selected indicators to predict change, etc.). This project was conducted by the U. S. Geological Survey, Forest and Rangeland Science Center with the following objectives: 1) map riparian vegetative communities to a finer extent than had been done either by past GAP projects or previous researchers (Smith et. al. 1994); 2) within dominant geomorphic and vegetative strata, provide a monitoring baseline of hydrogeomorphology; structure, composition and function of upland- and riparian-associated vegetation; and potentially management-sensitive edaphic properties; 3) test whether instream conditions and physiographic covariates clearly predicted accompanying vegetation patterns across the four target streams.

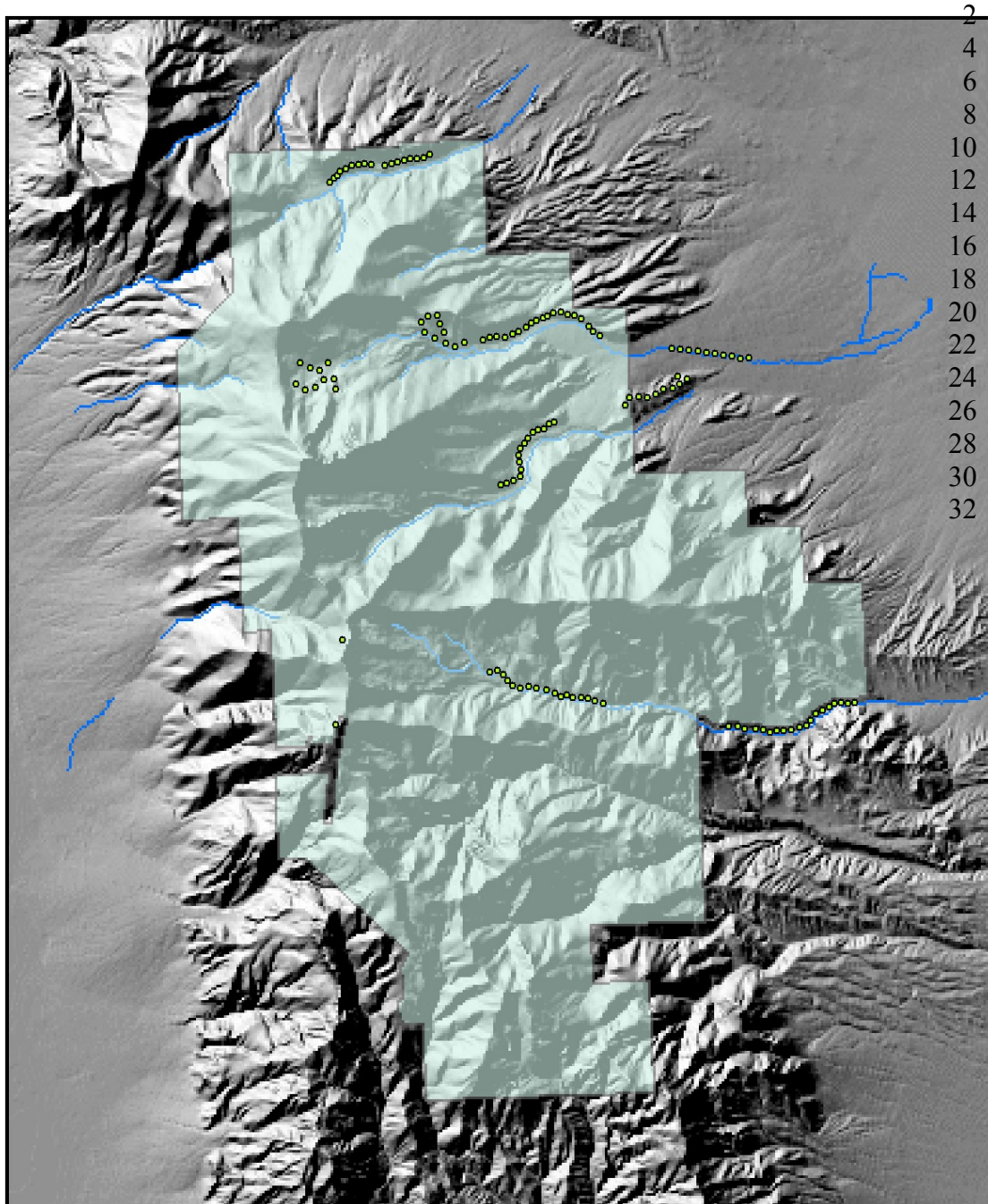


Figure 27. Breeding landbird monitoring network point-count locations within Great Basin National Park, established through the Nevada Partners In Flight/Great Basin Bird Observatory, Nevada Bird Count (2002 – present). (Represents 7 transects; 10 points per transect spaced 300m apart; Approximately 130-180 transects established state-wide.)

Secondarily, the park wanted, to the extent possible, to determine the magnitude of change in stream conditions that may be detected with different levels of sampling intensity (Beever et. al. 2005). This work will serve as a good baseline for future monitoring of riparian communities in this park.

The most significant monitoring within network parks related to human use and ecosystem processes is related to park visitation and alteration of fire processes. Almost all parks document the location, size, and intensity of fires within park boundaries. Several parks are currently developing fuels maps and some are conducting research on post-fire recovery of native plant communities that may serve as a baseline for future monitoring. Visitation is currently monitored in all network parks through the NPS Public Use Statistics Office. This office produces for parks a variety of reports ranging from monthly visitation summaries to annual statistical abstracts and in-depth analyses examining changes in visitation over decades, current trends in visitation, and short-term visitation projections. Protocols used to conduct monitoring are available on-line at <http://www2.nature.nps.gov/npstats> (Accessed 30 August 2005). Level of visitor satisfaction in parks is monitored through the Visitor Services Project developed in 1998, by the NPS Social Science Program. Visitor survey cards are used annually to systematically measure and report performance toward GPRA goals IIa1 (visitor satisfaction) and IIb1 (visitor understanding and appreciation).



Figure 28. Superintendent, Mary Martin and Dr. David Miller, USGS, RVDE at Mojave National Preserve. (NPS Photo)

Also worthy of note is the U. S. Geological Survey, Recoverability and Vulnerability of Desert Ecosystems Program (RVDE), established in 1998 in cooperation with desert land managers (Figure 28). RVDE is a subsidiary project of the Priority Ecosystems Science (PES) program, which integrates U. S. Geological Survey research in specific, critical ecosystems, including the Chesapeake Bay, Greater Yellowstone, Salton Sea, and Mojave Desert. The goal of PES is to provide in-depth scientific information on the ecological framework that underlies environmental responses. Within the Mojave Desert, RVDE seeks to understand the various processes that characterize the Mojave Desert ecosystem, model the vulnerability and/or recoverability of selected ecosystem components, and provide this information to land managers to facilitate a land management approach that incorporates a comprehensive understanding of the system of interest. In addition to the focus of this program being Mojave National Preserve, RVDE provides significant opportunities for partnership and shared knowledge across the network. Table 20 provides an overview of current project components that will be the program focus for the next 5 years.

In addition to monitoring efforts by the NPS and others inside park boundaries, a wide variety of monitoring efforts have, and continue to, occur in the Mojave Network outside of park boundaries. These efforts are aimed at numerous natural resources including wildlife, vegetation, air quality, water quality and weather conditions, and many of these efforts may provide opportunities for partnership with the MOJN (Table 21).

Table 20. Components of the U. S. Geological Survey, Recoverability and Vulnerability of Desert Ecosystems Program (From Bedford et. al. 2004).

RVDE Program Component	Project Component Description
Vegetation Recovery	Evaluation of natural vegetation recovery rates under varied soil and climate conditions on sites disturbed historically (old town sites) and with little or no post-abandonment disturbance.
Vegetation Dynamics	Repeat measurements of Beatley long-term monitoring plots (N=66) established in 1963, to understand the effect of climatic fluctuations on ecological processes, as well as evaluate the ability of disturbed areas to recover naturally.
Regional Vegetation Processes	Examination of how plant establishment and performance are influenced by factors such as soil moisture, soil texture, nutrient availability, and ground cover.
Vegetation Cover	Investigation of vegetation mapping methods using both on-the-ground measures and remote sensing.
Restoration Cost-Benefit Analysis Tool	Evaluation of the 'success' and costs associated with implementation of common restoration practices.
Distribution and Recovery of Biological Soil Crusts	Development of methods for predicting the occurrence of biological soil crust species at specific sites, as well as predicting the resistance and resilience of these organisms after soil surface disturbances.
Seed Dispersal and Establishment of Perennial Vegetation	Examination of seed dispersal patterns, seed dispersal mechanisms (e.g. wind, rodents, etc.), seed survival, etc. for perennial plant species - an important determinant of recovery in desert systems.
Soil Compaction Effects on Plant Growth	Evaluation of soil compaction on germination, establishment, and growth of common Mojave Desert plant species.
Vehicle Routes as Vectors for the Spread of Exotics	Examination of the introduction and spread of invasive plant species along roadways.
Soil Compaction Processes	Examination of and prediction of soil vulnerability, under wet and dry conditions, to soil compaction.
Soil-Texture Modeling	Evaluation of and modeling of soil texture (size distribution of sediments in surficial materials and vertical stratifications that occur as soils develop over time) at a landscape-scale.
Soil Surface Erosion by Wind	Determination of the vulnerability of different soils to wind erosion and rate of recovery post-disturbance.
Landscape Mapping and Modeling	Mapping of surficial geology and examination of the relationship between surficial geology and distribution of vegetation.
Proliferation of Roads	Mapping of road system at Mojave National Preserve over time.
Monitoring in the Mojave Desert	Open file report documenting the variety of monitoring activities being conducted across the Mojave Desert.

Table 21. Existing monitoring related to high priority network vital signs being conducted by non-NPS entities at a regional scale (or larger) in the Mojave Network.

MOJN Vital Sign	Agency(s) Involved/Potential Partners ^a	Sites In Parks ^b
Groundwater dynamics and chemistry	California State Water Resources Control Board-Groundwater Ambient Monitoring and Assessment, Nevada Division of Water Rights, U. S. Geological Survey	
Surface water dynamics	<i>U. S. Geological Survey-National Stream Gauging Program</i>	Y
Surface water chemistry	California State Water Resources Control Board-Surface Water Ambient Monitoring and Assessment, CA Department of Health and Safety (public water supply), Nevada Division of Environmental Protection, U. S. Environmental Protection Agency, U. S. Geological Survey, Utah State University-National Aquatic Monitoring Center	
Occurrence of invasive plants – status and trends	U. S. Geological Survey	
Occurrence of invasive plants – early detection		
Air chemistry – ozone	California Air Resources Board, Environmental Protection Agency, <i>NPS Gaseous Pollutant Monitoring Network</i>	Y
Air chemistry – visibility and particulates	California Air Resources Board, Environmental Protection Agency, <i>Interagency Monitoring of Protected Visual Environments program</i>	Y
Air chemistry – wet and dry deposition	California Air Resources Board, <i>Environmental Protection Agency-Clean Air Status and Trends Network, National Trends Network</i>	Y
Weather – basic meteorology	California Air Resources Board, <i>National Oceanic and Atmospheric Administration, U. S. Geological Survey, Natural Resource Conservation Service-Snow Surveys</i>	Y
Riparian communities		
[Riparian] bird communities	<i>Great Basin Bird Observatory-Nevada Bird Count, Point Reyes Bird Observatory, U. S. Geological Survey-North American Breeding Bird Survey, National Audubon Society-Christmas Bird Count, Institute for Bird Populations-MAPS, Nevada Department of Wildlife, California Department of Fish and Game</i>	Y

^a Agencies/programs in italics represent regional (or larger scale) monitoring with data collection points within parks.

^b Monitoring programs being conducted on a regional (or larger) scale that have data collection sites within parks are also indicated in Table 19.

Table 21. (Con't.)

MOJN Vital Sign	Agency(s) Involved/Potential Partners ^a	Sites In Parks ^b
Visitor use, visitor satisfaction, visitation	<i>National Park Service-Visitor Services Program</i>	Y
Soil chemistry and nutrient cycling	U. S. Geological Survey	
Soil hydrologic function	Bureau of Land Management, U. S. Geological Survey, U. S. Department of Agriculture, Natural Resource Conservation Service	
Soil erosion and deposition	Bureau of Land Management, U. S. Department of Agriculture, U. S. Geological Survey, Natural Resource Conservation Service	
Soil disturbance	Bureau of Land Management, U. S. Department of Agriculture, U. S. Geological Survey	
Biological soil crust dynamics	U. S. Geological Survey	
Vegetation change	Bureau of Land Management, <i>U. S. Forest Service-Forest Inventory and Analysis program</i> , U. S. Geological Survey, California Department of Parks and Recreation-Inventory, Monitoring and Assessment program, <i>Desert Botanical Garden</i>	Y
At-risk populations	CA Department of Fish and Game, Nevada Department of Wildlife, California Department of Parks and Recreation-Inventory, Monitoring and Assessment program, California Native Plant Society	
Federal T&E species	<i>U. S. Fish and Wildlife Service, CA Department of Fish and Game, Nevada Department of Wildlife</i>	Y
Cave and karst processes		
Land use, land cover, and landscape pattern	NASA, U. S. Environmental Protection Agency, U. S. Geological Survey-Land Cover Trends project	
Bighorn sheep	<i>CA Department of Fish and Game</i> , Nevada Department of Wildlife,	Y
Fire and fuel dynamics	Bureau of Land Management, NPS-Fire Monitoring Program, U. S. Forest Service, <i>U. S. Geological Survey</i>	Y
Cultural landscape condition		
Reptile communities	U. S. Geological Survey	Y
Small mammal communities		

^a Agencies/programs in italics represent regional (or larger scale) monitoring with data collection points within parks.

^b Monitoring programs being conducted on a regional (or larger) scale that have data collection sites within parks are also indicated in Table 19.

5.1.1 Water Resource Monitoring in Mojave Network Parks

Prior to the MOJN Water Resources Monitoring Workshop in April 2005, a survey of water monitoring projects was conducted for the parks in the Mojave Desert Network primarily through interviews with key personnel. The following resource specialists were contacted and interviewed regarding their knowledge of on-going monitoring projects related to water quality and water quantity:

Park Code	Park Water Resource Contact(s) ^a
DEVA	Terry Fisk, Hydrologist, Mel Essington, Geologist and Linda Manning, Wildlife Technican
GRBA	Gretchen Baker, Ecologist
JOTR	Luke Sabala, Physical Scientist and Margaret Adams, Biological Technician
LAME	Bryan Moore
MANZ	Frank Hays, Superintendent
MOJA	Anne Kearns, Hydrologist
PARA	Kari Yanskey, Botanist

^aTom Culhane, Regional Hydrologist, Pacific West Region and Debra Hughson, Science Advisor, Mojave National Preserve, provide support and expertise to all network parks related to water resource issues.

Information regarding on-going water monitoring projects being conducted within parks is provided in Table 22. Water monitoring in most Mojave Desert Network parks is generally limited. In stark contrast, Lake Mead is one of the most intensively monitored lakes in the country (Bryan Moore, *pers. comm.*) due to its importance as a regional source of drinking water, recreational value, and designation as critical habitat for several special status fish species. In addition to identification of existing water-related monitoring in network parks the MOJN developed and prioritized monitoring objectives for water-related vital signs at the 2005 MOJN Water Resources Monitoring Workshop. Monitoring objectives are presented in Chapter 3.

Table 22. Water resource monitoring (quality and quantity) within Mojave Network parks.

Park Code	Organization	Location	Parameters	Frequency
DEVA	National Park Service	5 wells in Darwin drainage, 2 wells in Scarcobatus flats, 5 wells in Furnace Creek area, 2 wells at Death Valley Junction, 1 well on Amargosa river	Groundwater level	Monthly
	National Park Service	Devils Hole	Water level	15 minute intervals
	National Park Service	Travertine springs, Texas spring, Nevares Spring, Furnace Creek Inn Tunnel	Water Flow	15 minute intervals
	National Park Service	Potable water supplies	Water quality requirements	Unknown
	U.S. Geological Survey	Devils Hole	Comprehensive suite of parameters	Irregular intervals
	U.S. Geologic Survey	Bond Gold Mine (now called Bullfrog Gold mine) 2 to 4 of 9 wells	Groundwater levels	Monthly
	U.S. Geological Survey	Network of 19 wells related Yucca Mtn	Groundwater levels	Quarterly
	Desert Research Institute	Park Springs Inventory (estimated at 500 springs)	Dissolved oxygen, pH, conductivity, temperature, spring physical and biotic characteristics	Ongoing inventory
GRBA	U. S. Geological Survey	Lehman Creek, Strawberry Creek, Rowland Springs, Baker Creek, , Snake Creek (4 sites), South Fork Big Wash, Decathlon Canyon, Williams Creek, and Shingle Creek	discharge and temperature; dissolved oxygen, conductance, pH	Stream gauges are continuous, water quality is twice a year
	National Park Service	Mill, Strawberry, Upper Snake, South Fork Big Wash, South Fork Baker (streams where Bonneville Cutthroat trout have been reintroduced)	Water chemistry	periodically
	National Park Service	425 perennial springs and seeps	Temperature, pH, conductance, physical and biotic descriptions	Spring inventory conducted in FY03-04 (potential baseline for monitoring)

Table 22. (Con't.)

Park Code	Organization	Location	Parameters	Frequency
JOTR	US Geological Survey	Oasis of Mara	Groundwater depth	Unknown
LAME	National Park Service	Lake Mead (Boulder Beach, Hemenway Harbor, Box Car Cove, Sandy Cove, James Bay, Teakettle Cove, Middle Point Cove), Lake Mohave (Katherine's Landing, Six Mile Cove)	E. Coli, fecal Coli, fecal streptococci	After every major summer holiday (Memorial Day, July 4 th , Labor Day) and every two weeks in between
	National Park Service	Parkwide	Secchi depths	4 times annually
	National Park Service	Marinas on Lake Mead	Zebra mussels	Monthly
	National Park Service	Gregg's Basin and marinas	New Zealand Mud Snail	Intermittent (during dives)
	National Park Service	Lake Mead coves	Aquatic plants including invasives	Intermittent
	National Park Service	Grand Canyon-Parashant National Monument	Temperature, dissolved oxygen, flow, site observations on water, vegetation and wildlife	On-going spring inventory in 2004 and 2005
	National Park Service (beginning in January, 2005)	Overton arm of Lake Mead, Virgin Basin	Dissolved oxygen, pH, temperature, turbidity, conductivity, Chlorophyll, (hydrolab profile),	Two floating platforms conduct water quality profiles every six hours
	U. S. Geological Survey/National Park Service (beginning in 2005)	Boulder Basin (plan to expand lake-wide)	Endocrine disruptors in fish	Unknown
	U. S. Geological Survey	Boulder Basin and Las Vegas Wash	Dissolved oxygen, pH, temperature, turbidity, Chlorophyll, conductivity (hydrolab profile), secchi depth	Two floating platforms conduct water quality profiles every six hours
	U. S. Geological Survey	Lake Mead (Callville Bay, Hemenway Harbor), Lake Mohave (Katherine Landing, North Telephone Cove)	Volatile organic compounds	High use times (three per summer)
	U. S. Geological Survey	Rogers Spring, Blue Point Spring, Virgin River	Surface water flow	Continuous
	Lake Mead Water Quality Forum/ Algae Task Force (multi-agency)	Lake Mead (Boulder Basin and Overton Arm) and Lake Mohave	Toxic algae (<i>Cylindropermopsis</i>), chlorophyll A, Hydrolab profile, air temperature, wind speed, secchi depth	Bi-weekly from July thru October

Table 22. (Con't.)

Park Code	Organization	Location	Parameters	Frequency
LAME	Nevada Department of Environmental Protection	Boulder Basin (Las Vegas Wash)	Perchlorate, selenium and additional parameters	Unknown
	Southern Nevada Water Authority	Boulder Basin (Las Vegas Wash)	Comprehensive water quality suite of parameters	Daily (basic parameters), every two weeks (additional parameters)
	Southern Nevada Water Authority	Virgin and Muddy Rivers near Park Boundaries	Hydrolab profiles	Unknown
	City of Las Vegas	Las Vegas Wash and into Boulder Basin	Comprehensive water quality suite of parameters	Every two weeks, additional parameters monthly
	Bureau of Reclamation	Overton Arm, Virgin and Muddy Rivers, Virgin Basin, Boulder Basin	Hydrolab profiles, chlorophyll, E. Coli, fecal coli, perchlorate	Every two weeks
MANZ	City of Los Angeles	Water wells onsite	Groundwater depths	Unknown
MOJA	National Park Service	Water quality of Lake Tuendae	Temperature, DO, pH, conductivity	Hourly
	National Park Service	Spring inventory in park	Cations, anions, isotopes (some)	Ongoing inventory
	Molycorp Inc.	Groundwater monitoring at Mountain Pass Mine	Contaminants	Unknown
	Viceroy Company	Viceroy Mine at Castle Peak	Water levels in Lanfair Valley, discharges into Paiute stream	Quarterly
	Barrick Gold	Coliseum mine wells and pitlakes	Water levels in 8 wells and 2 pit lakes	Unknown
	Morningstar Mine	Morningstar Mine wells and discharges	Contaminants	Unknown
PARA	NONE KNOWN			

Chapter 2. Conceptual Ecological Models

2.1 Introduction

A conceptual model of the system of interest is considered a critical element in the design of a scientifically credible monitoring program and management of ecological systems. An ecological conceptual model is a visual or narrative summary that describes current understanding of system dynamics, identifies important processes and illustrates connections between indicators and ecological states or processes. Development of conceptual models helps in understanding how the physical, chemical, and biological elements of a monitoring program interact, promotes integration and communication among scientists and managers from different disciplines, and provides justification for the choice of indicators (Gross 2003). The conceptual model for the Mojave Network does not attempt to explain all possible relationships or identify all possible components of the ecosystem but instead simplifies reality by presenting information most relevant to the preservation of natural resources within the Mojave and Great Basin Deserts (Margoluis and Salafsky 1998).

The objectives of the Mojave Network conceptual model(s) are to:

- Formalize current understanding of ecosystem functioning and structure (cumulative, holistic, multi-scale) in the Mojave Network.
- Identify system drivers, major system stressors, attributes affected and impacts at a broad scale.
- Identify relationships between attributes of interest and indicators.
- Aid in defining relevant spatial and temporal scales for monitoring.
- Aid in the interpretation and presentation of monitoring data.
- Serve as a means of communication between the NPS and others representing a common understanding of the connections between management decisions and natural systems (DeAngelis et. al. 2003).

No one model form describes an entire system adequately. Model generality is needed to characterize broad-scale influences and relationships among park resources. Model specificity is required to identify detailed relationships and components in the system that can be effectively monitored and subsequently managed. Consequently, both broad-scale models and specific models are needed to adequately represent ecological systems having the spatial scale of national parks in the Mojave Network. The models presented herein are developed from published literature, NPS staff knowledge and USGS staff knowledge. They omit many important details that will be included in future more detailed models, in order to emphasize the landscape-level features of the ecosystem and the most fundamental ecosystem processes and forcing functions. We develop a general overall conceptual model and conceptual models of several components, with the goal of providing insights for prioritizing and selecting vital signs. The simple general model describes factors and processes controlling the structure and function of ecosystems, and the component models describe key aspects of ecosystem dynamics with particular implications for vital signs monitoring.

Models presented are intended to represent ecosystem components, processes, functions and responses to disturbance or variation in the Mojave and Sonoran Desert Ecoregions and the southern part of the Great Basin Ecoregion, within which all park units of the network lie. This vast region is encompassed by the Basin and Range Physiographic Province and is sometimes discussed as a unit (Brussard et. al. 1998). Transitional margins with the Colorado Plateau desert and Sonoran desert are also considered where appropriate for the Grand Canyon-Parashant and Lake Mead units, as well as, the Sierran Ecoregion with respect to Manzanar National Historic Site.

Contemporary ecological theory suggests that conservation should emphasize the maintenance of *ecosystem processes* because ecosystems and ecosystem components are inherently dynamic both in space and in time and thus cannot be conserved as static entities (Pickett et. al. 1992, Christensen et. al. 1996). The process-based perspective described for ecosystems is equally important to other levels of organization including populations, species, and landscapes. Ecosystems are connected with other ecosystems by flows of materials, energy, and organisms in spatially structured landscape mosaics (Turner et. al. 2001). Thus landscape-level considerations are encompassed in the ecosystem and are emphasized in our models, as are forcing functions external to the ecoregions under consideration.

Some of the most difficult aspects to incorporate into ecological models are the temporal and spatial variability on various scales of natural systems. Ecosystem processes depend on scales of time and space, and these dependencies are difficult to model in many cases. Table 23 provides some examples of how ecosystem attributes can be experienced in vastly different ways depending on the temporal scale considered; likewise, spatial scales influence perceptions and understandings of how the ecosystem functions. Ecosystem components (e.g. plants, animals, soils, etc.) respond to different scales such as different lengths of drought or intensities of rainfall, so scales and variability are fundamental to understand to predict ecological response. In addition, processes and components can vary spatially in complexly interacting ways. Many of these spatial and temporal scales are not explicit in the conceptual models we present below but must be considered in subsequent detailed models and in vital sign and monitoring design. In addition, it is important to understand that ecosystems are not static. There is a vital need for temporal data from the recent and distant past to allow us to evaluate the current condition and make best estimates of the path the ecosystem will take in the future.

2.2 Broad Ecosystem Models: Components and Processes

In broadest terms the components involved in ecosystem processes for any system include global climate, time, topography, parent material and a variety of potential biota which in turn affect regional atmospheric resources and conditions and disturbance regime, soil/water relations, and biological functional groups (Jenny-Chapin model as modified in Miller and Thomas 2004)(Figure 29). This model illustrates how ecosystem characteristics are determined by four interactive controlling factors, climate, soils-resource supply, major functional groups of organisms and disturbance regime (Miller and Thomas 2004). Ecological models in arid and semi-arid environments must capture the dynamics of water. The water budget is largely a function of climate, recent weather, topography, geology (soils and bedrock), and ecosystem

Table 23. Examples of highly divergent results and perceptions that result from sampling different temporal periods. Examples are examined from the perspective of a snapshot taken in August 2004, and examining current and historical conditions for the stated time period.

Attribute	Century	30 yr	5 yr	1 yr	summer	Daily	hourly
Rainfall	Wet	Pacific Decadal Oscillation	El Nino	drought	wet	Monsoon	flood events
Perennial plant health	positive	positive	negative	negative	positive	mid-day depression of photosynthesis	Photosynthesis
Small animal health	positive	positive	negative	negative	positive	Positive	?
Influence on fire	?	?	↑	↑	↓	↓	↓
Mountain-front spring	↑	↑	↓	↓	—	—	—
Temperature	↑	↑	↑	↑	—	—	↓
Snowpack	↓	↓	↓	↓	↓	↓	↓

components. Particularly important for most aspects of the ecosystem in the Mojave Network are the near surface soil moisture dynamics in which the available moisture is driven by spatial and temporal interactions with climate, vegetation, and soil (Noy-Meir 1973, Rodriguez-Iturbe 2000, Reynolds et. al. 2004). Availability of groundwater is key to riparian habitat, seeps, springs, lakes and river aquatic systems, and even features such as wet playas. These features are essential to phreatophytic vegetation by definition.

One direct consequence of aridity is low vegetative cover, which commonly leads to unstable materials at the surface that may limit or preclude use by soil biota. While some soil organisms may be adapted to moderately unstable materials, such as dunes, small changes in surface sediment fluxes, whether by wind or water, may have large effects on that part of the ecosystem, which may in turn affect nearby environments (e.g. sand dune mobilization).

This conceptual model will describe the important climatic regimes in the Mojave Network, as well as, describe how soil characteristics and processes are linked to landscape characteristics and processes. Inputs from the climate system are partitioned into recharge, runoff and infiltrated water stored in the near surface, and thereby provide water for different components of the ecosystem and make water available (or not) to the biotic system. These same processes will affect the surface sediment fluxes, and thus surface stability. Furthermore, we intend to portray the linkages between soil-biotic landscapes within the broader Mojave Network. Key in

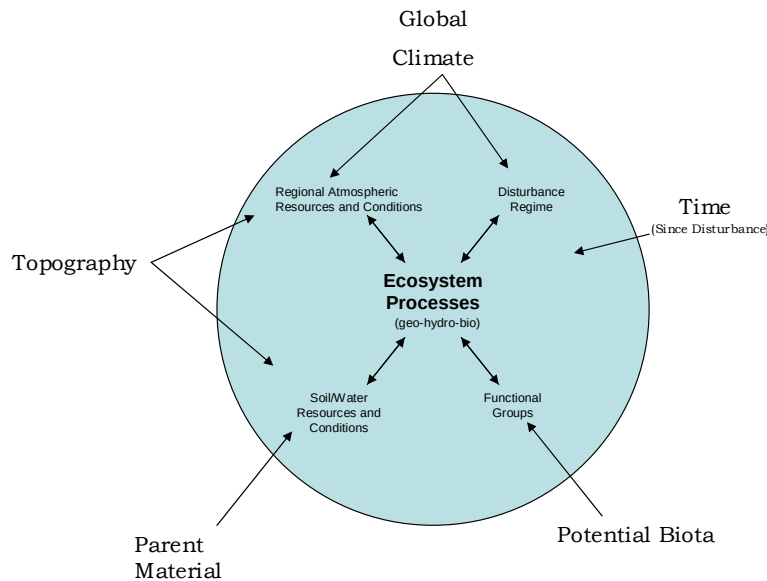


Figure 29. Modified version of the Jenny-Chapin model as revised from Miller and Thomas 2004. Soil and ecosystem processes are determined by five state factors: climate, organisms, relief, parent material and time since disturbance that affect interactive control factors including functional groups, soil/water resources, atmospheric resources and disturbance at the regional level and interact with ecosystem processes.

understanding ecosystem dynamics will be an understanding of the roles of climate variability, hydrologic interactions with soils, and adaptive strategies of biota to capitalize on spatially and temporally variable moisture and nutrient dynamics.

2.3 General Ecosystem Characteristics

Despite the term "desert", applied to both arid and semi-arid parts of the Mojave network, little of this region is covered by the archetypical desert landforms, sand dunes. Wooded, rocky mountains, shrub-covered rocky piedmonts, and playas are the common landforms. The resulting elevation gradients strongly influence ecosystem attributes because precipitation, temperature, and effective moisture availability follow the elevation gradients. The essential feature of these desert regions from an ecological point of view is the scarcity of water, whether fresh or saline, and whether materials are in saturated or unsaturated conditions. The fundamental hypothesis underlying this conceptualization of the region is that health and sustainability of arid-land ecosystems are dependent on maintaining the capacity of these systems to capture and retain water and nutrients (Whitford 2002). Westward, from the Mojave Network, lies a nearly continuous chain of high mountains that create the rain shadow that exerts the fundamental water deprivation for the ecoregions. The mountains effectively exclude all maritime influences.

1 Mojave Network parks actually occur in three distinctive desert biomes and some of the parks
2 are in proximity to other biomes such that the influence of those areas (or their components) can
3 be found in the parks. The Great Basin, Mojave and Sonoran desert biomes are contiguous,
4 running north to south across the arid landscapes of the southwestern United States. The current
5 boundaries among these and adjacent biomes have been delineated using climatic,
6 physiographic, hydrologic and biotic information (Shreve 1929, MacMahon 1979, Spaulding
7 1990, Grayson 1993). To the east of this vast area is the Colorado Plateau which influences the
8 biota of Grand Canyon-Parashant National Monument and Lake Mead National Recreation Area.
9 This delineation creates units that are useful for discussions to compare and contrast large
10 regions.

11
12 Great Basin National Park is distinguished from all the other parks in the network because it
13 exists entirely in a cold desert and because the land surface is almost entirely mountainous with
14 little representative valley habitat compared to all the other parks in the network. The Great
15 Basin is distinguished from the other parts of the network as being a cold desert because more
16 than half of the precipitation falls as snow (MacMahon 1979) and freezing conditions change soil
17 behavior and require different adaptations by organisms. The Great Basin is the furthest north
18 and has the highest average elevation of all North American deserts, further distinguishing it as
19 the coldest of the North American deserts. The Great Basin is further characterized
20 physiographically by the mostly north-south running mountain ranges. Most of the valley
21 bottoms in the Great Basin are above 1,219 meters (Grayson 1993). Most surface waters flow
22 into high land-locked valleys, hence the name Great Basin. The west, north and east
23 boundaries of the Great Basin are clearly defined by hydrologic (e.g. strictly interior draining
24 watersheds) and physiographic (Sierra Nevada, Range, Columbia Plateau, and Rocky Mountains,
25 respectively) characteristics, but the southern boundary with the Mojave Desert lies along an
26 irregular line that is defined by the occurrence of hot desert plant species – the creosotebush and
27 Joshua tree – that is distributed throughout the Mojave Desert and other warm deserts.

28
29 The Mojave Desert is the smallest of North American deserts and considered by some to be
30 transitional between the Great Basin and Sonoran Deserts. Certainly it is intermediate on an
31 environmental gradient from north to south, and with respect to elevation. The Mojave Desert
32 biome represents a northward gradient of decreasing temperature caused by northward decrease
33 of insolation and increasing average elevation. However, this desert also is home to a desert icon
34 – the Joshua tree – and as such is distinguished from all other deserts by this fact alone. The
35 basin and range physiography continues to run through the Mojave Desert, however, the ranges
36 tend to be less unidirectional than those found in the Great Basin. Death Valley National Park is
37 situated near the northern boundary of the Mojave Desert with many Great Basin species
38 dominating mountains and valleys at higher elevation and the northern extremes of the park.
39 Mojave National Preserve is situated in the south-central portion of the Mojave Desert with fairly
40 strong floristic influences from the Sonoran Desert at its southern boundaries. Lake Mead
41 National Recreation Area occurs on the northeast boundary of the Mojave Desert and has
42 representative portions of the Colorado Plateau biome on the high plateaus at the eastern edge of
43 the Recreation area. Just north and adjacent to LAME is Grand Canyon-Parashant National
44 Monument with low elevations represented by classic Mojave desertscrub, and upper elevations
45 fully represented by the Colorado Plateau vegetation.

1 The Sonoran Desert is the warmest of our North American deserts, having the lowest average
2 elevation with fewer large mountain ranges interspersed through the area. The Sonoran Desert
3 receives roughly 55% of its precipitation as winter rain and the other one-half as summer
4 precipitation. The summer portion increases as one moves further south or east. Although the
5 Sonoran Desert is most often depicted as the home to the giant saguaro cactus (*Carnegiea*
6 *gigantea*), or the palo verde (*Cercidium microphyllum* or *C. floridum*), they are absent in the
7 Mojave Network. Instead we delineate the boundary between the Sonoran and Mojave deserts by
8 the southern distribution of the Joshua tree.

9
10 Within the biomes of the Mojave Network, local systems diverge from regional patterns in some
11 places, many of these resulting in local endemic species or ecological attributes that require
12 special attention. Examples of local systems of high ecological importance are caves, dunes,
13 limestone cliffs, springs and streams, lakes, saline wet playas, and hot springs – some of which
14 are singled out in this general model and others that will be covered in future specific models.
15 Both regional and local systems are affected by input and output of resources and attributes
16 (examples include inflow and outflow of rivers, migratory animals, etc.) and external forcers
17 (dust, climate change, nutrient increases from pollution, invasive species). As a result, the
18 ecosystems cannot be considered without knowledge of the external forcings and connections.
19 Many of these forcings are directly controlled by, or strongly influenced by, humans. Examples
20 are controlled water flow on the Colorado River, air pollution from California coastal cities, past,
21 current and future drawdown of aquifers feeding springs in terminal basins, and altered
22 migratory waterfowl pathways caused by closing of natural and opening of artificial wetlands,
23 subsidized predators from man-made water sources and refuse, and increased fragmentation by
24 utility and travel corridors and recreational trails.

25 26 **2.4 Regional Climate and Role of Topography**

27
28 Desert conditions prevail across the Mojave Network because this region is in the rain shadow
29 created by the Sierra Nevada and the Transverse Ranges of California. As air masses leaving
30 coastal California meet the mountain ranges they rise and cool on the windward side of these
31 mountains, atmospheric moisture condenses and precipitates, while beyond the leeward side, air
32 masses descend and warm, reducing the potential for rainfall. The rain and snow that precipitates
33 on the mountains ultimately enters watersheds, some of which empty in desert basins; the
34 Mojave River is an example of such a watershed. Runoff in the mountains creates surface flows
35 that can transport large sediment loads, which are deposited downstream in the alluvial valleys
36 and playas. Under certain conditions, the sand may be mobilized by wind and becomes a critical
37 resource for sustaining active dune systems.

38
39 The rain shadow created by Sierra Nevada and Transverse Ranges, in combination with other
40 regional factors, creates a moisture gradient with drier conditions prevailing in the west grading
41 toward greater total annual precipitation in the east. In the west, precipitation mostly results from
42 regional winter storms originating over the North Pacific Ocean. Toward the east, there is
43 increasing likelihood of summer precipitation resulting from localized convective storms or the
44 remains of large tropical depressions moving northward from the Gulf of California and the
45 tropical Pacific Ocean.

1 During winter, several gradients related to freezing temperatures are strong determinants of
2 desert ecosystems (Figure 30). In general, winter temperatures decrease with increasing elevation
3 and increasing latitude in the Mojave Desert and Great Basin, but this pattern is complicated by
4 the closed basins characteristic of the Basin and Range physiographic province. During
5 nighttime, cold air drains from the surrounding mountains, descends, and accumulates around
6 playas, creating an atmospheric inversion of cold air under warmer air. As a result, low
7 temperatures frequently increase with increasing elevation above playas, then decrease toward
8 the tops of mountain ranges. This temperature inversion can affect the elevational distribution of
9 plants, but may disappear toward the northern Great Basin due to strong winter storms that mix
10 the air more thoroughly and disrupt the inversions (Grayson 1993). Because of cold-air drainage,
11 deeply incised washes may have far colder temperatures than nearby higher ground at
12 approximately the same elevation. In the Mojave Desert, some species, such as brittlebush
13 (*Encelia farinosa*) may have responded to these topographic patterns of freezing temperature
14 with different genotypes that occur on hillslopes versus adjacent to washes.

15
16 Within large regional areas additional variation in climatic factors is influenced by topography.
17 Winter precipitation is strongly orographic (e.g. related to increase in elevation due to
18 mountains), increasing from approximately 100 mm at lower elevation sites to more than 500
19 mm near the tops of some mountain ranges. Average temperature decreases approximately 6°C
20 for every increase in elevation of 1000 m (Ricklefs 1990). Thus, topography directly influences
21 the amount and timing of precipitation across large spatial gradients (across basins and ranges)
22 and more proximal elevation gradients (e.g. on a single mountainside), and the variation in
23 temperature combined with topography results in high variability of potential evapotranspiration
24 (e. g. water vapor resulting from evaporation from the ground and open waters, plus that
25 resulting as a by-product of plant physiological processes) and soil-moisture storage in the
26 Mojave Network. Patterns of plant distributions related to these environmental variables were
27 formalized in a conceptual model over one hundred years ago (Merriam 1890) and are further
28 elaborated on in the vegetation section of this document.

29
30 The basin and range topography characteristic of the Mojave Network also promotes seasonal
31 climatic phenomena. During warm seasons, “dust devils” form when thermal energy in desert
32 basins increases and rises in thermal columns causing large updrafts. During the summer, playas
33 are a remarkable source of thermal activity as on regionally calm days the dust devils form,
34 carrying a load of dust that increases their visibility. These thermal updrafts may contribute to
35 the seasonal monsoon rains when humidity is sufficient in the area. At a broader scale, the
36 increase of regional air pressure affects air flows such as the Santa Ana winds that blow out of
37 the deserts at high velocity toward the west coast. The locations of important climatic microsites
38 are dependent on the finer details of these relations and are influenced by local slope and aspect.

39
40 For example, at any given elevation, a northeast-facing slope will likely have a significantly
41 different temperature and moisture regime than a comparable southwest-facing slope. Steep
42 slopes (>45%) further complicate plant and animal distributions. Higher angles of slope reduce
43 the stability of surfaces and usually promote highly unstable talus or bare bedrock that are
44 unfavorable habitats for most plant species. This creates a feedback: with less vegetation, there is



Figure 30. Regional view of major climatic trends. The solid gray arrow illustrates that decreasing latitude and increasing minimal elevation moving northward in the Great Basin resulting in generally cooler and wetter conditions. The light colored arrow with blue outline illustrates a gradient from the northwest to southeast Mojave Desert indicating how precipitation increases across this gradient and also there is a greater tendency for more summer precipitation and less dominance of winter precipitation across this gradient.

more exposed solid rock and soil that absorbs and releases thermal energy from increased insolation. Thus, summer temperatures are quite high on the south-facing slopes and winter temperatures are lower on north-facing slopes.

An even finer resolution and more ephemeral effect of local topography and regional climate includes the canyon effect. Warm air that rises as daily temperature increase tends to be funneled into canyons causing strong upslope winds in larger canyons. At night, denser cool air rushes back down the bottoms of canyons. The diurnal temperature fluctuations induced by this air movement creates opportunities for plants to exceed their normal elevational limits. For example, in some areas ponderosa pines or firs may be found lower in canyons than they would be if on more-exposed slopes.

2.5 Geology and Geomorphology

In deserts, geology provides the template with which biota build integrated ecological systems. The availability of water is crucial, and small variations in available water can drastically affect plant and animal communities. Both physical and chemical geologic attributes commonly control

1 important variation in soil and water availability. Soil, water, and air are the media from which
2 primary producers acquire nutrient resources. As the abiotic matrix that supports the biota, they
3 form the foundation of ecosystems. These media also are characterized by condition attributes
4 (e.g. temperature, surface stability) that affect the physiological performance of organisms.

5
6 At the regional level, geologic control in the form of basin-bounding block faults (Jones et. al.
7 1992) is the cause of mountains and basins and thus the elevation gradients so important to the
8 varied ecosystem. These faults also control regional groundwater systems. The carbonate aquifer
9 of southern Nevada provides water for numerous springs and caves in southern Nevada and
10 adjacent California, effectively communicating recharge areas of northern Nevada to discharge
11 in the deserts by a complex pathway of faulted Paleozoic carbonate rocks. At the local level, the
12 rock type and associated fracture characteristics in individual mountains influences the location
13 and rates of infiltration, and thereby the degree to which runoff to basins vs. recharge to local
14 and regional aquifers occurs. The rocks, their structure, and their weathering therefore exert a
15 fundamental influence on the ecosystem.

16
17 Geomorphic systems exert the next most basic influence on moisture availability and biotic
18 systems in the desert. A typical desert mountain-basin pair (Figure 31) consists of a mountainous
19 area with relatively high moisture availability that is being weathered and eroded. Below the
20 mountain are alluvial fans, coalesced fans termed bajadas, erosional systems such as pediments,
21 and various other landforms that collectively can be termed the piedmont. These areas are
22 primarily depositional systems, where sediment eroded from the mountains accumulates over
23 long time periods. Farther from the mountain front, in general, are complex distal piedmont
24 systems that are quite variable through the region; sand dunes, sand sheets, intermixed eolian
25 sand and alluvial fans, and even wetlands (e.g. Ash Meadows) occur in this landscape position.
26 The basin axis (bolson of Peterson 1981) is typically occupied by a playa or axial stream system,
27 more rarely by a perennial lake.

28
29 Of the many geomorphic environments in the desert, mountains and piedmonts cover the greatest
30 area. Mountains have relatively high near-surface moisture that is locally stored in small
31 colluvial and alluvial sediment deposits within the complex topography underlain by eroded
32 rock. The environment is highly variable with complexly varying attributes driven by both
33 substrate materials and topographic factors such as slope, aspect, and curvature. Mountainous
34 areas may also contain extensive water in the bedrock that may flow to caves and to piedmont or
35 valley axis groundwater discharge systems. Plant communities are highly variable on piedmonts,
36 primarily in response to elevation gradients and their influence on effective moisture availability,
37 but also in response to characteristics of geologic deposits. Surficial geologic deposits vary in
38 soil texture (grain size distribution and packing), bulk density, and other factors; horizontal
39 variations are largely influenced by depositional processes and vertical variations by soil
40 development (pedogenesis). Soil texture is critical in the moisture budget since, in general,
41 coarse soils have higher infiltration rates, whereas finer grained soils have lower infiltration rates
42 but higher

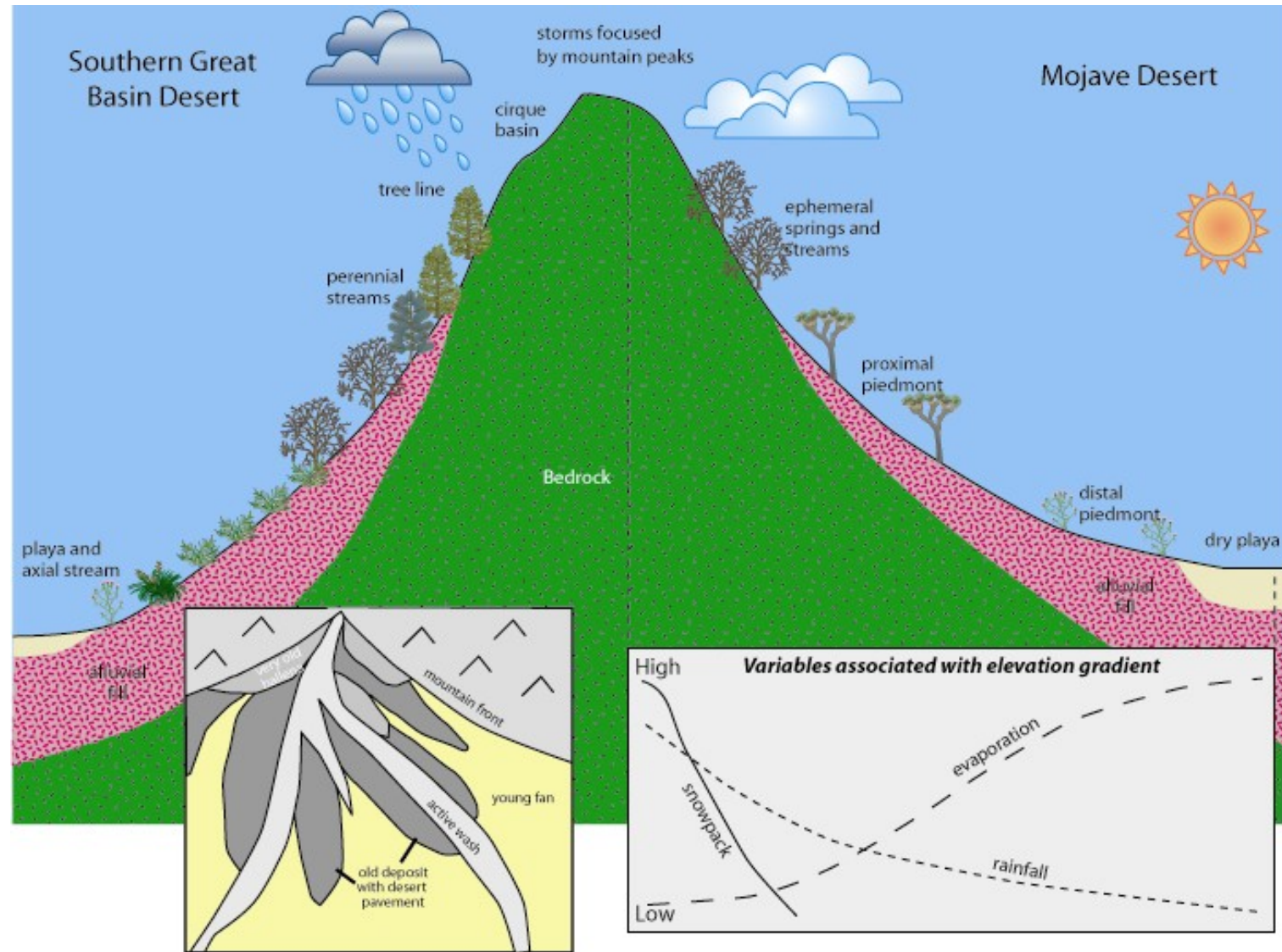


Figure 31. Components of Mojave Network desert landscape shown in elevation profile, with inset perspective view of an alluvial fan. Great Basin elevation gradient is represented on the left side and Mojave Desert on the right.

retention capacities. Deposits in general decrease in grain size from mountain front downward to distal piedmont, as do topographical features such as channel incision and slope (Blair and McPherson 1994). Superimposed on these textural and topographic patterns are the patterns from the history of bajada deposition, with parts of the area ranging from remnant fragments of very old piedmont deposits to actively depositing segments (Figure 32). The resulting patterns are crucial to ecosystems because abandoned depositional landforms acquire pedogenic soils that alter infiltration and storage properties for soil moisture (McFadden and Knuepfer 1990, McDonald 1994).

Soil erosion and deposition is mediated by stability conferred by chemical and biological crusts and by vegetation; areas of dense crust or vegetation are relatively stable. Precipitation dynamics govern the location and type of erosion, transportation, and deposition of sediment, as does the landform. In general, streams in the Great Basin are perennial in proximity to medial piedmont position, and sediment transport from mountains to distal piedmont is ongoing, with pulses driven by snowmelt and intense storms. By contrast, few streams in the Mojave Desert are perennial beyond the canyon mouths of most mountains, and sediment pulses onto the piedmont are highly stochastic with respect to time and location.

2.5.1 Soil-Water Relationships

Pedogenesis proceeds by progressive accumulation of infiltrated eolian fine-grained materials, chemical deposition, and weathering within sediment deposits (Pavich and Chadwick 2004). Downward translocation of materials results in a layered system, with layers (horizons) varying in hydrologic and other properties. Pedogenesis is a continuous process, and its effects are more accentuated with time. Older deposits generally exhibit more intense soil horizonation, with correspondingly greater influence on soil moisture properties than in younger soils. Because piedmont environments are depositional, deposits that are stranded above more geomorphically active (and younger) areas are allowed to develop soil horizons. As a result of the progressive development of pedogenic soils, and the presence of deposits of varying ages in the piedmonts, the piedmont environment is a complex mosaic of areas with varying soil properties (Figure 33). In general, plant cover decreases with age of deposit, apparently as a result of decreased soil moisture availability (Hamerlynck et. al. 2002). An exception is the low plant cover evident in many active washes, where unstable substrate and abrasion during floods probably play a large role in reducing plant establishment and persistence. Studies of soil moisture response to rainfall events, as well as models of soil systems, indicate that near-surface A_v horizons retard infiltration, reducing total moisture available at depth. Typical saturated conductivity values for Mojave Desert piedmont soils range from about 7 cm/hr in young deposits to 1 to 0.1 cm/hr for very old soils (D.M. Miller, Unpub. data 2005). However, Bt horizons below the advanced A_v horizons typically are fine textured and contain enhanced amounts of clay, and therefore retain

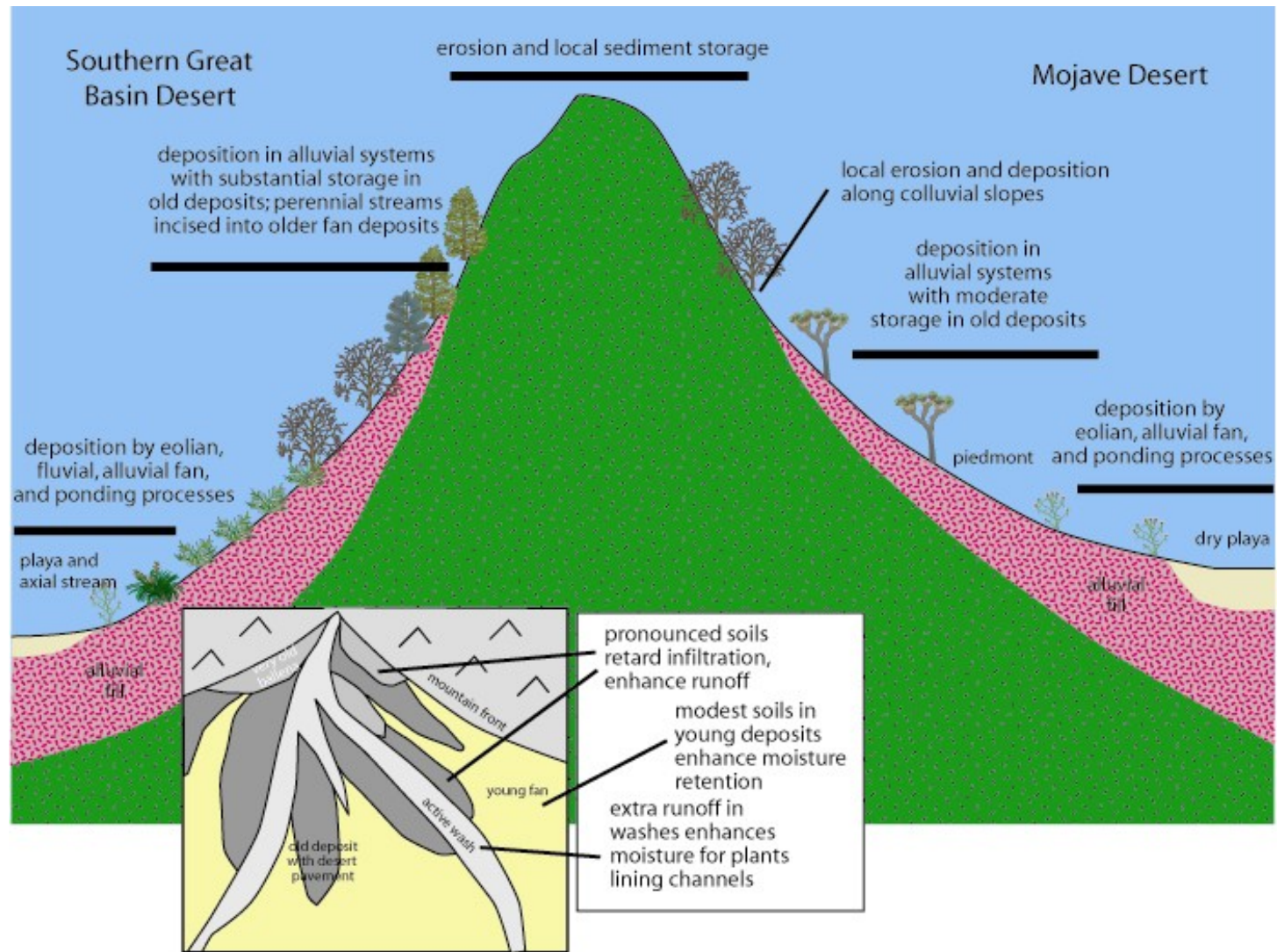


Figure 32. Processes operating on an elevation gradient representing desert mountain and alluvial systems.

soil moisture for a longer time period than coarse-textured soils (Figure 33). As a result, older deposits generally are occupied by plants whose roots take advantage of modest amounts of shallow, persistent moisture, as opposed to deeper more ephemeral moisture available in younger deposits.

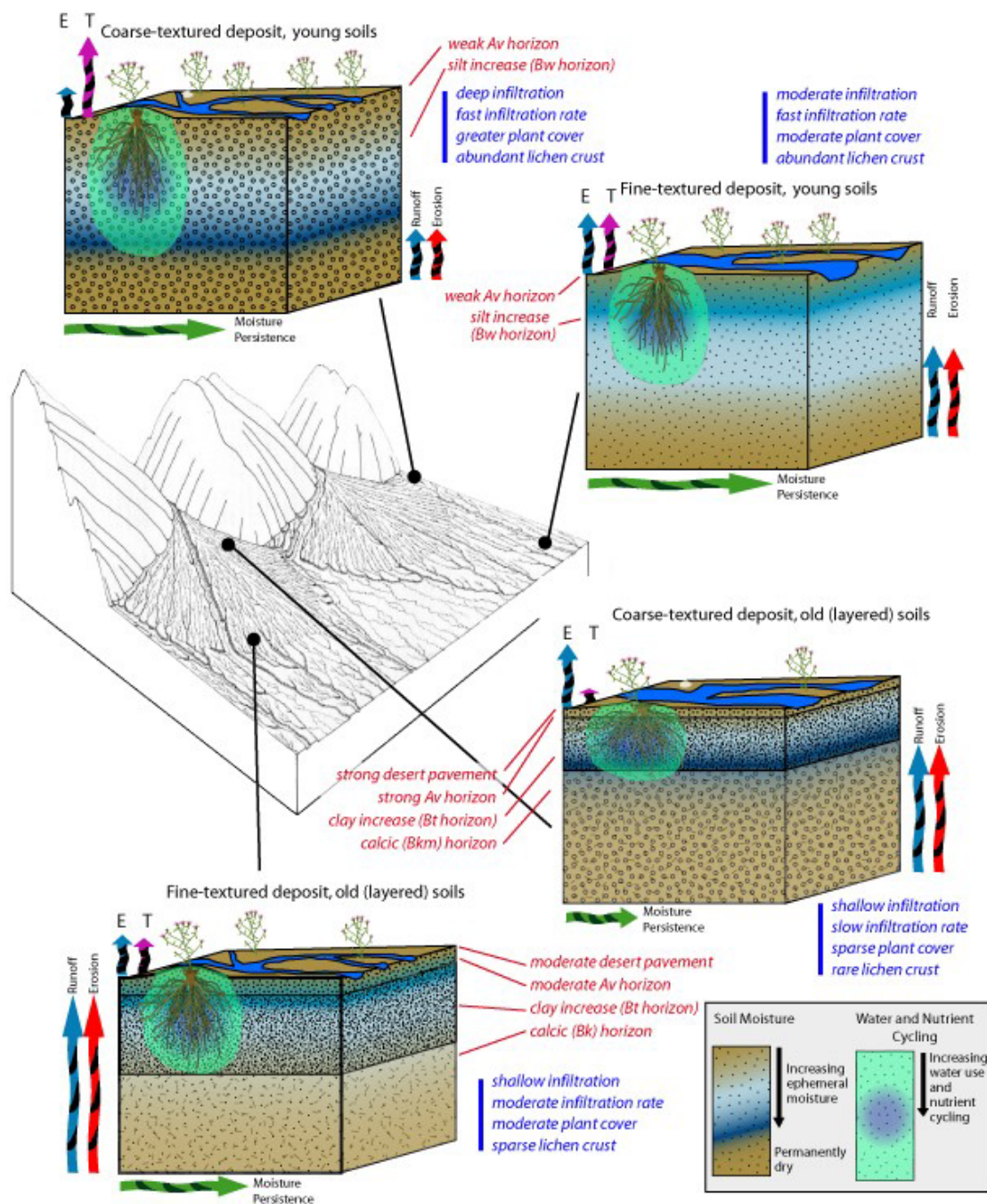


Figure 33. Plant-soil-water relations in a desert bajada.

2.5.2 Geologic Features of Special Ecological Significance

2.5.2.1 Dune Systems

Eolian sand deposits are common in locations with abundant sand supply, such as downwind of major rivers and washes, playas, and disturbed areas. Dunes are generally composed of well-sorted fine- to medium-grained sand. The sorting results in deep water infiltration and rapid evaporation of shallow moisture, and hence relatively short periods of near-surface water availability. Dunes are inhabited by distinctive plants that are able to colonize unstable materials, and this plant cover is crucial to dune stability; cover less than about 14% generally results in dune migration (Wiggs et. al. 1995). Vegetation and biologic crust cover has been shown to vary with the effective moisture function (P-Ep), where P is precipitation and Ep is potential evapotranspiration; this function plus mean wind speed determine dune stability reasonably well (Woodruff and Armbrust 1968). Destabilized dunes and sheets can undergo blow-out, which can rapidly destabilize areas in a chain-reaction effect and migrate into areas that have not experienced eolian activity.

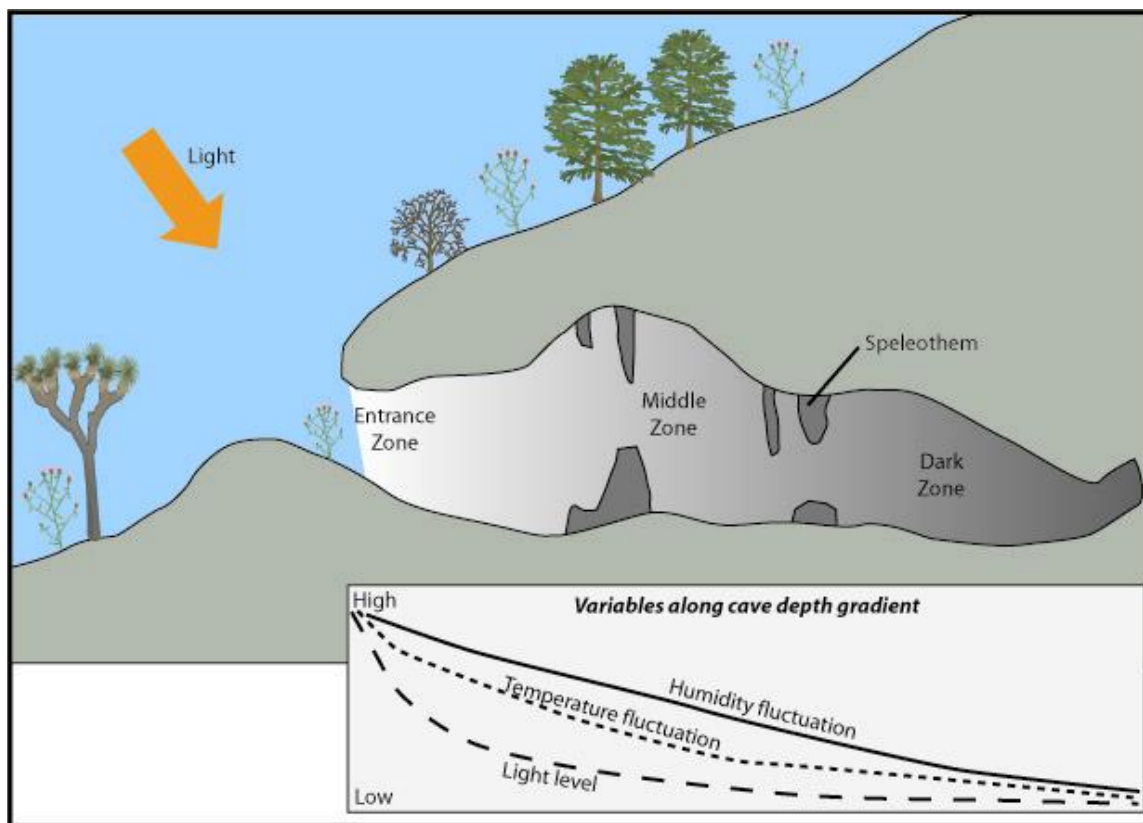
Deep infiltration in dunes in some cases results in deep “ponded” water above underlying less permeable deposits. Deep-rooting plants such as mesquite may take advantage of this relative persistent water source. Mesquite-anchored dunes tend to be stable because the vegetation reduces wind velocity, reducing sand transport. Stands of mesquite, known as bosques, can provide important cultural resources for tribal groups. Human activities that reduce the amount of plant material near the ground surface (e.g. fuel cutting or trimming trees) could result in higher wind velocity that promotes an increase in the loss of dune surface around the base of the trees and a decrease in dune material deposition. However this potential disturbance activity has not been studied to determine its effect.

2.5.2.2 Cave Systems

All network parks contain natural caves except Manzanar National Historic Site. Great Basin National Park contains over 30,000 acres of karst geology and over 30 natural or “wild” caves. Cave resources are listed as an exceptional natural resource in the park General Management Plan and are equally important from a visitor experience perspective. Lehman Cave, one of the primary reasons for establishment of GRBA, is famous throughout the world for an unusual concentration of cave formations and abundance of shields (NPS 1992a). Cave and karst systems are sensitive to many environmental factors including changes in hydrology (e.g. lowered water table), changes in water quality, atmospheric changes (e.g. CO₂, temperature), and altered geologic processes (e.g. erosion). Cave environments, particularly obligate cave invertebrate communities, may provide a sensitive indicator of environmental change.

These caves are mostly dry, hydrologically inactive caves, but at least one wet, active cave is reported from Mojave National Preserve and Grand Canyon-Parashant National Monument and others are contained within Great Basin National Park. Both dry and wet caves are spatially structured systems with pronounced gradients in light, humidity, air flow, and air chemistry from the cave mouths inward (Figure 34). In general, the variability in the environment declines with

1 increasing distance into the cave as the cave interior becomes increasingly decoupled from
 2 external climate fluctuations and increasingly approaches temperature and humidity controlled
 3 by surrounding rock.
 4



5
 6 Figure 34. Components of a wet cave ecosystem. Dry caves are similar in most respects but
 7 speleothems are inactive.
 8

9 Unique, cool microclimates near cave mouths may be important for several plant and animal
 10 species. Speleothem growth relies on dependable percolation of groundwater (Figure 35),
 11 groundwater chemistry remaining fairly stable, and unchanging humidity and temperature in the
 12 cave interior. Animals dependent on dark, stable habitat, such as bats, rely on caves in great
 13 numbers.
 14

15 Caves are generally stable environments when compared with surface ecosystems, often showing
 16 remarkable consistency in temperature and humidity from day to day and year to year. However,
 17 disturbances caused by rock falls or the flooding of subterranean streams induce temporal
 18 variability. As one moves closer to the cave mouth, conditions become more variable and may be
 19 affected directly or indirectly by surface disturbances (Figure 36). Alterations to the cave mouth
 20 that increase gas exchange, or increase temperature and humidity of the cave, reduce speleothem
 21 growth and alter cave habitat. In addition, climate changes will exert muted but potentially
 22 significant changes in cave environment. Animals dependent on the cave environment may be
 23 greatly affected by seemingly minor disturbance to the cave.

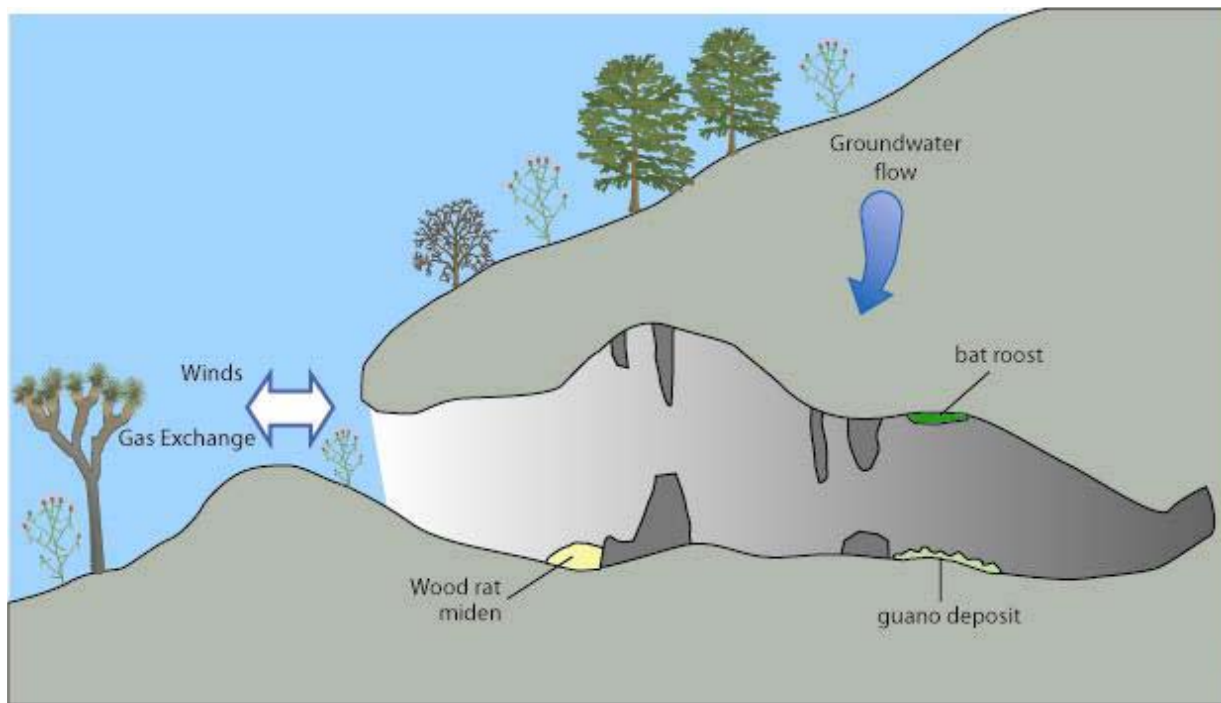


Figure 35. Processes operating on wet caves.

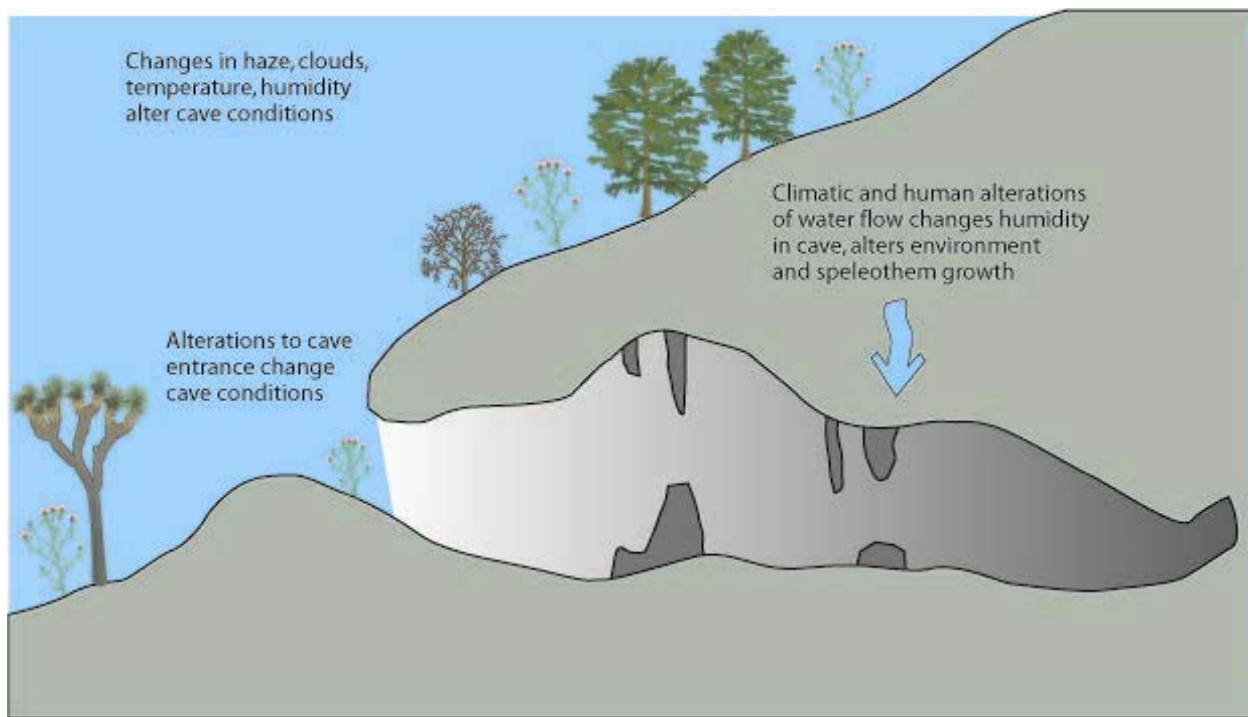


Figure 36. Changes to cave processes caused by forcings such as climate change and human modification.

2.5.2.3 Playa Systems

Playas are complex valley bottom systems that serve as terminal water flow and sediment deposition sites in most cases, although a few playas are flow-through systems, with exiting washes (e.g. Silurian Lake, Soda Lake). Playas can be broken into two fundamental types, wet and dry. Wet playas have shallow groundwater, and undergo ground-water discharge, resulting in abundant salts, soft and sometimes unstable surfaces, and possible adjacent springs (e.g. Bristol Lake, Searles Lake, Death Valley floor, Soda Lake). Dry playas have deeper water tables and are sites of periodic inundations by surface water but have much less salt buildup than wet playas (e.g. Ivanpah Lake, Silurian Lake, Racetrack Playa). Dry playas undergo deposition by distal piedmont alluvial processes, by shallow ephemeral lakes, and by eolian dust and sand. The resulting deposits of the playa and its fringing zones are highly variable mixed-process environments and typically defy categorization. Playas tend to consist of high clay- and silt-content sediment, which inhibits infiltration. Margins of playas are commonly sites of eolian sand and dust mobilization.

Change in the groundwater regime, such as drawdown by pumping wells or sustained drier climate, may cause wet playas to dry. This change may concentrate potentially toxic salts and trace elements that are available for wind erosion and transport. Playas with their mineral crusts are relatively stable but are highly susceptible to disturbance. Once the crusts are broken, fine particle size renders the playa deposits susceptible to wind erosion. Indeed, playas are favored prospecting sites for meteorites because the wind erosion over millennia concentrates heavy objects.

2.6 Hydrology

Both unsaturated zone and saturated zone (ground water) hydrology are key ecosystem components in the Mojave Network. System dynamics within unsaturated zone hydrology are affected by rainfall-runoff relations, infiltration, soil-water retention and spatial distribution, and percolation to the saturated zone. Ground-water hydrology is important for wet cave systems, ground-water discharge zones and phreatophytic plant communities (e.g. those plant species depending on water in the saturated zone for survival), and ground-water resources.

Dynamics on the surface and within the near-surface unsaturated zone are driven by interactions between climate, soils, and biota. A key factor in arid and semi-arid environments is that precipitation (as rainfall and snowfall) is highly variable. Precipitation events can be conceptualized as pulses of water that get partitioned into runoff and soil-moisture components through interactions between precipitation, soil-surface properties (e.g., infiltration capacity and water retention capacity), and temporal interactions (e.g. the duration between rainfall events). The biologic effects of pulses to soil moisture will vary with the magnitude and duration of the moisture pulse, as well as the type of biota considered (e.g., larger and longer pulses will be useful to a wider set of biota). The biologic effects can persist for hours to decades and can range from small changes in nutrient cycles to significant episodes of community succession (Schwinning and Sala 2004).

1 Ground-water hydrology is controlled by factors affecting recharge through the unsaturated
2 zone; discharge at springs, seeps, and other ground-water discharge sites; and storage in ground-
3 water aquifers. Much of the present-day recharge in the Mojave Network is discharged to the
4 atmosphere by evapotranspiration from the plants, the soil, or open water (lakes, spring pools,
5 and wet playas). In the absence of any human development, the ground-water systems in the
6 Mojave Network are in dynamic equilibrium with long-term climatic patterns. Rain and snow
7 provide recharge to the ground-water system, which is balanced by an equal amount of discharge
8 plus short-term changes in ground-water storage. Storage is depleted during periods of drought
9 and replenished during wet periods. Over the long term, however, the system remains roughly in
10 balance.

11
12 The principal aquifer types within the Mojave Network are regionally extensive carbonate rock,
13 localized areas of volcanic rock, and basin-fill deposits (Figure 37)(Harrill and Prudic 1998).
14 Basin-fill deposits consist of unconsolidated to consolidated clastic materials eroded from
15 adjacent mountains. These deposits can be thousands of feet thick and form the most productive
16 aquifers, especially in the Mojave and Sonoran Deserts. Ground water flowing through basin-fill
17 aquifers typically remains within its originating basin, except that water which infiltrates
18 downward into underlying carbonate rock. Carbonate rocks form a regionally extensive aquifer
19 within the Basin and Range and northern Mojave Desert. This laterally extensive aquifer allows
20 for interbasin flow, as ground water flows beneath mountain ranges and crosses surface-water
21 divides (Harrill and Prudic 1998).

22
23 Recharge is derived from rain and snow falling in the Mojave Network. Climatic factors,
24 partitioning of precipitation to runoff or infiltration, spatial linkages of runoff, biotic use,
25 evapotranspiration, and soil hydraulic properties all affect whether recharge occurs, and its
26 locations and amounts. In low lying basins, where precipitation is low (2-6 in/yr), rainfall
27 provides moisture to the surface soils but is insufficient to saturate the underlying soils and to
28 percolate into the ground-water system (Hevesi et. al. 2003). Ground-water recharge occurs
29 primarily in the mountains and upper piedmont areas where annual precipitation is from 6 to
30 more than 30 inches (Hevesi et. al. 2003) and elevations are greater than 5,000 ft (Maxey and
31 Eakin 1950, Rice 1984)(Figure 38). In northern colder regions (e.g. Great Basin National Park),
32 or where mountains reach high altitudes (e.g. Spring Mountains), winter snow pack provides the
33 dominant source of recharge to the ground-water system. In the southern regions (Mojave
34 National Preserve), rainfall is the dominant source of recharge. Most recharge occurs in the
35 winter and spring, when precipitation is high and evapotranspiration is low. Diffuse recharge
36 may reach the saturated zone (ground-water system) as deep infiltration of precipitation through
37 fractured or porous rock in the mountain blocks (Figure 38). Alternatively, where bedrock is
38 impermeable or topography is steep, snowmelt or rain may channel and flow down the mountain
39 front onto the upper piedmont. Most channeled water infiltrates into the streambed and some
40 recharges the underlying basin-fill aquifers as focused recharge (Figure 38). An extreme example
41 of this is in the Mojave River basin, where 80 percent of the recharge to the basin is estimated to
42 be from leakage of floodwater from the Mojave River into the underlying basin-fill aquifer
43 (Stamos et. al. 2001).

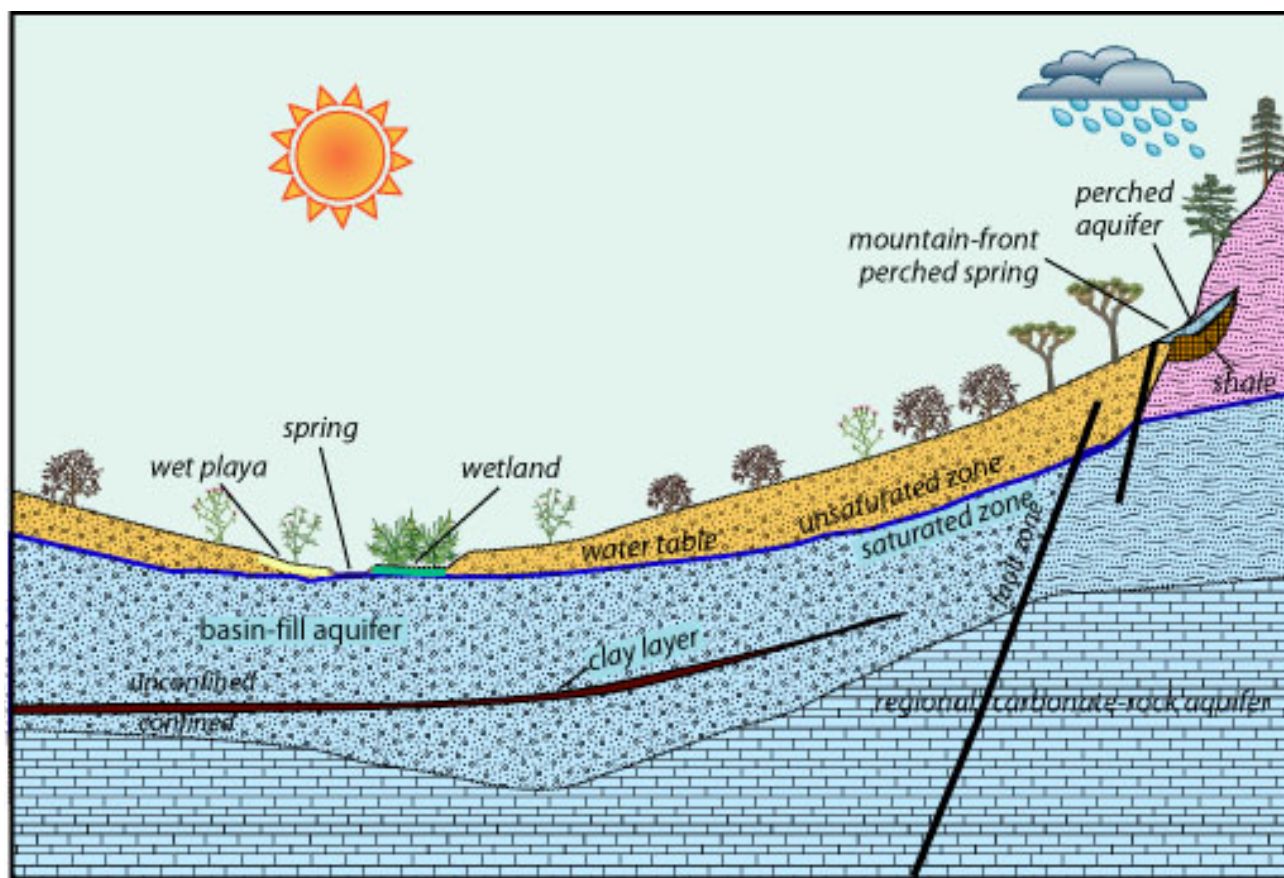


Figure 37. Components of an aquifer system.

Recharge water that infiltrates into the saturated ground-water system flows from high to low hydraulic head (generally from upland areas to lowland areas). The water flows toward a discharge area along the path of least resistance. This flow path is predominantly through aquifers, which readily transmit water (Figure 38). Ground water typically flows at a rate of several feet to several thousand feet per year. The elapsed time that a water particle takes to travel along a flow path is short for perched systems (months to decades), intermediate for basin-fill aquifers (decades to centuries), and long for regional carbonate rock (centuries to millennia).

Low-permeability confining units separate aquifers and restrict flow, creating confined aquifers (i.e., aquifers under pressure). Confining units also can dam ground water by forcing ground water in an aquifer to rise in order to flow around or over the barrier. An example of this is Ash Meadows, where regional ground water is forced to the surface by confining deposits that juxtapose the regional carbonate aquifer (Winograd and Thordarson 1975). Perched aquifers result from confining units that impede vertical movement of infiltrating water, creating a “pond of water” in the unsaturated zone. In mountainous regions, perched water often flows downward along the surface of the confining unit exiting the system from hillside springs (Figure 38).

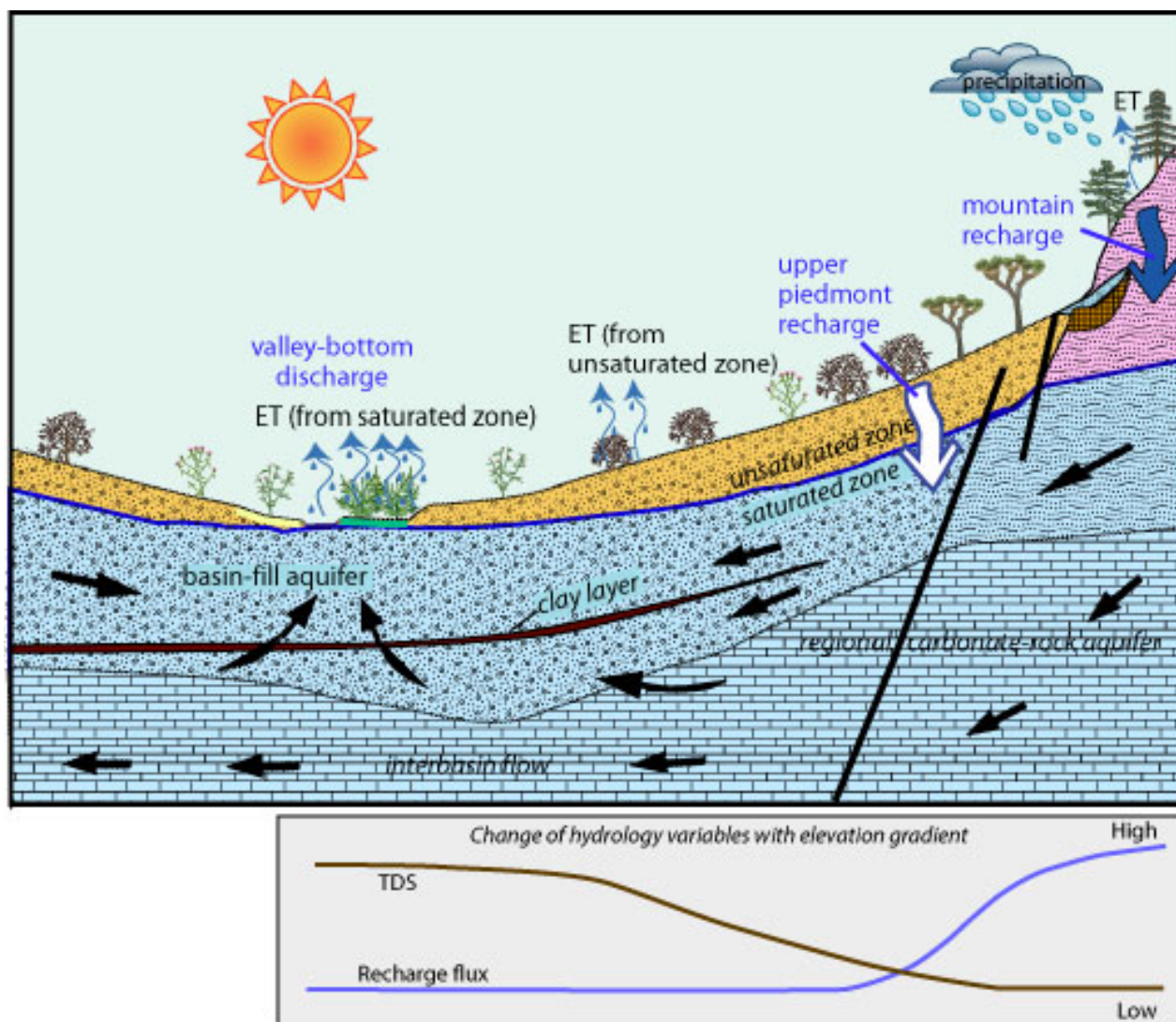


Figure 38. Processes affecting a common aquifer system, graph depicting elevation effects on aquifer recharge.

Ground water ultimately discharges from aquifers forming springs, seeps, wet playas, wetlands, streams, and rivers (Figure 38). This discharged water is consumed primarily by plants and evaporation (Laczniak et. al. 2001). The location of these discharge zones is dependent on land-surface elevation and geologic structure. Water typically discharges along the margin or at the low point of a valley, where the potentiometric surface intercepts land surface, such as at the springs in Death Valley. Discharge at higher elevations can result from ground-water damming or perched systems intersecting a mountain face. In some areas, especially where the regional carbonate-rock aquifer provides continuity between basins, ground water can underflow a basin, leaving the local playa dry with no discharge.

Surface water, as pools, lakes, wetlands, streams, and rivers, is supported by ground water, precipitation runoff, or some combination thereof. Perennial streams are common in the mountain ranges of the Basin and Range. These streams (e.g. Baker Creek) are fed both by

1 snowmelt and ground-water discharge. In the Mojave Desert, mountain streams flow
2 intermittently during spring runoff or during storm events. In the upper piedmont, streams lose
3 water to the streambed and underlying soils and can be important sources of ground-water
4 recharge. Typically, streams in the Mojave Network lose their water before reaching their
5 terminus, except during large floods when a lake may form at the terminus (e.g. Badwater basin).
6 In the extreme example, the Colorado River sustains perennial flow across the desert despite
7 losing large amounts of water to the underlying sediment. Streams are rare along the valley
8 floors, but can occur where they are fed by springs or ground water. For example, ground water
9 currently supports flow in some reaches of the Mojave River, but supported flow in much of the
10 pre-development Mojave River (Lines 1996). Wetlands and pools in the Mojave Network
11 typically are supported by ground water flowing from lowland springs and seeps.

12
13 Stream runoff is strongly affected by precipitation-pulse dynamics, which control amounts, rates,
14 and spatial patterns of overland flow and erosion. Generation of overland flow is largely
15 controlled by precipitation rates and durations, and spatial variability of soil-surface
16 characteristics and vegetation (Dunne et. al. 1991). With overland flow comes the potential for
17 redistribution of sediment. The capacity to transport sediment is controlled by frequency, flow
18 depth, and velocity of runoff, whereas the availability of transportable sediment is controlled by
19 soil surface properties; climatic factors, such as raindrop size, velocity, and intensity; and by
20 natural and human disturbances to the soil surface. Overland flow and erosion can have
21 beneficial effects on ecosystems by redistributing water (Schlesinger et. al. 1989) and by
22 accelerating recovery from disturbance, as well as destructive effects such as destabilization of
23 soil and nutrient loss.

24
25 Springs can be fed from locally or regionally derived precipitation. Perched springs, typically
26 located above the basin floors, receive only locally derived precipitation. These springs are
27 characterized by small, seasonally fluctuating flows that often go dry in the summer or during
28 dry years. Because water discharging to a perched spring has a short, shallow flow path, the
29 spring water is cool in temperature, relatively young, and low in dissolved solids. In contrast,
30 large springs located near or on basin floors (e.g. Texas Spring, Rogers Spring, and Crystal
31 Spring) have large flows that are generally consistent from year to year. These springs are
32 characterized by warm waters that are relatively high in dissolved solids. These characteristics
33 result from long flow paths (as great as several hundred miles) and long residence times (up to
34 tens of thousands of years) (Thomas et. al. 1996).

35
36 Disturbances to the hydrologic system can alter the quantity and quality of ground- and surface
37 water. Long-term climate change affects the quantity of recharge to the ground-water system. A
38 future climate that is warmer and wetter in the Mojave Network, due to increased atmospheric
39 carbon dioxide, may result in increased recharge and ultimately more discharge (D'Agnese et. al.
40 1999). Changes to discharge will first show in local springs where flow paths are short. Larger
41 springs may be stable for many years before any effect is measured. Changes in long-term
42 discharge patterns also will affect phreatophyte distributions supported by spring- and seep-flow.

43
44 Decreases in discharge resulting from a subtle climate change often are difficult to discern from
45 regional pumping effects. Pumping removes water from storage. In basin-fill aquifers, the
46 amount of water stored between grains is large—potentially millions of acre-feet of water in a

single basin (Leake et. al. 2000). In carbonate-rock aquifers, storage of water in fractures also is large because of the immense volume of carbonate rock in the Great Basin and northern Mojave Deserts. When water is pumped from the basin-fill aquifers, which commonly are unconfined, the drawdown cone spreads slowly as the aquifer is dewatered (Figure 39). In contrast, confined aquifers, such as the carbonate-rock aquifer, have a rapid response to pumping. When confined aquifers are pumped, water is removed by depressurizing the aquifer and water-level changes will propagate miles within a very short time following pumping as water is released from storage.

As stated earlier, when a ground-water system is in equilibrium, recharge equals discharge. When pumping occurs, water is removed from storage. This lowers water levels and ultimately decreases natural discharge with re-equilibration of the system. Because the amount of storage in these aquifers is large relative to the typical quantities of water being pumped, measurable changes in spring discharge and distant water levels and the re-equilibration of the system may take many years to decades. Conversely, if pumpage is terminated, many years may be required to bring the system back to conditions prior to pumping. Often, responses to pumping will be subtle and difficult to measure because the effect is spread out over a large area. Also, some of the discharge captured by pumping may be little-noticed water that had once been evaporated from a wet playa. If the wet (now dry) playa had no plant communities prior to pumping, the response may not be immediately apparent. Monitoring plant communities, water levels, water quality, and spring flow is essential to determining natural variability and anthropogenic effects.

Natural water quality in the Mojave Network varies from nearly pure (e.g. mountain lakes in Great Basin National Park) to highly saline (e.g. Badwater Spring). Paradoxically, the more pure the water, the more susceptible it is to human contamination. Pure water typically is young and exposed at the land surface or is shallowly buried. Shallow water in basin-fill aquifers also is relatively low in dissolved solids and vulnerable to contamination. Percolation of waters from irrigation and septic systems provide ground-water recharge and nutrient loads to shallow water tables (Figure 38). Contaminants from urban runoff, landfills, industrial waste, and mine waste also can reach shallow basin-fill aquifers and ultimately arrive at a spring, wetland, or pumping supply. A high-profile case of industrial contamination is perchlorate that entered the Las Vegas Wash through contaminated shallow ground water and surface water, and then flowed into Lake Mead (Nevada Division of Environmental Protection 2005).

2.7 Plant-Soil-Water Relationships

It has long been established that precipitation is the single most important component for the survival of living things in desert ecosystems controlling production and the sequestration of carbon and nitrogen for plant production (Noy Meir 1973, Reynolds et. al. 2004). These models emphasize that water is important because it is a limiting resource for desert biota, yet water is generally of low availability, high variability, and very unpredictable (Noy-Meir 1973). Water inputs may vary in magnitude, frequency and timing of precipitation events and this also plays an important role in the distribution and abundance of biota in desert systems (Went 1948, Jurhen et. al. 1956, Beatley 1969 and 1976, Schwinning and Sala 2004)(Figure 40). Large amounts of

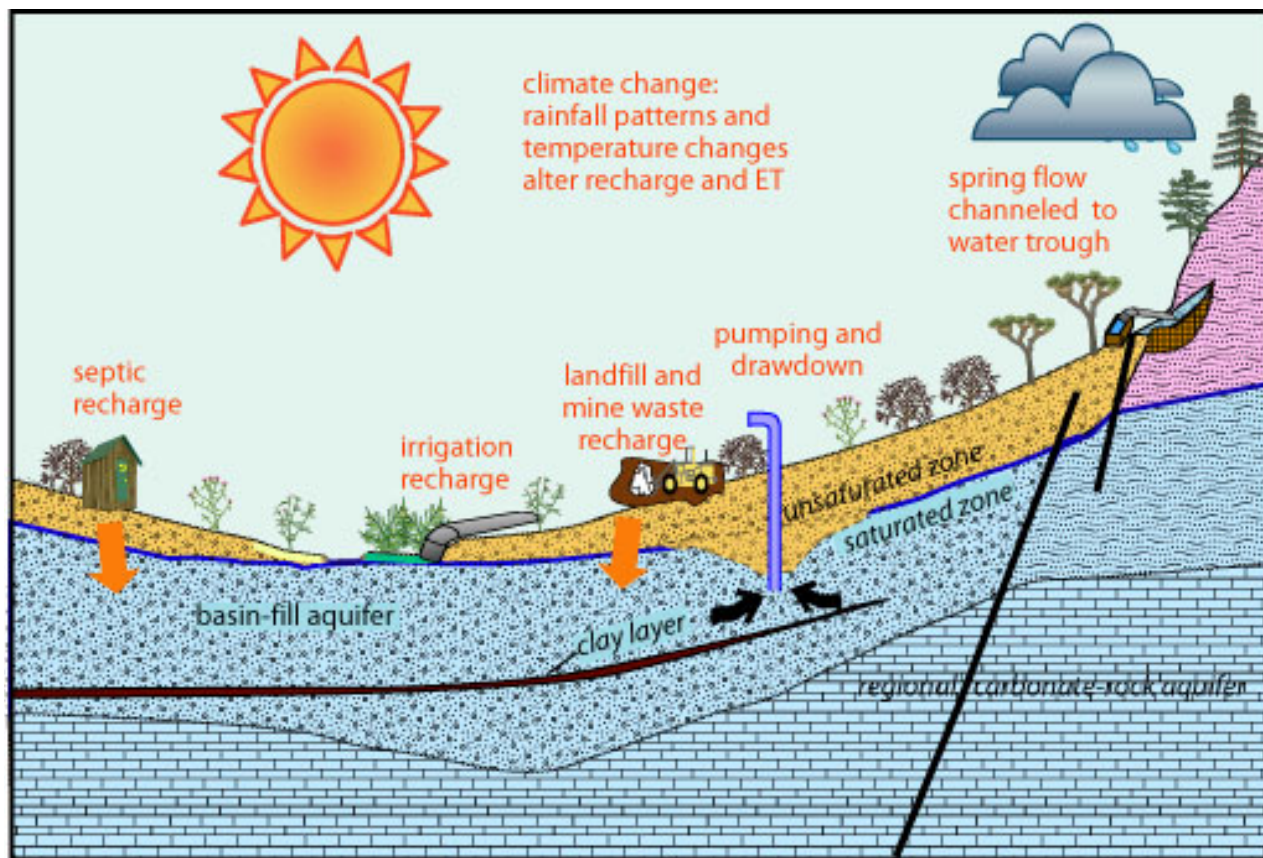


Figure 39. Human affected disturbances to a common aquifer.

water that enter a system in the form of precipitation or in a flash flood in a watercourse and come to rest on an impermeable surface may evaporate and leave the ecosystem all within a matter of minutes, hours or days. Alternatively, water may infiltrate surfaces, especially on mountain sides or on coarse grained piedmonts and sandy soils and move slowly through the unsaturated zone, water tables, or remain temporarily stationary in various aquifers only to discharge later and become available to plants (see Hydrology section this document). The amount of infiltration depends on the parent material, presence or absence of soils and the age and development of those soils (Hamerlynck et. al. 2002) and the moisture content of the soil prior to the event in question (Reynolds et. al. 2004). All these factors interact in complicated ways with soil surfaces or subsurface flows to affect the availability of water to plants (Schlesinger et. al. 1989, Reynolds et. al. 2004) and animals.

The components of biotic systems in desert ecosystems respond the environmental changes at various scales of time and over different sized spatial areas (Figure 40). Small, short-term precipitation pulses activate single-celled organisms at the soil surface and within the smallest habitat patches (e.g. shrub canopies). The single-celled organisms are shown to respond to the spectrum of pulse durations and pulse sizes. In contrast, individual plants, plant and animal populations and entire communities require successively larger pulses in the magnitude of space and time for quantifiable changes to occur.

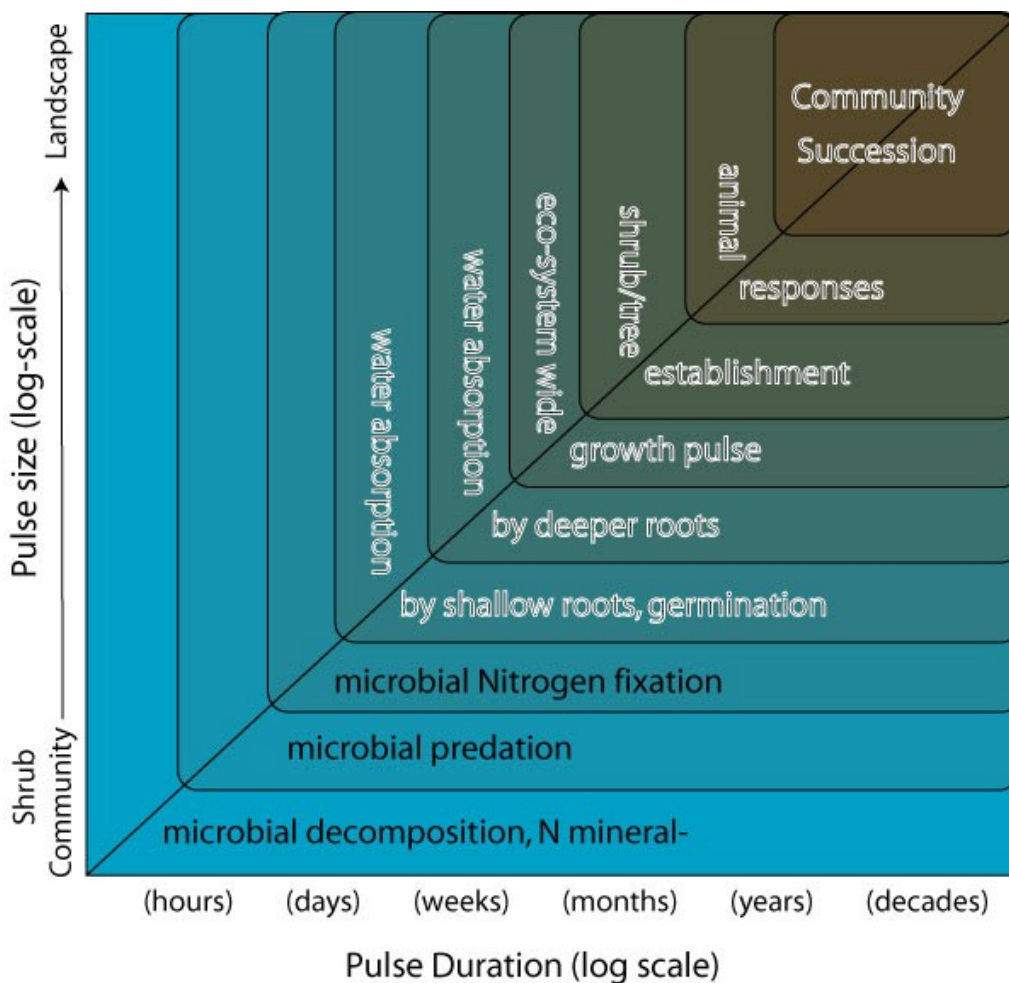


Figure 40. The ecological response hierarchy to soil moisture pulses of variable size and duration. Single-celled organisms at the soil surface respond to very small pulses, but plants and animals respond only to larger sized pulses and entire community responds to pulses occurring over landscapes and durations of up to decades.

Desert perennial plants are found in predictable units that can be categorized and explained in terms of environmental conditions. Several examples of categorization of desert plants, either in older classification systems (Beatley 1976, Brown and Lowe 1980), from a landform-based system (Ostler et. al. 2000), or the more-recently accepted system of alliances and associations (Sawyer and Keeler-Wolf 1994, Thomas et. al. 2004).

Within the arid southwestern United States, elevation and aspect influence temperature, soil moisture, and ultimately soil morphology, and these abiotic influences have long been known as correlates of plant assemblages (Merriam 1890, Figure 41). At the lowest elevations in the region (below sea level in Death Valley National Park), and in the rain shadow of the Sierra Nevada, salt flats have sparse vascular perennial vegetation. At the edges of barren salt flats and playas are salt scrub plant communities represented by saltgrass (*Distichlis* sp.), arrowweed (*Tessaria sericea*), and pickle weed (*Allenrolfea occidentalis*). In Mojave Desert, near the margins of playas and the base of dune complexes, are mesquite stands - occasionally quite thick

1 – and frequently interspersed by arrowweed, where they take advantage of both deep and
2 shallow water tables seasonally. Alternatively, in the Mojave Desert and Great Basin on gravelly
3 soils at the base of piedmonts and sometimes to the margin of playas are saltbush communities
4 represented by saltbush (*Atriplex* spp.), greasewood (*Sarcobatus vermiculatus*), and a variety of
5 other salt-tolerant shrubs.

6
7 In the middle of piedmonts, desertscrub alliances dominated by creosote bush and white bursage
8 occur over much of the Mojave Desert. These two common shrubs may be interspersed with a
9 variety of other shrubs, cacti and semi-succulents such as wolfberry (*Lycium andersonii*),
10 cottontop cactus (*Echinocactus polycephalus*), and Mojave yucca (*Yucca schidigera*). The most
11 common desertscrub community at intermediate elevations is dominated by blackbrush
12 (*Coleogyne ramosissima*), which can form near monospecific stands on old geomorphic surfaces.
13 Although previously viewed as a species-depauperate vegetation type, recent studies have
14 indicated that blackbrush dominated communities are as speciose as other desertscrub alliances
15 (Brooks et. al. 2004). Blackbrush occurs over a greater expanse of Great Basin landscape than
16 Mojave Desert landscapes and may have different population dynamics in response to
17 disturbance depending on temperature and precipitation variability.

18
19 Unique vegetation alliances are also present and are highly valued. Near the upper piedmonts of
20 the Mojave Desert, desertscrub alliances may border savannah grassland represented by
21 perennial bunch grasses (e.g. *Pleuraphis rigida*, *Pleuraphis jamesii*, *Achnatherum hymenoides*),
22 scattered shrubs including blackbrush, and Joshua tree.

23
24 At still higher elevations, big sagebrush (*Artemisia tridentata*) may dominate stands that may or
25 may not include pinyon pine (*Pinus monophylla* or *P. edulis* in the east) and (or) juniper (mostly
26 *Juniperus osteosperma*, but sometimes *J. scopulorum*). In the Great Basin, pinyon-juniper
27 stands seem to be “superimposed” within stands of big sagebrush that have a broader
28 elevational range (Billings 1951 in Grayson 1993).

29
30 At the upper piedmont and the lower slopes of mountain ranges may be found in sclerophyllus
31 woodland characterized by evergreen trees including: pinyon pine (*Pinus edulis* or *P.*
32 *monophylla*) and Utah juniper interspersed with shrubs such as bitterbrush (*Purshia glandulosa*)
33 and mountain mahogany.

34
35 At higher elevations the montane slopes are characterized by forests that are dominated by
36 several different conifer species that range across an elevational gradient by a series of conifer
37 tree species ranging from limber pine, spruce (*Picea engelmannii*), and bristlecone pine just
38 below tree line. These forests are highly variable in species composition and typically occur on
39 the higher mountain peaks in the region, including in Great Basin National Park, Clark Mountain
40 in Mojave National Preserve, and the Panamint Mountains of Death Valley National Park. At the
41 highest elevations, above 11,000', trees and shrubs give way to montane tundra with a variety of
42 plants that grow as prostrate growth forms.

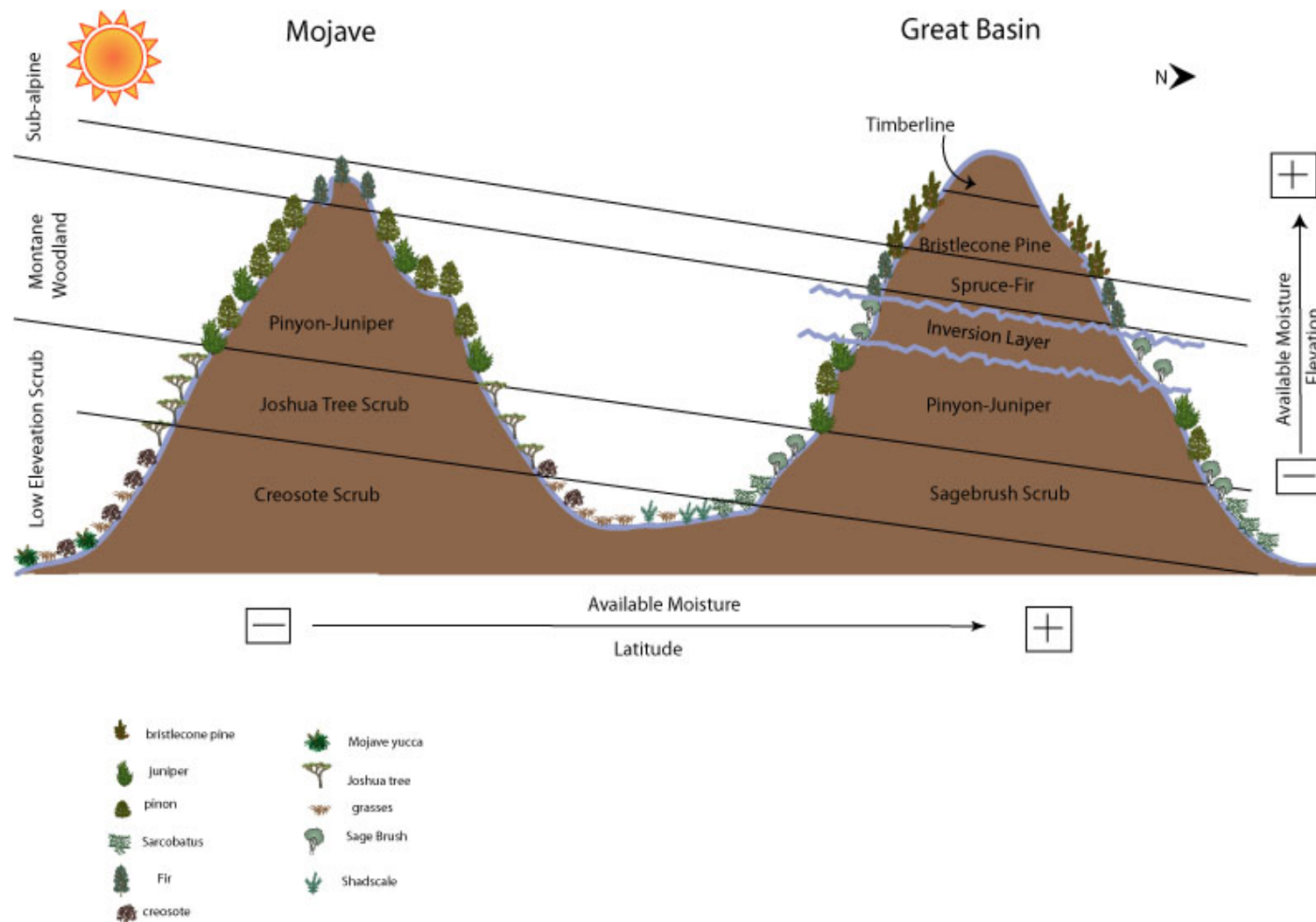


Figure 41. Vegetation zones in the Mojave Network. As latitude increases, vegetation zones move down in elevation due to decreasing temperature and increasing available moisture.

2.8 Disturbance and Variability

For nearly 100 years after the first exploration of the Basin and Range Province, the primary interest in desert environments was either how to cross them alive or mineral extraction. The evidence of early mineral explorations are still visible at locations across the deserts including many sites inside Mojave Network parks (Webb and Wilshire 1980). The impoundment of water from more mesic locations and transport of fantastic volumes of water made it economically feasible for vast numbers of people to inhabit the desert (at least in the short term). In combination with advances in refrigeration technology and abundant electrical energy associated largely with water impoundments and mineral extraction, large human populations started moving into the sun belt of the southwestern United States in the 1960s. With development of desert lands became economically feasible, dramatic land cover changes began to occur and tremendous changes in land surface cover are now occurring.

The landscape of the Mojave Network NPS units has been altered significantly through historic patterns of land use and continues to be threatened by competing human interests, particularly related to water use (water diversion, grazing, development, nonnative species, etc.) and human encroachment (pollution, recreation, non-native species, etc.), as well as climate change. Consumptive uses are certainly obvious conflicts, but even recreational activities may result in negative responses of the natural environment as with the loss of native vegetation near rock-climbing areas (Camp and Knight 1998). Several of these factors are summarized in Figure 42 (Jenny-Chapin model II). Abiotic and biotic disturbances and variability that occur across gradients in space, time and magnitude are important to the composition and physiognomy of desert ecosystems and may interact in complicated ways (White 1979). Abiotic disturbances in deserts are caused by acute climatic events such as storms that result in flooding, severe freezing temperatures (Jones 1979, Steenburgh and Lowe 1983), drought (Shreve 1929, Pockman and Sperry 2000, Webb et. al. 2003), long term variation known as climate variation (Betancourt et. al. 1990, Smith et. al. 1997, Dettinger et. al. 1998), or climate change when the variation is human-induced. Climatic events interact with the landscape to change the magnitude or frequency of processes causing disturbances by fire (Humphrey 1974, U. S. Fish and Wildlife Service 1994), erosion, or ground subsidence (Bowers et al. 1997).

Examples of biotic disturbance include herbivory and granivory (*reviewed in chapter 3*), and soil disturbances or bioturbation (Soholt and Irwin 1975, Jones et. al. 1994). Disturbance also results from direct or indirect effects of human populations including surface activities for urbanization, agriculture and infrastructure development (Vasek et. al. 1975a, 1975b, Webb and Wilshire 1980, Jones et. al. 1994, Lovich and Bainbridge 1999), invasions of plants and animals that change processes, recreation (Lathrop 1983), livestock grazing (U. S. Fish and Wildlife Service 1994, Oldemeyer et. al. 1994) or other plant harvesting activities.

1

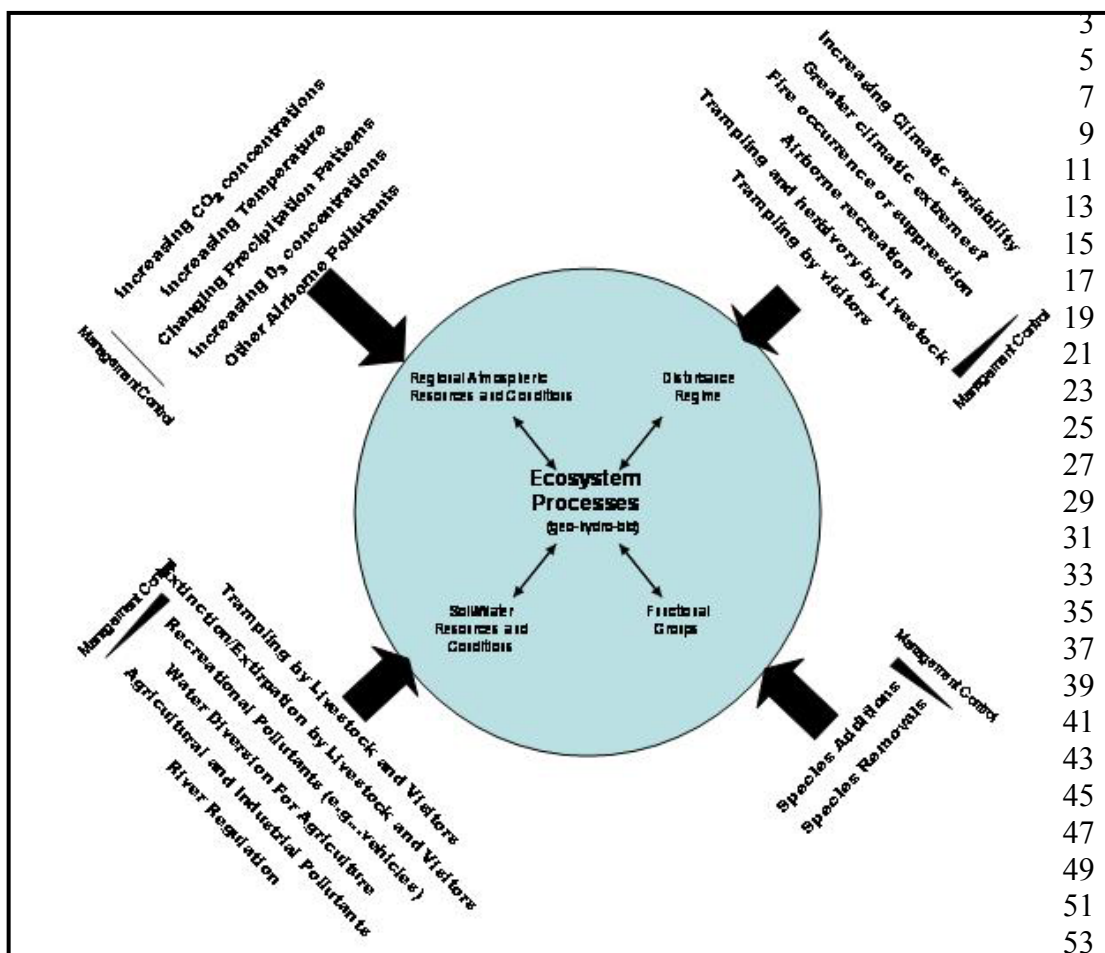


Figure 42. Interactive controls of the Jenny Chapin Model. Factors that change the status of interactive controls can bring about ecosystem change.

Detecting meaningful change is complex because ecosystems are inherently dynamic and spatially heterogeneous. Yet an important goal of monitoring is to differentiate the effects of intrinsic variability from those resulting from human-induced patterns of change (Noon et. al. 1999, Osenberg et. al. 1994). The aims of characterizing natural variability are to understand how driving processes yield different effects from site to site, reconstruct how these processes influenced systems in the past, and predict future outcomes (Landres et. al. 1999). Historical ecology informs us about the pathways that brought ecosystems to their current state and may help identify anomalous conditions (Swetnam et. al. 1999). Thus, the historic range of natural variability provides an important context for evaluating current anthropogenic effects despite the likelihood that current and future changes in atmospheric chemistry, climatic conditions, and land-use / land-cover patterns will render historic patterns of variability less and less attainable over time.

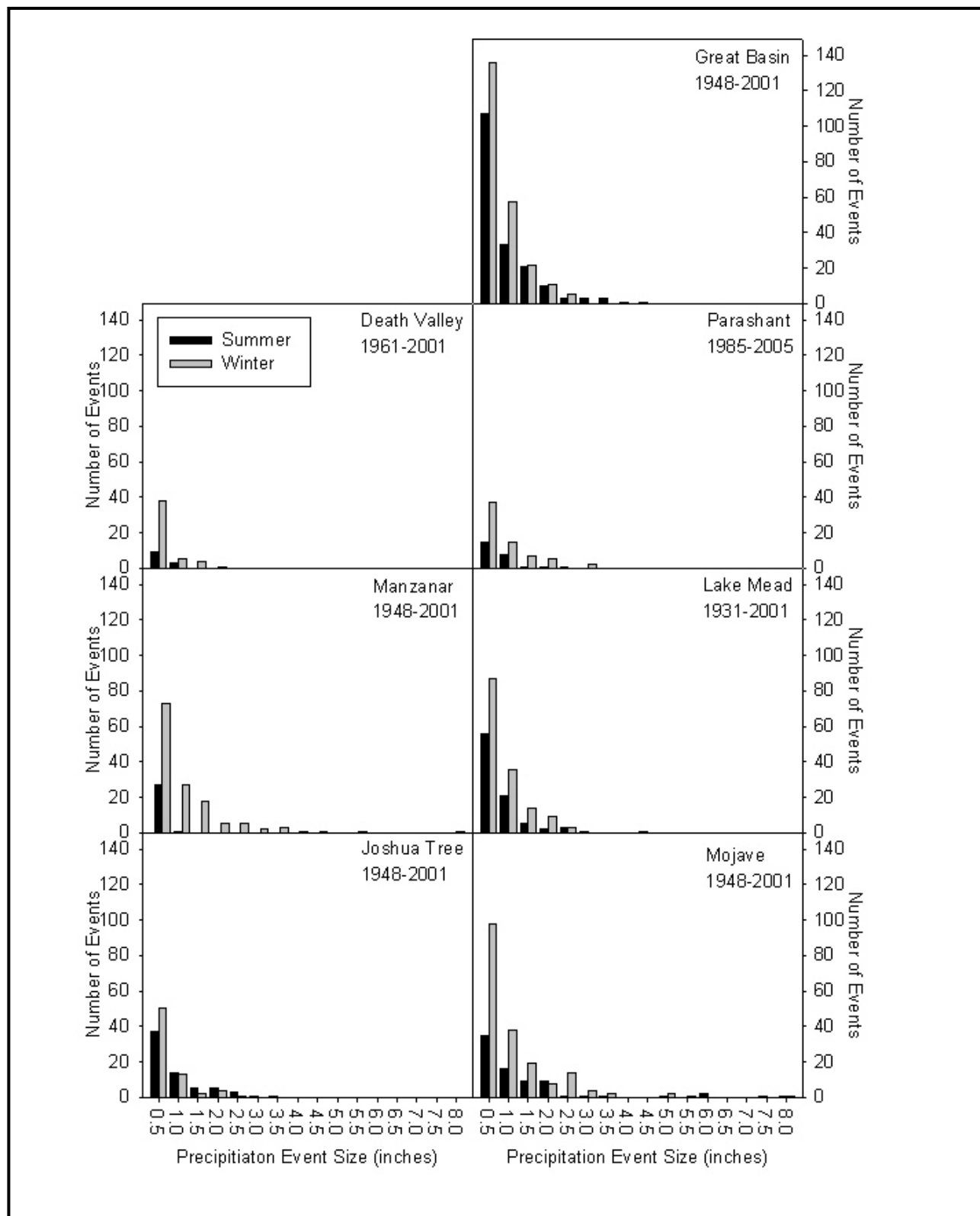
1 A primary goal of conceptual models is to describe our understanding of how natural drivers
2 influence key structural ecosystem components, their functional relationships and interactions,
3 and system dynamics. Depending upon stochastic and cyclic variability in climate attributes, key
4 disturbance patterns and other driving forces, we expect to observe a range of dynamic states in
5 structural ecosystem attributes. Our ability to detect the effects of current anthropogenic stressors
6 is dependent upon interpreting trends in resource condition against the backdrop of intrinsic
7 variation. Hypotheses concerning the effects of anthropogenic stressors on ecosystem structure
8 and function must be grounded in an understanding of the relationship between natural drivers
9 and the structure and dynamics of ecosystems.

10
11 Disturbances can generally be categorized into two types: external forcings and direct
12 disturbances. External forcings such as climate change and nitrogen deposition will alter
13 ecosystems attributes and processes in ways that are at least partly predictable. With improved,
14 detailed models and understandings of processes the predictions of ecosystem change due to
15 external forces such as climate change will be improved. In addition to forcings, direct human
16 disturbance such as road-building or introducing non-native species will drive ecosystem change.
17 This section describes some of the more comprehensive forcings and disturbance types and their
18 effects on the ecosystem.

20 **2.8.1 Climate Variability and Change**

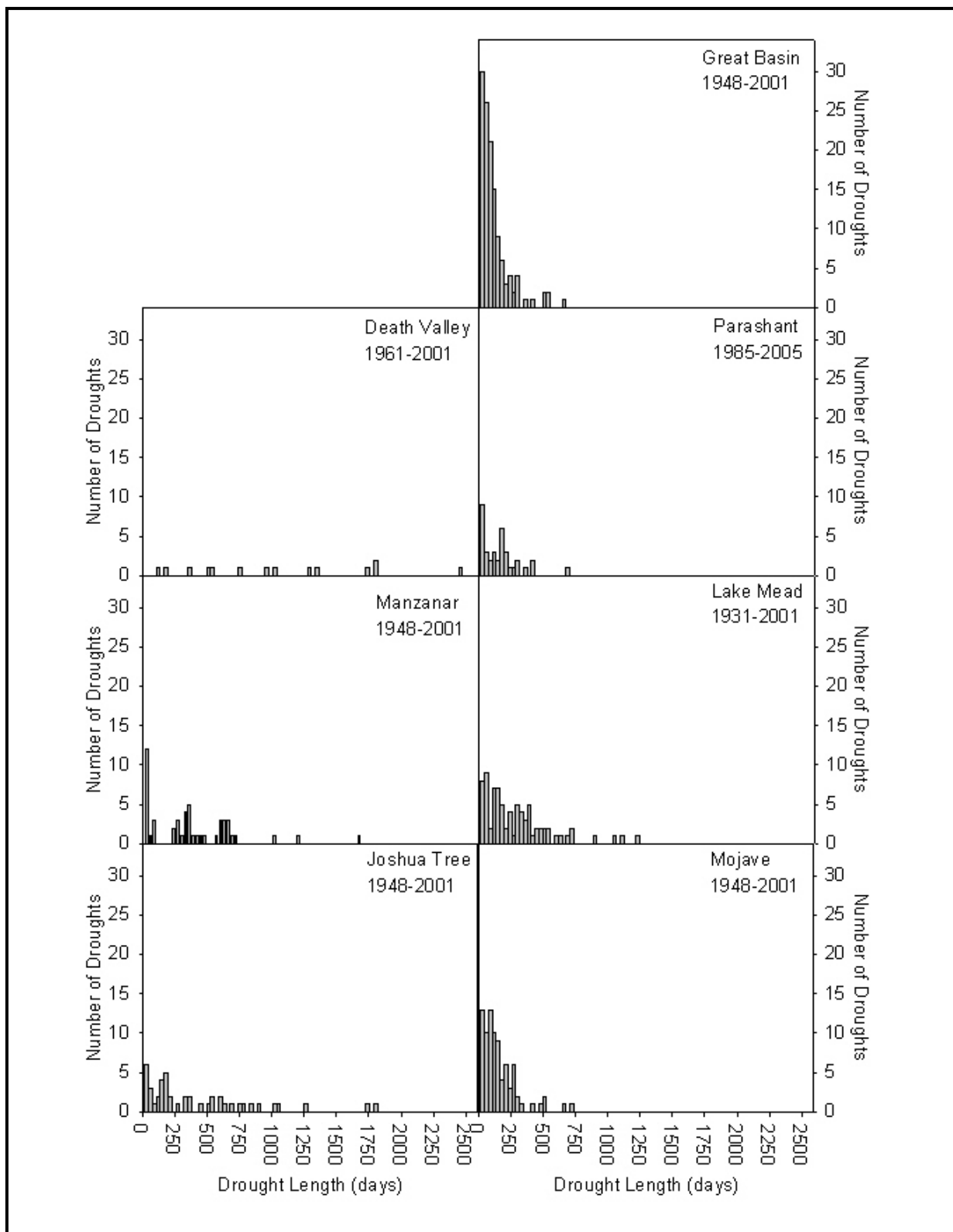
21
22 Climate varies depending on what time scale is used to measure it, for example from brief
23 intense storms to wet winters to multi-year drought to multi-decade wet periods and Little Ice
24 Age cool periods. This climatic variability creates a complex framework for understand past,
25 current, and future features in the desert that are dependent on climate patterns, features such as
26 plant viability, plant-animal interactions, soil moisture availability, and persistence of ephemeral
27 and perennial streams. On top of the background of climate variability is superimposed the short-
28 and long-term effects of climate change caused by human effects such as heat islands in and near
29 cities, insulating effects of increased CO₂ and aerosols, and decreased insolation by haze
30 blankets. The net effect of human-caused climate change has become quite clear: global
31 warming of unprecedented rate (Giorgi et. al. 2001). Isolating the effects of climate change from
32 climate variability is an essential, but daunting, requirement for managing the deserts.

33
34 Monitoring climate to track climate variability and change is essential for the Mojave Network
35 because a large number of ecosystem attributes and processes, described already in this
36 document, depend in some measure on moisture, temperature, and wind speed. Effective
37 monitoring will provide a basis for establishing the variability and change components of climate
38 and will provide a database for projecting hydrologic and biologic health of the system. Having
39 good climatic records provides opportunities for retrospective analyses of significant
40 precipitation pulses (e.g. floods at this time scale) and inter-pulse periods (e.g. drought at this
41 time scale, Figure 43 and 44, respectively). Obviously there are periods of up to 4 consecutive
42 years when nothing above trace precipitation has fallen on at least one site in the Mojave Desert.
43 This type of event was likely to have caused local shifts in plant and animal populations.
44 Conversely, large flood events are also fairly infrequent.



1 Figure 43. Rain events, data from weather stations surrounding 5 Mojave Network park units.

2



1 Figure 44. Drought events in Mojave Network parks, data taken from local weather stations.
2

Variability and change in climate has effects that we can measure locally, and these effects multiply and combine in complex patterns that affect entire populations, species, ecosystems at the regional level. Desert plant and animal communities are highly adaptable to the short-term variability in climate but respond on the scale of millennia to large swings in climate variability, which ultimately drives change in the plant and animal communities in the deserts.

Hydrology: Climate affects groundwater and surface water chemistry, abundance, and temperature, all of which can affect aquatic and non-aquatic biota of the riparian environment. Small changes in mean annual temperature, for instance, can greatly change winter snowfall, altering snowpack and the streams and recharge that are dependent on snowmelt. Changes to stream and lake temperature from changed flow volume or changes in air temperature can affect aquatic species, as can water chemistry, volume, and duration of water in ephemeral systems. Even small changes in climate parameters can have great affects in soil moisture, since a delicate temperature-precipitation-plant transpiration balance governs the availability of this tiny fraction of the water budget, the fraction that is essential to plant life over most of the desert landscape.

Changing perceptions of climate variation and vegetation: The relationship between climatic variation and its influence on vegetation in the American Deserts continues to be topic of scientific debate. As paleobotanical distributions were constructed, early researchers called into question the paradigms of community composition, structure, and change in North American deserts. Early on, it was thought that the geographic distribution of desert plants remained mostly stable over geological time (Muller 1940) and evolved slowly as the climate became gradually more xeric (*as discussed by* Axelrod 1950, Betancourt et. al. 1990). With the discovery that plant remains found in ancient woodrat middens near the mouth of the Grand Canyon, Arizona could be dated and used to describe desert vegetation communities of the distant past, change in the desert took on new meaning (Martin et. al. 1961). From the data in woodrat middens researchers concluded that plant species were re-distributed across the landscape during the late Pleistocene and that the early Holocene was more dynamic than previously known (Trimble 1989, Betancourt et. al. 1990). Two common extant species, creosote bush and white bursage (*Ambrosia dumosa*), are thought to have appeared in the current floristic region of the Mojave Desert within the last 11,000 years (Spaulding 1990) and in much of the area as recently as 6,000 years ago (Koehler et. al. 2005); as a floristic entity the Mojave Desert did not exist before that time (Grayson 1993). Likewise, Great Basin valley floors were occupied by pine forests as recently as 9,000 years ago, and the sage desert is a relatively recent floristic entity. Although vegetation (and animal) change in response to climate variation is well supported by paleontological records such as those of middens and pollen studies of ancient sediment, empirical evidence for the redistribution of plant species during historic times is sparse. This is partly because such change occurs somewhat slowly relative to our life times – over large areas (entire valleys) such change is probably in excess of decades. Thompson et. al. (2004) have summarized changes in Great Basin and Mojave deserts over several thousand years using pollen and midden data, and by inferring bioclimatic data associated with modern plant distributions, have assigned changes in climate characteristics over those time periods. This approach has potential for forecasting future vegetation changes in response to climate variability and change, although rapid climate change may impose conditions that require more rapid migration rates than ever experienced in the past.

1 This brief description of prehistoric plant distributions and how they changed in response to
2 climate variation indicates that increases or decreases in the amount, frequency or timing
3 (seasonality) of precipitation or similar variations in temperature have overriding effects on the
4 deserts as we know them. Indeed, our prehistory of the natural world is the only empirical record
5 of such change that is possible. Only in the past several decades have detailed climatic and
6 ecological records been available to unravel the complicated interactions between biotic and
7 abiotic community constituents. The drastic changes, such as have occurred across the Mojave
8 Desert and Great Basin during the past 11,000 years, happen as the result of responses by
9 individual plants and animals which are manifested as population changes and ultimately
10 changes in the distributions of species affecting the composition of communities and ecosystems.
11 The responses of individuals occur as individual or population responses to factors that affect
12 production of propagules and their viability, germination (also hatching or gestation),
13 establishment (early survival of hatchlings or neonates), and survival to reproduction. Any factor
14 that changes the output of these life stages has the prospect of changing population status and if
15 such changes are strong enough populations will either decrease or increase their distributions.

16
17 **Climate change linked to life histories of plants:** Reproduction, seed viability, propagule
18 success, establishment, production and survival to reproduction are all essential for plant
19 populations to sustain themselves through variable climate episodes. Organisms respond to the
20 availability of water, nutrients and temperature at every step of their lives. Even adult plants may
21 respond to variation in climate factors such as the availability of CO₂ and temperature changes
22 (Huxman et. al. 1998, Loik et. al. 2000). Changes in the amount, frequency or timing of
23 precipitation in combination with temperature variation may disrupt the reproduction, viability,
24 propagule success, establishment, or survival to reproduction of some desert species.
25 Furthermore, some plants may be dependent on other organisms for pollination or the dispersal
26 of their seeds. Climate changes may disrupt the life history of those organisms such that they are
27 not capable of fulfilling the roles in the life histories of the plant species that depend on them.
28 Even less clear cut are competitive interactions that may occur among plants in which the ability
29 of neighbor plants (inter- or intraspecific) may usurp resources of plants at early life stages thus
30 affecting the composition of vegetation stands (Miriti et. al. 1998). The scale of disturbances
31 that affects fundamental life history parameters may be important to some species. In deserts,
32 variability in the availability of critical resources is the norm, but the scale of such disturbances
33 is important in species responses.

34
35 For example, some perennial plant species, such as creosote bush, are considered to be
36 opportunistic in their use of available precipitation in that they can respond to the availability of
37 water whether it is available in winter or summer. Thus minor variation in the timing and amount
38 of precipitation would not be limiting to the survival of individuals. However, creosote bush
39 requires warm, continuously wet conditions for the germination of their seeds. Increases or
40 decreases in resources that persist outside the normal realm of variation may cause population
41 level changes. For example, precipitation decreases for up to several years may ultimately result
42 in a lack of replacement such that populations begin to decline. At the other extreme, if
43 precipitation increases such that reproduction or establishment is increased, then populations
44 may increase in abundance. However, if precipitation were to increase outside the requirement of
45 a certain species, then conditions may degrade for the species of concern, and be better for
46 another species which may eventually displace the species that was first observed there.

1 In general, desert-adapted species are resilient to climate variations at the temporal scale of
2 years, but sustained climate variations over several-year periods and longer are more likely to
3 affect plant and animal populations. Establishing the variability in climate parameters that is
4 “okay” for a species, and over what time period and degree of extreme climate values, becomes
5 essential for predicting and understanding climate response on a species level. Because the
6 climate parameters vary complexly and plants and animals interact at various temporal and
7 spatial scales, the problem is quite challenging. The best approach is to monitor climate and key
8 abiotic and biotic parameters.

9
10 **Climatic influences on invertebrate populations** - Because invertebrates experience the
11 environment on a much smaller temporal and spatial scale than larger animals they are good
12 indicators of climate variation (Brussard et. al. 1998). Production of annual plants is closely tied
13 to precipitation (Beatley 1974). The abundance and diversity of annual vegetation is correlated
14 with the abundance of several invertebrate herbivores. During high precipitation years, the white-
15 lined sphinx caterpillar may respond eruptively, and can be seen eating many of the desert annual
16 species, primarily those in the family *Nyctaginaceae* (Grant 1937). The caterpillars eat
17 continuously until they pupate in the soil. While caterpillars, they can process prodigious
18 amounts of vegetation. In high population years, the soil can sometimes look tilled with all of the
19 caterpillars pupating in the soil. When the sphinx moths emerge, they may pollinate many plant
20 species while nectaring within the desert, including the evening primrose (*Oenothera* spp.).
21 Along with sphinx caterpillars, population levels of grasshoppers during favorable climatic
22 conditions.

23
24 Eruptive outbreaks of grasshoppers, and other invertebrate herbivores, can occur when favorable
25 conditions exist, such as an abundance of food in high precipitation years (Belovsky et. al. 1996).
26 In dry areas, such as the desert, grasshoppers tend to eat more predictable plant species (Otte and
27 Joern 1977). However, when precipitation increases, grasshoppers are not so picky and eat what
28 is available (Joern et. al. 1996), leading to greater numbers of grasshoppers due to availability of
29 resources.

30
31 Mormon crickets (*Anabrus simplex* Haldeman) are an invertebrate species representative of the
32 Great Basin. The Mormon cricket is not a true cricket, but behaves more like a grasshopper.
33 Populations develop in shrub-steppe communities in the Great Basin. The cricket is known to
34 feed on sagebrushes and when grasses and herbaceous plants develop, they climb the plants to
35 reach the nutritious propagules (USDA 1994). Outbreak densities of Mormon crickets have been
36 recorded and have lasted from five to 21 years. The exact nature of cricket outbreaks is not
37 known, but variations in weather have been suspected. It has been observed that after prolonged
38 periods of rain, snow, or daily freezing temperatures, numbers of crickets in the nymphal stage
39 have declined (USDA 1994).

40
41 **Climatic influences on vertebrates:** Reptile communities are diverse and abundant in deserts.
42 Much of their success can be attributed to a suite of traits that enable them to play ecological
43 roles very different to those of avian and mammalian communities. Unlike endotherms, which
44 use internal heat production to maintain high, relatively constant body temperatures, reptiles are
45 ectothermic- meaning their body temperature varies with the thermal characteristics of their
46 environment (Brown 1986). Most desert reptiles require a narrow range of relatively high body

1 temperatures, and they employ behavioral mechanisms, such as basking, to attain these activity
2 temperatures. Associated with the differences in thermoregulatory and activity patterns, reptiles
3 have a much lower energy requirement than those of birds and mammals within the same
4 ecological community.

5
6 The physiological and behavioral traits of reptile species are noteworthy in comparison to birds
7 and mammals. The variable metabolic rates that reptiles have are capable of much more efficient
8 use of energy and other resources than their warm-blooded counterparts. Therefore, a habitat or
9 food resource that could sustain only a small population of birds or mammals could potentially
10 support a much larger population of lizards, snakes, or tortoises (Brown 1986).

11
12 The interaction of reptile communities and desert ecosystems may be one major component to
13 understanding the biotic and abiotic thresholds that will sustain desert life. Pianka (1973), in a
14 study of North American desert lizard assemblages, found that ecological time, spatial
15 heterogeneity, length of growing season, and amount of warm-season productivity were related
16 to the number of species occurring in the area. The most important was spatial (mainly
17 vegetative) heterogeneity of the environment. He suggested that the effect was indirect and that
18 climatic variability allows the coexistence of many plant life-forms, the variety of which in turn
19 controls lizard-species numbers. However, additional studies suggest that the most important
20 variables influencing reptile communities seemed to be plant species diversity and mean annual
21 precipitation.

22
23 As a general rule, most widespread species show substantial geographic variation in genetic,
24 morphological, ecological, physiological, and behavioral traits (FWS 1994). This is largely
25 attributed to natural selection favoring different character states in different climates and biotic
26 communities (Darwin 1859), or genetic drift (Wright 1931). The desert tortoise, is no exception
27 to this generalization, because groups of populations within the Mojave region exhibit different
28 habitat preferences, food habits, periods of activity, selection of sites for burrowing and egg-
29 laying, and social behavior (FWS 1994). Desert tortoises are well adapted to living in a highly
30 variable and often harsh environment. In adverse conditions they retreat to burrows or caves
31 (Figure 45), at which time they reduce their metabolism and loss of water and consume little
32 food. Adult desert tortoises lose water at such a slow rate that they can survive for more than a
33 year without access to free water of any kind (FWS 1994). Desert tortoises can balance their
34 water budgets and have a positive energy balance, providing the opportunity for growth and
35 reproduction (Nagy and Medica 1986).

36
37 Over the past three decades, scientists have noticed a steady decline in desert tortoise populations
38 in several parts of the southwestern United States. Declines became so precipitous that in
39 August 1989, the USFWS listed the Mojave population of this species as “Endangered” under
40 the emergency provisions of the Endangered Species Act of 1973, as amended. Subsequently, in
41 April 1990 the USFWS permanently listed the Mojave population of the desert tortoise as
42 “Threatened.” Populations have declined in many areas due to two main human attributable
43 reasons: the direct loss of individuals and habitat degradation / fragmentation. Individual
44 tortoises are lost due to poaching, collection for pets, military activities, vehicular impact, and



Figure 45. Desert tortoise (*Gopherus agassizii*) emerging from burrow at Joshua Tree National Park. (NPS Photo)

livestock trampling. Habitat degradation and fragmentation occur mainly through the spread of urban sprawl, mining, roads, and agricultural development. In addition, desert tortoise populations are also declining as a result of predation, recent encroachment by ravens, and the occurrence of diseases such as the upper respiratory track disease.

The desert tortoise may be affected by climatic change that results in limitations for animals to fulfill their life history requirements to sustain populations. This species offers an opportunity to explore this possibility hypothetically because the gender of desert tortoises is actually determined in the egg by exposure to specific temperature averages, and this is known as “temperature determined sex”. Depending on the average temperature desert tortoise eggs are exposed to during incubation offspring may be all female (high temperatures), all male (low temperatures) or 50% male and 50% female (average temperatures)(Rostal et. al. 2002). Therefore if climate changed such that tortoises could not find microsites providing both male and female offspring on a population level, then it is possible that the population would eventually become so skewed as to become dominated by a single sex and thus inviable. If this were to happen, then the distribution of the species could shrink or become locally extirpated if it were not able to migrate to more equitable climate. Alternatively, if temperatures changed such that more areas were available for producing offspring in sex ratios sufficient to support populations, then a previous biophysical constraint could be released and the geographic distribution of the species could be expanded.

1 In response to the declines of desert tortoises and other reptile species, scientists and land
2 managers have attempted to create a recovery and monitoring plan that would exhibit upward
3 trends or stabilization in population numbers. To accomplish this goal, it is essential to
4 understand the relationships and interactions between the biotic and abiotic components within
5 this unique desert ecosystem. For example, to fully understand if the upper respiratory tract
6 disease (URTD) plays a significant role in the decline of desert tortoise populations, it is
7 necessary to understand what the driving ecological components are and what interactions they
8 possess. URTD is currently stated as being a major cause of mortality in the western Mojave
9 Desert and perhaps elsewhere (FWS 1994). However, predisposing factors such as habitat
10 degradation, poor nutrition, and drought are also likely involved (Jacobson et. al. 1991). Drought
11 and concomitant poor nutrition have the potential to compromise desert tortoises
12 immunologically and, therefore make them more susceptible to URTD.

13
14 To fully understand the process of this disease and its interactions with wild tortoise populations,
15 scientists must first understand the signs of the disease, current and historical prevalence,
16 responsible pathogen, transmission, biotic and abiotic factors responsible for influencing any
17 stage of the disease, as well as addressing possible adaptations the pathogen or disease may
18 provide for desert tortoises. Understanding this process usually proves to be very problematic
19 due to lack of information and coordination between scientists.

20 21 **2.8.2 Fire Variability**

22
23 Fire is widely accepted as a natural process in Great Basin habitats and has been used as a tool to
24 manipulate forage for livestock over large areas. But because of the invasion of the alien annual
25 grasses, red brome in the Mojave and Sonoran Deserts and cheatgrass in the Great Basin Desert
26 (Salo 2004 and Mack 1986, respectively), fire frequencies and intensities have increased and fire
27 has become a resource management problem throughout low elevations in the Sonoran, Mojave,
28 and Great Basin deserts alike (Brooks and Pyke 2001). Prior to the invasion of the brome grasses
29 fires were not considered to be an important low elevation ecosystem process (Humphrey 1974).
30 With the invasion of these now ubiquitous species, fire has become a very real threat to desert
31 environments and the animals that inhabit them (Brooks and Esque 2003, Esque et. al. 2003).
32 Fuel and fire hazard maps do not currently exist for many of the plant communities in the arid
33 southwest United States (Brooks et. al. 2004).

34
35 Fire occurrence varies in response to elevation, seasonal precipitation, natural vegetation type,
36 the presence or absence of invasive plants, and proximity to roads (DeBano et. al. 1998). When
37 fuels are available, fire depends on local weather conditions such as humidity, and wind direction
38 and velocity. Finally, if all other conditions are conducive to fire, then an ignition source is
39 required which may exist as “dry” lightning, or human-induced sources such as sparks from
40 small motors, super-heated undercarriages of motorized vehicles, cigarettes and fireworks and a
41 multitude of other sources (Swantek et. al. 1999).

42
43 Fire risks include the direct loss of vegetation that can be very slow to recover (Billings 1990,
44 Brooks 1998, Esque 2004), changes in seed banks, and losses of wildlife species of special
45 concern (Esque et. al. 2003). Fire can directly affect soil structure and the massive loss of
46 vegetation cover can affect soil erosion and siltation. Montane habitats in the Great Basin are at

1 risk; especially because of more abundant surface water, complications of erosion and siltation in
2 watersheds is an important consideration. Loss of soils is a risk wherever fires occur, but is
3 particularly important where riparian obligate vertebrates and invertebrates are concerned as
4 their habitats can be completely inundated by siltation under severe conditions. Ultimately all of
5 these factors change the biophysical environment across burned sites creating openings for
6 invasive species, difficulty for establishment of native plants, lack of cover and forage for
7 wildlife, changes in nutrient availability and cycling and ultimately change disturbance regimes
8 that can result in process change that shapes these communities as we know them.

9
10 Fire risks vary by vegetation type because of differences in the amount of fuel and the structure
11 of vegetation (e.g. fuel) can affect fire behavior. The vegetation structure and composition vary
12 greatly between desert scrub habitats, woodlands, forests and alien annual grass communities.
13 The presence of fire can be discussed in relation to elevational zones based on vegetation.
14 Although empirical evidence is not available due to a lack of sufficient trees that record fire
15 records, fire is thought to have been relatively rare in warm desert scrub communities
16 (Humphrey 1974). Salt scrub communities and Mojave Desert scrub characterized by saltbush,
17 creosotebush, and white bursage experience fire infrequently because of the low amount of
18 vegetative cover in these habitat types. Fires probably burn out quickly for lack of fuel
19 abundance and continuity. However, the amount of vegetation and thus fuel can change with the
20 occurrence of invasive plant species. Blackbrush communities, frequently interspersed by Joshua
21 trees, are considered to be relict populations in the southern parks of the Mojave Network, but
22 are slightly more widespread and expansive in northern parks. Fire must have been inherently
23 rare in blackbrush communities; blackbrush is common and widespread, yet extremely slow to
24 recover from fire in the southern Great Basin and Mojave Desert (Callison et. al. 1985).
25 Sagebrush stands are increasingly at risk to fire and fire return intervals have decreased in recent
26 decades. Furthermore, once fires occur in sagebrush stands, there is now less chance that the area
27 will return to the former vegetation type (Allen and Knight 1984). Pinyon-juniper woodlands are
28 known to sustain high intensity fires and probably have always been prone to such fires (Barney
29 and Frischknecht 1974), especially in dense stands. Also, because these communities occur
30 mostly on the slopes of mountain ranges, lightning strikes are an ever-present ignition source.
31 Forested plant communities are only found on the largest mountain masses in the Sonoran and
32 Mojave deserts proper and as such fires are not a large threat to the Mojave Parks. Those forest
33 fires that occur on Lake Mead National Recreation Area should really be considered part of the
34 Colorado Plateau ecosystems. Great Basin National Park, however, has sufficient forested cover
35 to warrant forest fires as a real threat to their high elevation forests including even bristlecone
36 pine stands that usually grow on such rocky terrain as to preclude the rapid and expansive fires.

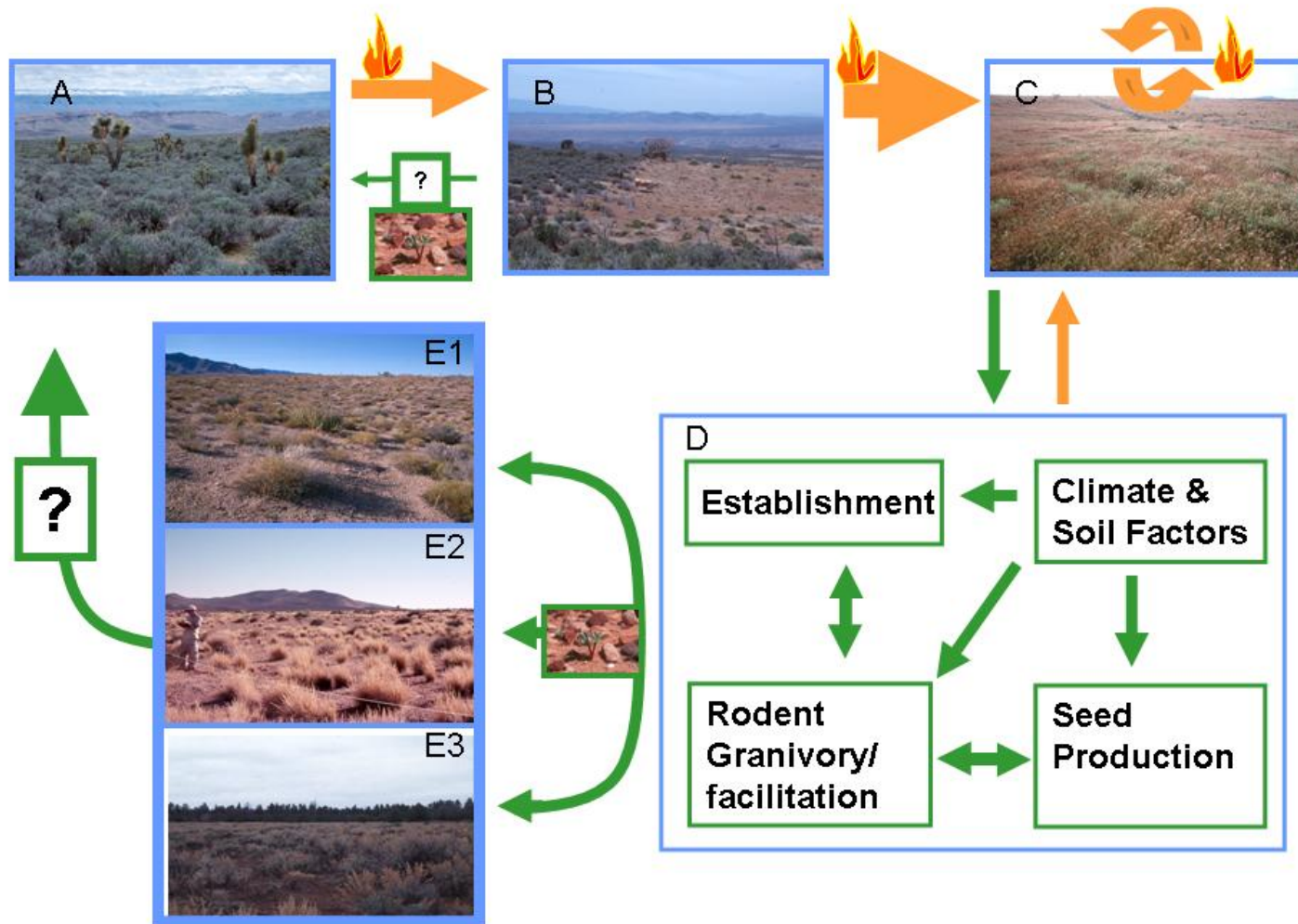
37
38 The recovery of desert shrubland communities from fire depends on a variety of interrelated
39 factors including short and long-term climate factors, plant species, soil conditions, and complex
40 interactions with granivores and herbivores. The long-term outcome of vegetation change may
41 be multi-directional as a result of the complex interactions in the environment (Figure 46,
42 *modified from Esque et. al. In Prep.*). Blackbrush stands are perhaps the most severe of
43 examples for natural restoration of burned desert plant communities, because blackbrush does
44 not recover from fire (Callison et. al. 1985). Figure 46A represents an undisturbed blackbrush
45 stand. Although such sites are thought to be of great antiquity, there is currently no way to
46 determine the age of such stands because individual blackbrush shrubs are clonal (Schenk 1999)

1 and older portions of clones deteriorate beyond recognition. When fire is introduced into such
2 stands, there is a loss of woody vegetation and the edges of such burns can be visible for at least
3 40 years (Webb et. al. 2003). Under most circumstances burned areas are invaded by brome
4 grasses (Figure 46B), thus initiating a grass/fire cycle that is a positive feedback system
5 promoting more fires (D'Antonio and Vitousek 1992). Observations over the past 2 decades have
6 shown that a return to shrubland after fire in arid zones is unusual and in the absence of
7 intervention will more likely tend toward an invasive annual grassland. After only 2 or 3 such
8 fires (Brooks et. al. 2003), large areas may be dominated by brome grasses with few woody
9 shrubs such as the photo (Figure 46C) from Parashant National Monument.

10
11 Once a large area is devoid of shrubs, seed sources become more distant with the increasing size
12 of repeatedly burned areas, and the biophysical and nutrient cycling aspects of the landscape may
13 be largely altered. Comparing Figure 46C to 46A indicates that physical heterogeneity is reduced
14 with greater insolation and more bare ground is exposed to raindrop energy which changes
15 erosion and infiltration rates. Furthermore, nutrient cycling may be changed with the loss of
16 woody plants that sequester carbon and nitrogen over long periods of time (Evans et. al. 2004).
17 This in turn must affect the availability of food plants for most herbivores, granivores and
18 pollinators, and all species that depended on the formerly diverse plant community. Virtually
19 every aspect of these sites has changed. This in turn will affect all processes.

20
21 Figure 46D represents the beginning of natural recovery (without human intervention) of such
22 sites. For species that are windblown seed sources may be effective with great distance.
23 However, many desert shrub species have seeds that do not appear to have any means of passive
24 locomotion such as appendages that facilitate wind dispersal or attachment to animals.
25 Alternatively, several of these heavy and large-seeded species may be transported by animals
26 that are usually only credited as seed predators (granivores such as ants and rodents). The
27 functional group most frequently named granivores quite possibly should be called granivore-
28 facilitators due to the prospect that their activities may promote the advance of seed germination,
29 and establishment of perennial plant species. These types of activities have been demonstrated in
30 several other systems (VanderWall 1990) and likely are widespread in deserts as well. Seed
31 availability depends on plant species, climatic conditions, the status of animal populations
32 (Figure 46D). Once seeds are released they depend on similar conditions, but in different ways.
33 The trajectory of the flora at any particular site likely depends on complex non-linear interactions
34 of all the factors not listed in this model (Schwinning and Sala 2004 or Reynolds et. al. 2004)
35 and may ultimately promote a variety of vegetation communities depending on geography and
36 conditions during recovery (Figure 46E, 1, 2, and 3). Figures 46E1 and 2 represent recovery in
37 Mojave Desert sites, while Figure E3 represents recovery in Great Basin plant communities.

38
39 Changes in vegetation from mechanical disturbances and soil compaction may take 70 to 100
40 years to recover to former vegetation cover values (Webb and Wilshire 1980). It appears that the
41 same may be true for recovery from fire. Even once cover has rebounded, the species
42 composition of such sites is not the same as that observed on undisturbed sites and may take
43 centuries to recover (Lovich and Bainbridge 1999). Unless something is done to change the
44



A. Figure 46. Shrub and fire model (*modified from Esque et. al. In Prep*).

distribution and abundance of brome grasses, the prognosis is not good for the return of blackbrush and some other shrub species over large areas of desert biomes. This is indicated by the question marks on the return arrows toward the original blackbrush community.

2.8.3 Invasive Species

Ecosystems are naturally dynamic in terms of the species that inhabit them, but it was human travel that facilitated transport of plants and animals across natural barriers and invasion of completely new areas devoid of natural constraints (e.g. Elton 1960).

It is generally accepted that plants and animals will live to maturity and reproduce indefinitely in the presence of significant resources (water, food, space, etc.) . However, resources in any system are finite. The struggle to procure the necessary amounts of limited resources is known as competition. It is predation and competition for resources which keep population sizes in check. An introduced species is considered invasive if it is more adept than native species at procuring resources, and is not significantly affected by predation, thus advancing unchecked. Without predation or competition this *invasive* species is free to grow and reproduce, exhausting the resources which native species require to exist.

Invasive species, especially plants, have become problems for managers of public lands. Invasive species may out compete native species for rare resources, and possibly more importantly may change the frequency or intensity of process such as fire and subsequent soil erosion. In the case of animals, we may consider feral equids which interestingly are also federally protected. But animal parasites may also be included among invasives – such as the Asian tape worm that parasitizes the endangered Mohave tui chub. Of particular note in the Mojave Network are tamarisk (*Tamarix ramosissima* and *T. athel*), knapweeds and star thistles (*Centaurea* spp.), tall white top (*Lepidium latifolium*), cheatgrass, red brome, a great variety of mustards the most widespread and recent problem being Sahara mustard (*Brassica tournefortii*).

The concern with species invasion is not merely one of aesthetics or nostalgia for our parks the way we knew them. Invasive species have the potential to completely change ecosystem processes (Billings 1990). These pests are mostly introduced exotic species and lack natural predators or constraints to reproduction. Without natural control, they are able to out-compete their native counterparts for necessary resources. This makes invasive species a particularly difficult management problem because attempts at removal most often involve putting stress on the ecosystem, a condition which favors the better competitor.

An invasion can take several forms, though nearly all those we are concerned with are human mediated. Many successful invasive species of plants were brought to this continent in deliberate attempts to establish them for economic gain. Others arrived as waifs, albeit in bulk shipments, associated with agricultural industry and have been on the continent since the earliest explorations (e.g., *Erodium cicutarium*, Mensing and Burne 1998). Ironically, some were introduced to inhibit soil erosion or create wind breaks (*Tribulus* sp., and *Tamarix* spp., respectively). More recently many invasives have escaped from gardens where they were brought as cultivated ornamental plants (e.g., fountain grass - *Pennisetum setaceum*). Many of the plants that invade the Mojave and Great Basin deserts originally evolved in the arid to semi-

1 arid Mediterranean regions of Southwestern Europe and the Northern regions of Africa, both
2 with similar temperature and precipitation regimes. In this new system, however, those species of
3 consumers and competitors which evolved with the invasive species are not present to limit
4 growth. Once in the wild, natural dispersal vectors and human interaction spread the seeds to
5 new areas. For example, checking your socks after a quick hike through the Mojave will reveal a
6 plentitude of invasive seeds and very few native seeds.

7
8 Harsh conditions prevent most animals brought by humans from surviving for long enough to
9 reproduce, and the same conditions prevent invasion from populations surrounding the deserts.
10 Invasive animal species in the Mojave Network are almost always human introduced. Feral
11 equids (e.g. horses and burros), for example, were brought to the Americas from Europe and
12 naturalized, so much so that they are considered by the general population to be native.

13
14 **Invasive Plants:** Much attention has been given to the occurrence of invasive plants within the
15 Mojave and Great Basin national parks. Invasive annual plants generally develop earlier and in
16 the presence of less moisture than native annuals. For example, Sahara mustard, an invasive
17 plant found in most Mojave Desert communities, will germinate and develop well before
18 competing natives, and grow into a wide basal rosette which prevents the sun from reaching
19 competing seedlings underneath it, effectively crowding them out.

20
21 Concern is also due in large part to the recent, invasion of alien annual grasses (Hunter 1991,
22 Kemp and Brooks 1998). These grasses are common in most desert upland communities and
23 include red brome, cheatgrass, mediterranean grass (*S. barbatus*). In addition to drawing usable
24 space and resources away from native annuals, grasses can grow in thick clumps capable of
25 carrying a fire in an area that has not been adapted for the effects of wildfire (Brooks and Pyke
26 2001). It has also been suggested that the normally absent thick patches of vegetation have a
27 negative effect on smaller fauna, making movement difficult and affecting vision (Esque and
28 Schwalbe 2002). There is also concern about the effects of annual grasses on the diets of primary
29 consumers. Large clumps of invasive annuals present ready forage for desert herbivores, but the
30 nutritional value to those animals, which have thrived on native vegetation, is not clear.

31
32 Invasive perennials which are causing concern are mainly found in riparian areas. For example,
33 several species of saltcedar (*Tamarix ramosissima*, and *T. athel*) have become established in the
34 springs and seeps of network parks. These trees are fire resistant, root sprout when cut, provide
35 little nutritional value as forage, and release accumulated salts into the soil, making the soil
36 unusable for many other plants. In addition, saltcedar have large taproots, and can effectively
37 monopolize the water supplies coming from a spring, which can crowd out native plants and
38 leaves less water available for animal use.

39
40 Single-leaf pine and Utah juniper are considered by some to be invasive in a very different way.
41 These two evergreen trees are the defining vegetation for the pinyon-juniper community type in
42 the Mojave and Great Basin deserts. It has been posited that the pinyon-juniper community has
43 been gradually spreading downward, from the higher elevations usually inhabited, as a result of
44 climate change.

Invasive Animals: There have been relatively few invasive animals found in the Mojave and great basin deserts, probably due to the inherent environmental extremes. The introduced wild equids (burro and horses) are perhaps the most visible. Although not technically invasive species, livestock such as domestic sheep and cattle have been present for about 150 years in most Mojave Network parks and their vicinities. These animals can reduce the biomass of vegetation throughout landscapes. Over time this can cause severe increases in erosion as well as a shift in the dominant vegetation, favoring those plants which respond well to grazing (mainly grasses and sub-shrubs). The introduction of livestock and overgrazing are also linked with the establishment of invasive plant species (e.g. the brome grasses) and consequent shifts in fire regimes that ultimately can influence disturbance regimes in such a way as to change whole landscapes.

The few native fishes found in the Mojave Network are at very high risk to invasive fish species. The invasive fish have been frequently dispersed by humans in an effort to control mosquitos, or for food or sportfishing. For example, three native fish species at Great Basin National Park including the mottled sculpin (*Cottus bairdi*), speckled dace (*Rhinichthys osculus*) and the red-sided shiner (*Richardsonius balteatus*) were extirpated by non-native fish introductions to improve recreational fishing opportunities. Park staff will attempt to repatriate them in the future.

Another potentially threatening form of invasive is not a fish but a parasitic worm. The endemic Mohave tui chub (*Siphateles bicolor mohavensis*) once ranging throughout the Mojave River drainage is now isolated to a few isolated ponds at Mojave National Preserve, Camp Cady, and China Lake Naval Air Weapons Station. Recently the Mohave tui chub has been found to be infected with the Asian tape worm (*Bothriocephalus achelognathii*, Hughson and Woo 2003) which is a fish parasite that is rapidly spreading across the United States. The tape worm is known to negatively affect other fish in the Cyprinidae family. The tape worm is not known widely to infect other desert fishes (e.g., Saratoga pupfish - *Cyprinodon nevadensis nevadensis*) none-the-less, other native desert fish species are at risk, because the vector for the tapeworm is unknown. One possible vector for the tapeworm is the mosquitofish (*Gambusia affinis*) that, while not invasive on its own, is frequently dispersed by people in an effort to control mosquitos. The Bonneville cutthroat trout was recently repatriated to streams in GRBA at great expense due to the cost of eradicating non-native fishes in the area.

Other invasive species found in the parks include the American bullfrog (*Rana catesbeiana*), rainbow trout (*Oncorhynchus mykiss*), and European starling (*Sturnus vulgaris*). Bullfrogs, kept as pets and released into sensitive riparian areas, have been classified as invasive in many places across the country. Rainbow trout are often stocked in Western bodies of water for sport fishing. Both bullfrogs and rainbow trout are voracious eaters, often eating the larvae of competing species as well as any other available food source. This is especially troublesome in an ecosystem where riparian areas are sparse and recruitment of native species from other areas is near impossible. The European starling, which has made its way throughout most of the country from a few hundred animals released in the Northeast, has been shown to be a very good competitor for nest sites, reducing valuable breeding ground for native birds.

2.8.4 Disease and Parasites

Plants and animals that are subjected to physiological stress may have increased incidence of disease and parasitism. Physiological stress may be brought on by injury, drought or starvation, or disruption of important routines by disturbance. Situations that increase the likelihood of inducing stress include but are not limited to climate variation, competition with introduced livestock, introduction of unfamiliar disease or parasites, increased contact with humans, plant invasions, and habitat fragmentation. Studied for long enough with sufficient detail, disease and parasites would probably be found for most vertebrate animals and invertebrates as well. The following sections highlights disease and parasites that are known for some high profile desert animals.

In desert terrestrial systems, disease and parasites are frequently linked to drought related stress. Perhaps the best known relationships between an organism and its diseases and parasites are represented by the body of knowledge collected for the desert bighorn sheep. Symbol of wild places, a renowned hunting trophy, and immortalized in ancient rock art (even at sites where it has been locally extirpated for at least decades), the desert bighorn sheep has been studied in some depth (Monson and Sumner 1990). Although some populations have suffered great losses in recent years, other sites in the Mojave and Great Basin deserts have robust populations.

Influence of anthropogenic encroachment on desert ecosystems: Even in harsh desert environments, disease and parasites persist, such as the Asian tapeworm described above. Stress leads to susceptibility to disease and parasites. Sources of stress in the Mojave Network include climate variation, competition with feral and domestic livestock, loss of air quality, disturbance from increased park visitorship and encroachment from nearby urban areas. Because disease and parasites tend to be very host specific, may have multiple hosts at different life stages, and are usually tied closely to the biology of each host, the general discussion of disease and parasites is of little value. Following are a few examples of the challenges of disease and parasites known for some high profile wildlife species in the Mojave Network.

Desert bighorn sheep are known to be susceptible to disease, especially when domestic livestock are introduced into their habitats. Common disease problems that exist with desert bighorn are chronic sinusitis, pneumonia, and psoroptic scapies. Evidence of ecthyma virus, blue tongue, Pasteurella, and parainfluenza-3 virus have been found in declining populations. In fact, unpredictable epidemics are a threat to the survival of the desert bighorn (USFWS 2000). As ungulates, wild and domestic, continue to compete for resources and humans encroach on their feeding and breeding grounds, and reducing connectivity of populations by travel and utility corridors, the potential for disease increases. Desert bighorn are sensitive to many human-induced environmental problems, making them good indicators of land health (McCutchen 1995).

One infamous disease with ramifications for human visitors is hantavirus pulmonary syndrome (HPS). Hantavirus is carried by infected rodents through their urine, droppings, or saliva. The disease was unknown until 1993 when it occurred in the Four Corners area of the western U.S. It was found to be carried primarily by deer mice (Brown and Morgan Ernest 2002). The outbreak of hantavirus in 1993, was the result of linkages between the El Niño events of previous years

1 that caused significant rainfall leading to increased plant production and ultimately increased
2 rodent populations. Factors that could lead to the emergence of greater rodent populations could
3 also be mass human migrations into once sparsely populated desert habitats.

5 **2.8.5 Pollution**

7 Although the Mojave Desert is considered to have superb air quality in comparison to some other
8 regions, areas near urban zones (such as the Los Angeles basin and Las Vegas) or fossil-fueled
9 power plants experience high levels of pollutants (Padgett et. al. 1999). Ozone, sulphur dioxide,
10 nitrogenous compounds, particulates, and many organic compounds are considered to be
11 particularly important attributes that may affect ecosystem process and function (Allen et. al.,
12 1999). Both ozone and sulphur dioxide can directly damage vascular plants and other organisms,
13 whereas nitrogenous compounds become soil fertilizers and may enhance growth of non-native
14 vegetation among other potential impacts (Mun and Whitford 1998, Fenn et. al. 2003). Because
15 nitrogen is limiting in desert soils, increases in nitrogenous compounds could alter the
16 competitive relations among species and thus the composition of plant and soil communities
17 (Allen et. al. 1999).

19 Hundreds of other compounds are present in air pollution, including a huge variety of organic
20 compounds released during application of herbicides or fertilizers or when fuels are incompletely
21 combusted. Deposition of metals such as lead, typically released from combustion of leaded
22 gasoline, and metalloids, in addition to fallout of radioactive elements such as ¹³⁷Cs, have an
23 unknown effect on ecosystem processes and health. Therefore, resource-related monitoring may
24 want to focus on the distribution of these substances in the environment as well as their long-
25 term additions to the ecosystem.

27 Particulates are another type of air pollution of special concern in deserts. Because plant cover
28 and rainfall are sparse, and other factors that stabilize surface soils (rocks, biological and
29 physical soil crusts) are easily disturbed by vehicles, livestock, and other human activities, levels
30 of airborne particulates may have a significant impact on the Mojave Desert ecosystem. Dust
31 storms reduce the highly-valued clarity of the desert air, often obscuring distant vistas in national
32 parks. Eolian transport of sand, silt, and/or clay by wind is one of the dominant processes in arid
33 environments (Breshears et. al. 2003). Dust transport has significant consequences for ecosystem
34 function via effects on soil texture and chemistry (Reynolds et. al. 2001), which affects soil
35 infiltration rates and nutrient concentrations (Breshears et. al. 2003) with possible feedback
36 mechanisms to the overall ecosystem. Accumulation of dust on leaves and stems of desert plants
37 may affect photosynthetic potential and decrease productivity (Sharifi et. al. 1997).

39 **2.8.6 Land Use**

41 Land use in its broadest sense encompasses myriad human activities such as: 1) physical
42 manipulation of the landscape surface, such as road-building, trenching, constructing buildings,
43 military training and testing, and agriculture and grazing; 2) modifications of plant and animal
44 communities, such as introducing predators such as cats and dogs, introducing invasive plants
45 and animals, selective herbivory, and causing habitat fragmentation; 3) and multiplicative
46 effects such as enhanced dust generation from gravel roads, and effects of visitation. In total, the

effect of pronounced land use in the desert environment is to isolate regions such as preserves, parks, and some military lands as relatively undisturbed ecosystem fragments. Each of these fragments has its own land-use effects, but remains in general less disturbed than surrounding areas influenced more heavily by urbanization, agriculture, grazing, and military training. Some of the more pervasive threats from land use are the generation of dust from large constructions sites and training and testing facilities, changes in groundwater chemistry from human habitations and agriculture, soil erosion, and introduction of non-native plants and animals.

2.8.7 Resource Extraction

Resource extraction includes groundwater pumping, harvesting of plants and animals, and mining operations. Of these, groundwater pumping is the most important because in most parts of the desert groundwater is not recharged at a rate commensurate with water use, resulting in drawdown. Drawdown in turn leads in many cases to poorer water quality, reduced stream and spring flow, and ensuing changes in plant and animal communities. Because of slow recharge in many cases, recovery of over-pumped systems may be exceedingly slow. Mining results in visual disfigurement of the landscape, and may enhance dust emissions. Depending on the mining technology and the material mined, there may be fill composed of toxic levels of unusual elements that can be hazardous to plants and animals, and that may be washed off during rainstorms and lead to groundwater. In cases of large, deep mines, the mining may occur below the water table and lead to direct degradation of water quality and quantity. Plants and animals are harvested despite laws to the contrary; high levels of harvesting can lead to pronounced degradation of communities and habitat.

2.9 Summary

Desert biomes of the Mojave Network are dependent on and driven by water availability. Climate parameters such as regional storm tracks and seasonal cyclonic system behaviors are the drivers for precipitation, and interact with topography to determine whether moisture is made available as snow or rain, and in what quantity and delivered at what rate. These factors then combine in various ways with rock and surficial materials to be partitioned into infiltration and runoff, which then become available to biota. Desert biota are adapted to all of the water-available environments, from lakes and streams, to ephemeral washes and springs, wet saline playas, and the vast piedmont and mountain regions that store near-surface moisture in soils. This intricate mosaic of water availability thus is a primary determinant of plant and animal habitat. Plants and animals in turn modify the water available by chemical changes in water, transpiring water, and creating macropores in soil that affects distribution of moisture. This web of water-dependent organisms is delicately balanced and exceedingly sensitive to changes in water chemistry and amount, and yet resilient to those changes that are typical of the long-term natural climatic variability. Human disturbance, whether altering the climate system, mining of groundwater, disturbing surface water drainage systems with roads, or changing soil characteristics by compaction has potentially far-reaching effects on biota of the desert landscape. The changes in biota, in turn, feed back into hydrologic system changes, and can have unforeseen consequences. Because water is at the root of the ecosystems, the most important characteristics of the desert biome are the water availability and quality.

2.10 Future Detailed Conceptual Models

Detailed models that address vital signs and monitoring needs are derived from the landscape-level conceptual models of this report. These component models will specifically address the processes and components relevant for monitoring of vital signs established for the Mojave Network. These models will have many inter-relations and will in part be hierarchical. Models currently anticipated are given below in Table 24 and illustrated in figures 47 through 50.

Figure 47 is an overview of the submodels derived from the Jenny-Chapin model as modified by Miller and Thomas (2004). Each of the three representative areas is later detailed in submodels. The hydrological cycle is further subdivided into a ground water, soil-water and surface water portions of a submodel, because of the very different ways that the hydrological cycle affects parts of the ecosystem.

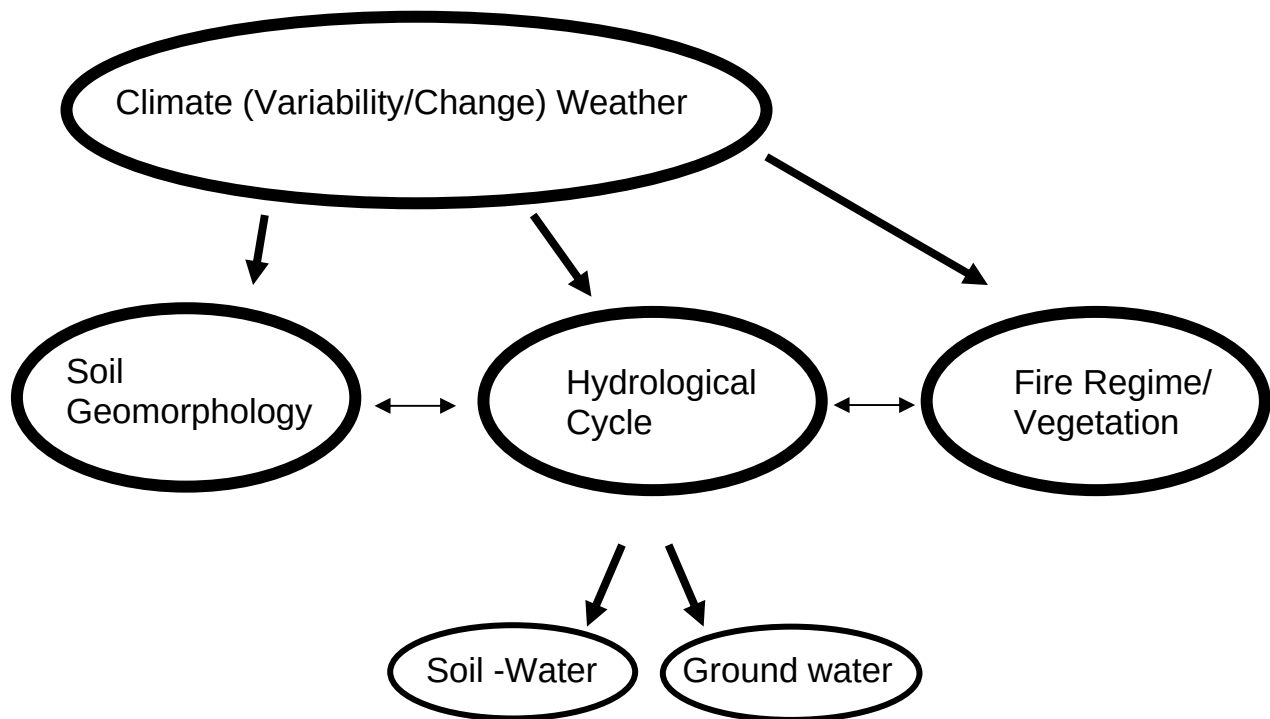


Figure 47. Ecosystem conceptual submodels to be developed for the Mojave Network.

1 Table 24. Examples of key sub-systems that will be modeled in Year 2, some high-level
 2 monitoring issues associated with those sub-systems, and associated vital signs.

Sub-Model	Vital Signs	Components
Park Hydrology	Groundwater Dynamics and Chemistry	Climate Parent material Pumping
	Surface Water Dynamics	Climate Parent material Pumping
	Surface Water Chemistry	Shade/cover Water temperature Pollution Pumping
	Riparian Communities	Invasive riparian plants Precipitation Local land use Invasives
	Riparian Bird Communities	Invasive riparian plants Human encroachment/use Water table subsidence
	At-Risk Populations	Invasive species Habitat loss Loss of food sources
	Cave and Karst Processes	Water chemistry, parent material
Park Soil and Geomorphology	Soil Chemistry and Nutrient Cycling	Soil structure Plant community Invasive plants Structure/density Salinity levels
	Soil Hydrologic Function	Precipitation Water table level Soil structure
	Soil Erosion and Deposition	Precipitation events Bioturbation Vegetation cover
	Soil Disturbance	Bioturbation Erosion Drought Invasive plants
	Land Use, Land Cover, and Landscape Pattern	OHV use Roads Hiking trails Park buildings and wells

Table 24. (Con't.)

Sub-Model	Vital Signs	Components
Fire Regime, effects and affects	Occurrence of Invasive Plants-Status and Trends	Microclimate Local topography Moisture availability Invasion vectors
	Occurrence of Invasive Plants-Early Detection	Vegetation surveys Control of invasion vectors
	Weather-Basic Meteorology/Climate	Global climate influences
	Vegetation Change	Invasive species Climate change Presence of grazing Disturbance
	Fire and Fuel Dynamics	Fuel loads Alien grass cover Moisture content
	Small Mammal Communities	Available Cover Food stores Abundance of predators

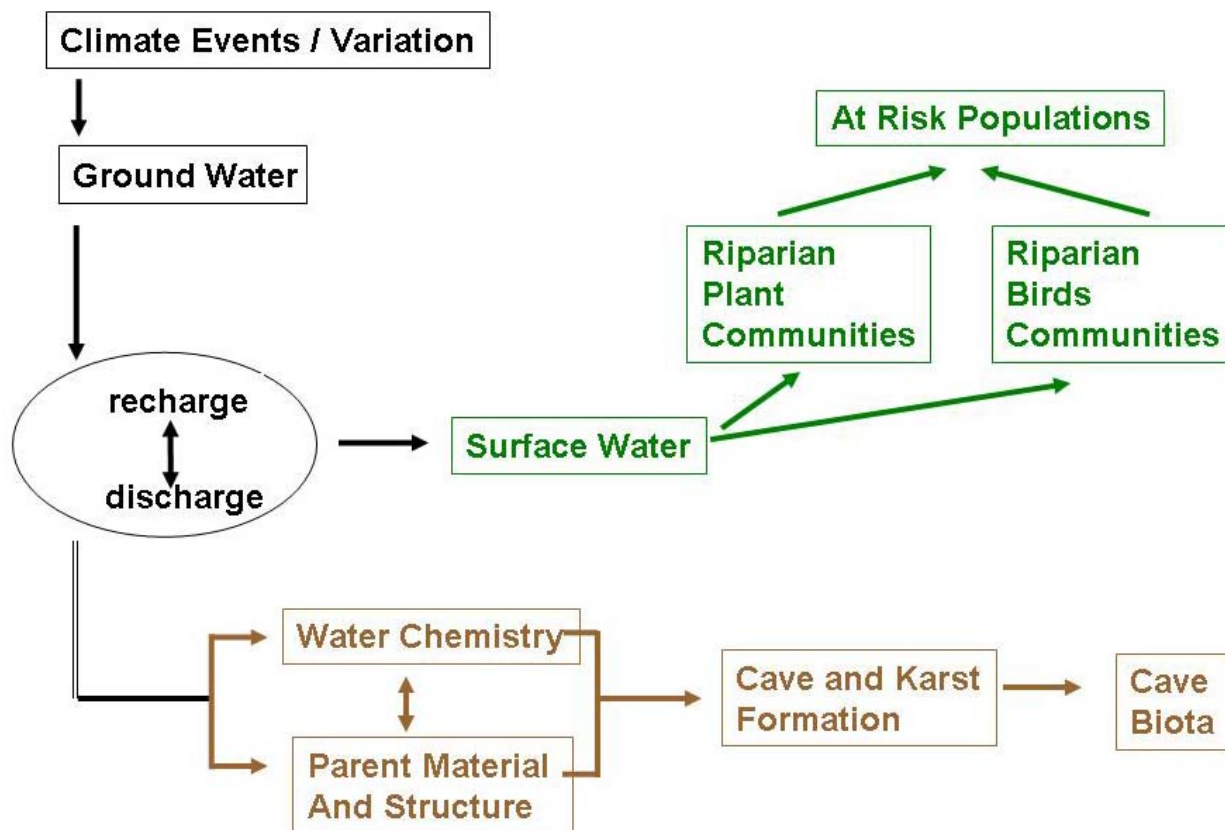


Figure 48. Hydrological submodel describing primary components and processes that in themselves may be used to guide inventory and monitoring work in the Mojave Network.

Generally, new water to the ecosystem enters from the atmosphere as recharge on mountain slopes or the upper portions of piedmonts, and the status of recharge and discharge is a dynamic state depending on climatic factors and more recently groundwater pumping (see Hydrology section, Figure 48). Throughout most of the Mojave Desert, however, some of the groundwater may enter ecosystems from regional aquifers originating some distance from the desert valleys where we normally associate it (e.g. the White River aquifer). Depending on the chemistry of the layers where the water passes (affecting water chemistry), the structure of bedrock materials and the age of the formations these processes may produce cave formations. Work on this submodel will be particularly important at parks with sedimentary bedrock layers and active caves. The surface water submodel describes a system that is also highly variable and susceptible (to varying degrees) to minor changes in climate variation and for some systems individual events. Because surface water is such a rare commodity, vital to many plants and animals, and at risk due to water usage by burgeoning human populations it is imperative to provide detailed submodels for this system and future work is highly desirable.

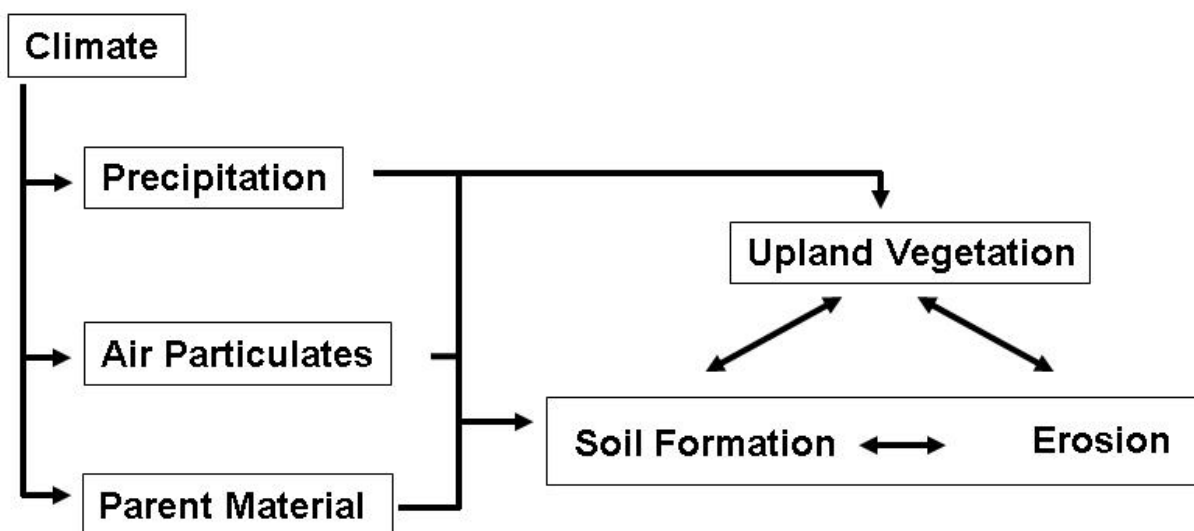


Figure 49. Ecosystem conceptual submodel for soil-water-plant interactions.

The soil-water-plant submodel (Figure 49) is much more susceptible to short term variation of climate responding to individual events such as storms that saturate the soil and the periods between storms when evapotranspiration exceeds precipitation thus affecting the status and health of upland vegetation. The theoretical framework for soil-water-plant relationships and climatic events that drive these relationships is a very active area of current desert research (Schwinning et. al. 2004) and will further developed with detailed models through the inventory and monitoring program for the Mojave Network.

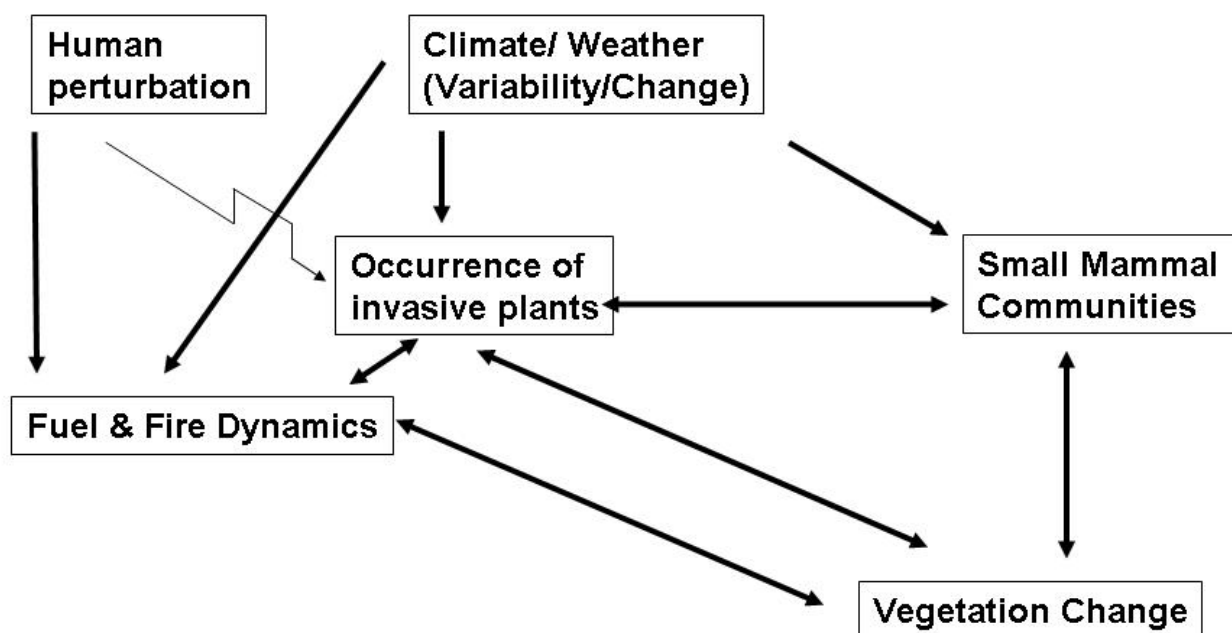


Figure 50. Ecosystem conceptual submodel for fire processes.

Submodels associated with fire (Figure 50) include fundamental ecosystem changes such as the loss/addition of components (e.g. the loss of native vegetation and addition of invasive species) as well as changes in ecosystem process. Although these topics have been studied for two decades in association with cheatgrass fires in the Great Basin, only in the past decade have studies been conducted in Mojave desert shrub habitats. At present, we have described the patterns of change in desert vegetation communities, but there is a great deal we have not quantified about processes. Future detailed models should focus on the mechanisms of plant invasions and how they are related to human perturbations and climate variation, interrelationships between plant establishment/failure and small animal communities, and the response of key vegetation communities to all of these factors.

Chapter 3. Vital Signs

3.1 Introduction

Monitoring seeks to determine the status of and detect trends in ecological indicators of interest (Busch and Trexler 2003). An effective monitoring strategy directly addresses resource monitoring goals (Elzinga et. al. 1998) that are applicable to land managers in determining appropriate actions and measuring success. These monitoring goals have traditionally been vague and reference maintaining or attaining some state of favorable “ecosystem health” or “ecosystem integrity” as their ultimate goal (Busch and Trexler 2003). As the traditional view of the balance of nature has been replaced by recognition that ecosystems are dynamic, variable systems, the use of ecosystem “health” and “integrity” has been criticized (Suter 1993). Further, these terms imply that science has some objective, precise, quantitative definition of a “healthy” ecosystem. Noon (2003) acknowledged the limitations of “ecological integrity,” but contended that, though vague, the term has merit for communicating monitoring goals to managers. We prefer the more value-neutral term “ecological condition,” (Busch and Trexler 2003) because:

A. Desired conditions are set by the managers and policy makers entrusted with the care of the land management unit. An overarching set of ideal conditions is not assumed. For the NPS, these desired future conditions are described in the mission of the park, environmental laws, and enabling legislation. Linking these generally vague mandates for resource management and protection to specific, measureable conditions is the shared task of scientists, managers, policy makers, and the public in whose name these lands are managed.

B. “Integrity” implies a binary assessment of ecological conditions; either the ecosystem has integrity (is functioning) or does not (is not functioning). While thresholds and trigger points play important roles in ecosystem dynamics and monitoring, “ecological condition” better reflects the non-equilibrium character of ecosystems, in which natural disturbances such as fire, flood, and climatic extremes play important roles.

Because the field of potential indicators to assess “ecological condition” is large, monitoring programs must select the best subset of those indicators for ecosystem study, working under such additional constraints as management relevance, budgetary and staffing limitations, and feasibility of implementation. The NPS has termed these ecosystem indicators “vital signs”, reflecting their similarity conceptually to such critical health measures as pulse and respiration. Vital signs may occur at any level of organization (e.g. landscape, population, community) and may be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes). Given this complexity, selecting the best vital signs for monitoring requires a logical, step-wise

Vital Sign

The subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or known condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.

approach. An 8-step approach was taken by the network to the identification, prioritization, and selection of vital signs. This process was designed to allow selection of vital signs at both the park and network level. The MOJN vital signs selection process was:

<u>Steps in Identification, Prioritization, and Selection of Vital Signs for the Mojave Network</u>	
1. Identify ecosystem drivers, stressors, and important processes through development of an initial conceptual ecological model for the network (NPS 2003).	8
2. Hold a series of small, park-based workshops to identify important resources (abiotic, biotic, processes), resources threats, management concerns, monitoring questions and vitals signs for each network park.	10
3. Identify similarities and differences across parks and summarize vital signs, threats, management concerns, and monitoring questions at the network-level within an Access database.	12
4. Review of network-level information by park staff.	14
5. Prioritization of vital signs for each park, by park staff, based on management significance and legal mandate.	16
6. Hold a network-level vital signs scoping workshop to complete scientific review of network-level vital signs and associated information, complete prioritization of vital signs based on ecological significance, and provide additional information helpful to monitoring for high priority vital signs (e.g. partnership opportunities, monitoring objectives).	18
7. Hold a small workshop(s) for network and park staff to initially select a “short list” of high priority vital signs for the Mojave Network of parks.	20
8. Hold a small workshop for network and park staff to select vital signs that the network will focus their efforts on in the next 5 years (to be completed).	22

Steps 1-5 resulted in an initial list of 113 candidate vital signs for the Mojave Network of parks. The initial list of candidate vital signs was reviewed and revised, to a total of 69 candidate vital signs, and initially prioritized through the Mojave Network Vital Signs Scoping Workshop, May 25-27, 2004, in Las Vegas, NV (Step 6). Initial selection of the “short list” of high priority vital signs (N=26) that will ultimately be included in a comprehensive network monitoring program (including monitoring by parks and the network) was completed at the July 2004 meeting of the network Technical Committee (Step 7). Initially selected vitals signs represent a combination of high priority vitals signs at the park and network level. The chapter that follows describes the

process followed by the Mojave Network to identify, prioritize, and select vital signs and presents the network's initial list of vital signs for Phase I. In early FY2006, the Mojave Network will hold a small workshop to narrow down the list of high priority vital signs to those we will focus on over the next 5 years.

3.2 Overview of Vital Signs Identification and Prioritization Process (Steps 2-6)

3.2.1 2003 Geologic Resource Evaluation Workshops at GRBA, JOTR, MANZ, MOJA, and PARA

Geologic Scoping Meetings were held for GRBA, JOTR, MOJA, MANZ, and PARA between May and September 2003. MANZ was discussed only briefly at the MOJA workshop. Workshop participants included park and network staff, NPS-GRD staff, and other non-NPS participants (e.g. USGS, university staff, etc.). Workshop objectives were: (1) to identify the status of geologic mapping efforts in each park, identify data gaps, and develop a strategy for acquiring information to complete baseline geologic maps; (2) introduce participants to the vital signs monitoring program and geologic indicators; (3) identify important geologic resources and related management issues and concerns; (4) identify resource threats; and (5) identify management/monitoring and research questions related to park geologic resources. Candidate vital signs were discussed and identified within the context of the geosindicator checklist initially developed by the International Union of Geological Sciences through its Commission on Geological Sciences for Environmental Planning and revised by NPS-GRD staff (Table 25). The primary workshop product was a final report including a basic description of park physiography and geology, important geologic features and processes, identification of threats and management concerns related to geologic resources, and identification of monitoring and research questions. The results of geologic resource evaluation workshops were used by the Mojave Network in conjunction with the results of other workshops to develop materials and populate databases used at subsequent park-level vital signs scoping workshops. Final geosoping workshop reports are available from the Mojave Network upon request (NPS 2003b, NPS 2003c, NPS 2003d, NPS 2003e, NPS 2004c, NPS 2004d, NPS 2004e).

3.2.2 Park-Level Vital Signs Scoping Workshops

3.2.2.1 1999 Lake Mead National Recreation Area Vital Signs Scoping Workshop

Development of candidate vital signs for the Mojave Network built upon those identified at the Lake Mead National Recreation Area Vital Signs Scoping Workshop, held in 1999 (NPS 1999e). The objectives of the LAME Vital Signs Workshop were to: (1) Provide a peer review of the park's current resource management program including comments on the overall program framework and ecosystem model, current management and monitoring activities; (2) Ensure that functions or processes necessary to maintain ecosystem integrity have not been overlooked in program planning; and (3) Provide direction for a monitoring program that assesses the health of the park's ecosystem including its condition and trend. The majority of workshop participants were scientists (academia) involved in research in the Mojave Desert or a similar ecosystem, represented federal or state agencies that had management or research activities occurring within the boundaries of the recreation area, and NPS staff. Workshop products included a list of reviewed ecosystem/park stressors and associated monitoring questions, and candidate vital

Table 25. Geoindicator worksheet (for Mojave National Preserve) used at geoscoping workshops in Mojave Network parks. Geologic (ecological) importance, degree of human influence, and management significance of selected geoindicators.

Geoindicators Identified in the Ecosystem	How important is the process to the park's ecosystem?	Rank the human impact on the geologic process	Significance to park management
ARID AND SEMIARID			
1. Desert surface crusts and fissures			
2. Dune formation and reactivation			
3. Dust storm magnitude, duration and frequency			
4. Wind erosion			
GROUNDWATER			
5. Groundwater quality			
6. Groundwater level			
7. Groundwater chemistry in the unsaturated zone			
8. Subsurface temperature regime			
9. Karst activity			
SURFACE WATER			
10. Stream channel morphology			
11. Streamflow			
12. Surface water quality			
13. Stream sediment storage and load			
14. Wetlands extent, structure, hydrology			
15. Lake levels and salinity			
SOILS			
16. Soil quality			
17. Soil and sediment erosion			
18. Sediment sequence and composition			
HAZARDS			
19. Slope failure (landslides)			
20. Seismicity			
21. Surface displacement			
22. Volcanic unrest			

0 - Not Applicable (N/A); 1 - LOW or no substantial influence on, or utility for; 3 - MODERATELY influenced by, or has some utility for; 5 - HIGHLY influenced by, or with important utility for; UNK - Unknown; may require study to determine applicability

signs. Candidate vital signs identified at the LAME workshop were adapted, as appropriate, to each individual network park and served as a baseline for subsequent park-level vital sign scoping workshops. The Lake Mead National Recreation Area Vital Signs Workshop Summary is available on-line at http://hrcweb.lv-hrc.nevada.edu/mojn/data/lamewksp_report.htm (Accessed 30 August 2005). A listing of vital signs identified at the workshop are provided in Appendix P.

3.2.2.2 2003 Park-Level Vital Signs Scoping Workshops at DEVA, GRBA, JOTR, LAME and MOJA

Between November and December 2003, the Network conducted park-level vital signs scoping workshops at Death Valley National Park, Great Basin National Park, Joshua Tree National Park, Lake Mead National Recreation Area and Mojave National Preserve. Participation in park workshops ranged from 13-18 individuals representing park and network staff, park cooperators/scientists and park volunteers. Park staff represented various branches/divisions including administration, interpretation, cultural resource management, natural resource management and protection. Workshop objectives were to: (1) identify important park resources; (2) identify important management issues; (3) identify and prioritize park stressors; (4) identify park monitoring and research questions; and (6) identify candidate vital signs. At LAME, the purpose of this workshop was slightly different in light of the park workshop held in 1999 (see above). The purpose of the LAME park-level workshop in 2003, was to review the vital signs, monitoring questions, etc. previously identified and to update appropriate information. Information and candidate vital signs for MANZ were cooperatively developed by the Mojave Network Coordinator and park Superintendent, Frank Hays.

Candidate vital signs at the park-level were identified within 5 broad categories: Air/Climate, Geology/Soils, Hydrology, Animals, and Plants. Issues related to human use were identified within each of the broader resource categories. For each resource category, participants were asked to identify 'specific resources' important to their park and responses ranged from small-scale, discrete resources (e.g. Devils Hole pupfish) to broad-scale ecosystem processes (e.g. geomorphic processes) and resources of value for societal reasons (e.g. charismatic species). This exercise was designed to be a brain-storming session for park staff to provide critical input on those 'resources' and resource issues important to individual park units. For each 'specific resource' identified park staff also identified associated ecosystem stressors, specific threats, management concerns, and monitoring questions. All information provided by participants was captured in an Access database able to be viewed on-screen during the course of the workshops (Figure 51). Fields under Geology/Soils were populated by network staff with information from park geo-scoping workshops and this information was primarily reviewed and revised during vital signs scoping workshops at parks. Park-level databases were merged into a single, network-level database (discussed in section 3.2.3) and used to develop a vital signs framework for the network that addressed both vital signs common across parks as well as vital signs relating to individual parks. A total of 113 candidate vital signs were initially identified for the Mojave Network of parks.

Figure 51. Access database used to present and capture information at park-level vital signs scoping workshops in the Mojave Network, 2003.

Prior to park-level workshops network staff used several sources of information to summarize priority resources, stressors, and resource concerns for the network. Park planning documents were reviewed and summarized and key resources identified through this process were reviewed and revised through park-level vital signs scoping workshops. Documents reviewed included General Management Plans, Resource Management Plans, and Strategic Plans. Ecosystem stressors identified in an early general conceptual model for the MOJN and reviewed through park-level scoping workshops also were prioritized for each park and the network. At each workshop participants broke into small groups and assigned scores (1=low, 2=medium, 3=high) to each park stressor based on significance to management and potential impacts on resources. For each park, scores were summed across all groups to provide an overall park ranking. Scores were summed across parks to identify stressors of most concern at the network-level. Stressors that were prioritized 'high' across the network, meaning they pose a significant threat to natural resources within network parks, were invasive species (#1), water quantity alteration (#2), land use change/development (#3), and air quality degradation (#4). Of note is that 3 parks identified resource management decisions that are incompatible with resource protection as an existing threat to park resources and at DEVA it was considered one of the most significant threats. (Table 26).

1 Table 26. Results from park-level vital signs scoping workshops ranking the relative importance of network ecosystem stressors by
 2 Park, 2003.

Resource Threats ^a	DEVA	GRBA	JOTR	LAME	MANZ	MOJA	MOJN Overall	Mean Score ^b	Priority Order
Air quality degradation	High	High	High	Medium	Medium	High	High	16.6	4
Climate change	Medium	Medium	High	Low	Medium	Medium	Medium	12.5	7
Altered disturbance regime	Medium	High	High	Medium	High	Medium	Medium	14.5	5
Water quality degradation	Medium	High	Medium	Medium	Medium	Low	Medium	12.5	8
Water quantity alteration	High	High	High	High	High	High	High	16.6	2
Land use change/development	High	Medium	High	High	Medium	High	High	16.6	3
Grazing/Agriculture	Medium	High	N/A	Medium	Low	Medium	Low	11.8	9
Resource extraction	Medium	Low	Low	Low	High	Medium	Low	10.2	11
Invasive species	High	High	High	High	High	High	High	16.8	1
Recreation/visitation	High	Medium	Medium	High	High	Medium	Medium	14.4	6
Habitat fragmentation	Low	Low	Medium	Medium	Medium	Low	Low	9.3	13
Disease	Low	Low	Low	Low	Low	Low	Low	7.6	15
Nutrient availability	Low	Low	Low	Low	Low	Low	Low	8.6	14
Increased native wildlife pops.	Low	Medium	Medium	Low	High	Low	Low	9.3	12
Soil alteration	Low	Low	Medium	High	High	Medium	Medium	11.6	10
Additional Stressors Identified^c									
Light pollution		High							
Noise pollution		Low							
Lack of funding/baseline data	High	High							
Resource mgmt decisions incompatible with resource protection	High		Low	Low					
Hazardous waste and materials						Medium			
River Operations and reservoir mgmt.				High					

^a Identified through park-level vital signs scoping sessions and general conceptual model for MOJN.

^b High = score > 15; Medium = score 11-14.9; Low = score < 11.

^c Identified at park-level vital signs scoping workshops by individual parks.

3.2.3 Development of Network-Level Vital Signs and Vital Signs Database

The network designed an Access database to capture information resulting from park-level workshops and facilitate organization of the information for the network-level vital signs workshop (Figure 52). This database was adapted from the NPS Cumberland Piedmont, Pacific Islands, and San Francisco Area Networks. Dr. Steven Fancy, NPS, Monitoring Program Lead, assisted with database development and algorithms for vital signs prioritization. Information obtained from each park-level workshop was reviewed by network staff and similarities and differences between parks were noted. Other information (e.g. management concerns, resource threats, monitoring questions) was also summarized at the network-level and entered into the network database. The populated, network-level database was sent to staff in network parks for review in February 2004.

Figure 52. Screen capture from Mojave Network Vital Signs Scoping Workshop database.

3.2.4 2004 Network-Level Vital Signs Scoping Workshop

The Mojave Network Vital Signs Scoping Workshop was held on May 25-27, 2004 in Las Vegas, NV. Over 60 individuals participated in the workshop representing 15 organizations including federal and state agencies, academic and research institutions, and non-profit

1 organizations. The workshop objectives were to: (1) review identified management and
2 scientific issues, resource threats, and monitoring questions; (2) review, revise, and coarsely
3 prioritize candidate vital signs that would serve as the focus of long-term ecological monitoring
4 at the network and park levels; (3) for the top 20% of vital signs, review justification statement,
5 develop initial monitoring objectives, identify existing protocols and methodologies, identify
6 potential partnerships and cost sharing opportunities, and identify appropriate ecological and
7 operational scale; and (4) create a network of stakeholders united to preserve the most important
8 resources in the Mojave Network. The primary means of providing information and capturing
9 comments during the workshop was an MS Access database (Figure 52).

10
11 Participants were organized into work groups (approximately 10 individuals per group) based on
12 5 broad categories: Air and Geology and Soils, Hydrology, Animals, Plants, and Human Use
13 and Ecosystem. Participants in the Human Use and Ecosystems group represented expertise
14 from each of the other groups. Each work group was assigned specific candidate vital signs to
15 work on and each group was provided a facilitator, recorder, and at least one park staff member
16 with appropriate expertise to facilitate work flow and capture of workshop results. Work groups
17 were combined for specific exercises (e.g. overall prioritization) and information sharing (e.g.
18 workshop introduction, group summary presentations). Criteria for vital signs prioritization were
19 based on management and ecological significance and legal mandate. Weightings for
20 management significance, ecological significance and legal mandate ranking criteria were 40%,
21 40% and 20%, respectively. Criteria for vital signs prioritization in the Mojave Network are
22 provided in Table 27.

23
24 Workshop products were: (1) reviewed and revised management concerns and resource threats
25 for level 2 vital signs; (2) reviewed and revised vital signs for the network (N=69 vital signs) and
26 individual parks (Table 28); (3) prioritized list of candidate vital signs for the network (Table 29)
27 and individual parks; and (4) Supporting information to minimally include the top 20% of
28 network level vital signs (e.g. justification statement, monitoring questions, identification of
29 existing protocols and collaborative opportunities). The Mojave Network Vital Signs Scoping
30 Workshop Report, 2004 is provided in Appendix Q. Report appendices including database
31 output is available on-line at:
32 <http://hrcweb.lv-hrc.nevada.edu/mojn/workshop.htm> (Accessed 30 August 2005).

34 3.2.5 Initial Selection of High Priority Vital Signs (Step 7)

35
36 The Mojave Network Technical Committee reviewed prioritized lists of vital signs for the
37 network and individual parks to initially select a “short list” of high priority vital signs for the
38 network. High priority vital signs on park lists that were not a high priority at the network level
39 were reviewed and discussed based on management and ecological significance (relevance and
40 management information need), potential partnership and cost-sharing opportunities, availability
41 of existing baseline data, and socio-political considerations. The “short list” of vital signs for the
42 Mojave Network and justification for initial selection based on review of prioritized network and
43 park vital signs is presented in Table 30. Ecological justification and monitoring questions for
44 each high priority vital sign is presented in Table 31.

- 1 Table 27. Criteria (management significance, ecological significance, and legal mandate) used
 2 to prioritize vital signs at the Mojave Network at the Mojave Network Vital Signs Scoping
 3 Workshop, May 2004.

Management Significance

The score for this criterion will be based on an evaluation of how well the data provided by the vital sign addresses the following:

- o There is an obvious, direct application of the data to a key management decision, or for evaluating the effectiveness of past management decisions.
- o The vital sign will produce results that are clearly understood and accepted by park managers, other policy makers, research scientists, and the general public.
- o Monitoring results are likely to provide early warning of resource impairment, and will save park resources and money if a problem is discovered early.
- o In cases where data will be used primarily to influence external decisions, the decisions will affect key resources in the park, and there is a great potential for the park to influence the external decisions.
- o Data are of high interest to the public.
- o For species-level monitoring, involves species that are harvested, endemic, invasive, or at-risk biota.
- o There is an obvious, direct application of the data to performance (GPRA) goals.
- o Contributes to increased understanding that ultimately leads to better management

Ecological Significance

The score for this criterion will be based on an evaluation of how many of the statements below you STRONGLY AGREE with:

- o There is a strong, defensible linkage between the vital sign and the ecological function or critical resource it is intended to represent.
- o The resource being represented by the attribute has high ecological importance based on the conceptual model of the system and the supporting ecological literature.
- o The vital sign characterizes the state of unmeasured structural and compositional resources and system processes.
- o The vital sign provides early warning of undesirable changes to important resources. It can signify an impending change in the ecological system.
- o The vital sign reflects the functional status of one or more key ecosystem processes or the status of ecosystem properties that are clearly related to these ecosystem processes. [Note: replace the term ecosystem with landscape or population, as appropriate.]
- o The vital sign reflects the capacity of key ecosystem processes to resist or recover from change induced by exposure to natural disturbances and/or anthropogenic stressors. [Note: replace the term ecosystem with landscape or population, as appropriate.]

Table 27. (Con't.)

Legal Mandate

This criterion is part of 'Management Significance', but is purposely duplicated here to give extra emphasis towards those vital signs and resources that are required to be monitored by some legal or policy mandate. The intent is to give additional priority to a vital sign if a park is directed to monitor specific resources because of some binding legal or Congressional mandate, such as specific legislation and executive orders, or park enabling legislation.

Examples of how to score attributes for this criterion:

Very High:	The park is required to monitor this resource by some specific, binding, legal mandate (e.g., Endangered Species Act for an endangered species, Clean Air Act for Class 1 airsheds), or park enabling legislation that mentions a specific resource to be monitored.
High:	The resource/vital sign is specifically covered by an Executive Order (e.g., invasive plants, wetlands) or a specific Memorandum of Understanding signed by the NPS (e.g., bird monitoring), as well as by the Organic Act, other general legislative or Congressional mandates, and NPS Management Policies.
Moderate:	There is a GPRA goal specifically mentioned for the resource/vital sign being monitored, or the need to monitor the resource is generally indicated by some type of federal or state law as well as by the Organic Act and other general legislative mandates and NPS Management Policies, but there is no specific legal mandate for this particular resource.
Low:	The resource/vital sign is listed as a sensitive resource or resource of concern by credible state, regional, or local conservation agencies or organizations, but it is not specifically identified in any legally-binding federal or state legislation. The resource/vital sign is also covered by the Organic Act and other general legislative or Congressional mandates such as the Omnibus Park Management Act and GPRA, and by NPS Management Policies.
Very Low:	The resource/vital sign is covered by the Organic Act and other general legislative or Congressional mandates such as the Omnibus Park Management.
None:	There is no legal mandate for this particular resources.
Null:	No opinion, or did not score this attribute

1 Table 28. Vital Signs framework for the Mojave Network^a – Revised based on NPS national framework and Mojave Network Vital
 2 Signs Scoping Workshop, June 2004.

Level 1	Level 2	Level 3	MOJN Vital Signs	Specifics	DEVA	GRBA	JOTR	LAME	MANZ	MOJA
Air and Climate	Air Quality	Ozone	Ozone		X	X	X	X	X	X
		Wet and Dry Deposition	Wet and Dry Deposition		X	X	X	X	X	X
		Visibility and Particulate Matter	Visibility and Particulate Matter		X	X	X	X	X	X
		Air contaminants	Atmospheric contaminants		X	X	X	X		X
	Weather/ Climate	Weather and Climate	Basic meteorology		X	X	X	X	X	X
			Patterns of Precipitation		X	X	X	X	X	X
			Surface Radiation Balance		X	X	X	X	X	X
		Windblown features and processes	Windblown features and processes		X		X	X		X
		Glacial features and processes	Glacial features and processes			X				
		Hillslope features and processes	Hillslope features and processes		X	X	X	X	X	X
		Stream / river channel characteristics	Stream / wash channel characteristics		X	X	X	X	X	X
Geology and Soils	Geomorphology	Lake features and processes	Lake features and processes		X	X		X		X
			Playa extent and frequency of inundation		X		X	X		X
		Caves / karst features and processes	Caves / karst features and processes		X	X		X		X
		Volcanic features and processes	Volcanic features and processes		X			X		X
	Subsurface Geologic Processes	Seismic activity	Seismic activity		X	X	X	X	X	X

^a Grand Canyon-Parashant National Monument not included as a separate park unit at park-level or network-level vital sign scoping workshops – treated within the context of Lake Mead National Recreation Area.

1 Table 28. (Con't.)

Level 1	Level 2	Level 3	MOJN Vital Signs	Specifics	DEVA	GRBA	JOTR	LAME	MANZ	MOJA
	Soil Quality	Soil function and dynamics	Soil erosion and deposition		X	X	X	X	X	X
			Soil aggregate stability		X	X	X	X	X	X
			Soil biota		X	X	X	X	X	X
			Disturbance - soil surface		X	X	X	X	X	X
			Soil organic matter		X	X	X	X		X
			Soil chemistry and nutrient cycling		X	X	X	X	X	X
			Soil hydrologic function		X	X	X	X	X	X
			Presence and dynamics of Biological Soil Crusts		X	X	X	X		X
			Desert pavement and mineral crusts		X	X	X	X		X
					X	X	X	X		X
					X	X	X	X		X
					X	X	X	X		X
Water	Hydrology	Paleontology	Paleontology		X	X	X	X		X
		Groundwater dynamics	Groundwater dynamics and chemistry		X	X	X	X	X	X
	Water Quality	Surface water dynamics	Surface water dynamics		X	X	X	X	X	X
		Water Chemistry	Surface water chemistry		X	X	X	X	X	X
		Microorganisms	Microorganisms		X	X		X		X
		Aquatic macroinvertebrates and algae	Aquatic macroinvertebrates and algae		X	X	X	X	X	X
			Aquatic ecosystem condition		X	X	X	X	X	X
Biological Integrity	Invasive Species	Invasive/Exotic plants	Occurrence of invasive plants - early detection		X	X	X	X	X	X
			Occurrence of invasive plants - status and trends	invasive grasses and other annuals	X	X	X	X	X	X
				tamarisk and athel	X		X	X	X	X
				sahara mustard	X		X	X		X

1 Table 28. (Con't.)

2

Level 1	Level 2	Level 3	MOJN Vital Signs	Specifics	DEVA	GRBA	JOTR	LAME	MANZ	MOJA
				alien palms	X			X		X
		Invasive/Exotic animals	Occurrence of invasive animals - status and trends	burros and wild horses	X			X		X
				non-native fish	X	X		X		X
				crayfish and other non-native invertebrates	X	X		X		X
				non-native frogs	X	X	X	X		X
				non-native birds	X	X	X	X		X
	Infestations and Disease	Animal diseases	Domestic sheep-bighorn sheep interactions			X		X		
			Desert tortoise disease		X		X	X		X
			Fish disease and parasites		X	X		X		X
			Hantavirus and Bubonic Plague		X	X	X	X	X	X
		Plant diseases	Forest Pathogens		X	X		X		X
	Focal Species or Communities	Desert communities	Vegetation Change	alpine/subalpine community	X	X				
				fan palm oases		X				
				pinyon-juniper woodland	X	X	X	X		X
				sagebrush-grass/scrub	X	X	X	X	X	X
				calcicolous scrub	X	X	X	X	X	
				relictual communities	X					
				mesquite communities	X			X		X
				dune communities	X		X	X		X

1 Table 28. (Con't.)

2

Level 1	Level 2	Level 3	MOJN Vital Signs	Specifics	DEVA	GRBA	JOTR	LAME	MANZ	MOJA
				blackbrush communities	X		X	X	X	X
				cactus communities	X	X	X	X		X
				joshua tree woodland	X		X	X		X
				ponderosa pine	X	X		X		X
				ancient bristlecone pine	X	X				
				smoke tree	X		X	X		X
				cliff communities	X	X	X	X		X
			Predators	ravens	X	X	X	X	X	X
				coyotes	X	X	X	X	X	X
				mountain lions	X	X		X		X
				bobcats	X	X	X	X		X
				raptors	X	X	X	X		X
		Riparian communities	Riparian Communities (springs, seeps, stream riparian communities)		X	X	X	X	X	X
		Terrestrial invertebrates	Invertebrate biodiversity		X	X	X	X	X	X
		Amphibians and Reptiles	Amphibians		X		X	X		X
			Reptile communities		X	X	X	X	X	X
		Birds	Riparian bird communities		X	X	X	X	X	X
			Land bird communities		X	X	X	X	X	X
		Mammals	Small mammal communities		X	X	X	X	X	X
			Bighorn Sheep		X	X	X	X		X
			Mule Deer		X	X	X	X		X

Table 28. (Con't.)

Level 1	Level 2	Level 3	MOJN Vital Signs	Specifics	DEVA	GRBA	JOTR	LAME	MANZ	MOJA
			Bats		X	X	X	X		X
			Elk			X		X	X	
	At-risk Biota	T&E species and communities	At-risk Populations	rare plants	X	X	X	X		X
				rare animals	X	X	X	X		X
			Federal T&E species and communities	desert tortoise	X		X	X		X
				Devils Hole pupfish	X					
				Mohave tui chub						X
			State T&E species and communities		X	X	X	X		X
Human use	Point Source Human Effects	Point-source human effects	Chemical contamination - Groundwater and Soils		X		X	X		X
	Non-point Source Human Effects	Non-point source human effects	Bioaccumulation of toxins					X		
	Visitor and Recreation Use	Visitor use	Visitor Use, Visitor satisfaction and Visitation		X	X	X	X	X	X
			Regional Population Growth		X	X	X	X	X	X
			Visitor Support Facilities: Infrastructure and Maintenance		X	X	X	X	X	X
			Spring/Riparian Restoration		X	X	X	X		X
			Disturbed Sites – Linear		X	X	X	X	X	X
			Disturbed Sites - Non-linear	abandoned mine lands	X	X	X	X		X
	Cultural Landscapes	Cultural landscapes	Cultural landscape condition		X	X	X	X	X	X

Table 28. (Con't.)

Level 1	Level 2	Level 3	MOJN Vital Signs	Specifics	DEVA	GRBA	JOTR	LAME	MANZ	MOJA
Landscapes (Ecosystem Pattern and Processes)	Fire and Fuel Dynamics	Fire and fuel dynamics	Fire and fuel dynamics		X	X	X	X		X
	Landscape Dynamics	Land cover and land use	Land use, land cover and landscape pattern		X	X	X	X	X	X
	Nutrient Dynamics	Nutrient cycling	Nutrient cycling		X	X	X	X	X	X
	Extreme Disturbanc e Events	Extreme disturbance events	Disturbance pattern and process		X	X	X	X	X	X
	Soundscape	Soundscape	Soundscape		X	X	X	X	X	X
	Viewscape	Viewscape/Dark night sky	Dark night sky		X	X	X	X	X	X

Table 29. Prioritized list of vital signs for the Mojave Network.

Rank	Score	MOJN Vital Sign Name/Specific	Vital Sign ID
1	4.8000	Surface water dynamics - streams, springs, seeps, lakes, playas	030602
2	4.7333	Groundwater dynamics and chemistry	030601
3	4.6333	Air Chemistry - Visibility and Particulate Matter	010103
4	4.6000	Occurrence of invasive plants & animals ^a	040801
5		Occurrence of invasive plants – status and trends (Not Scored)	
6		Invasive grasses and Other Annuals (Score: 4.6000)	040804
7		Tamarisk + Athel (Score: 3.4000)	040803
8		Sahara mustard (Score: 2.7333)	040809
9		Alien palms (Score: 1.4667)	040810
10		Occurrence of invasive plants – early detection (Not Scored)	
11		Occurrence of invasive animals (Not Scored)	
12		Non-native Fish (Score: 2.9667)	040805
13		Burros and Wild Horses (Score: 2.3000)	040802
14		Non-native Frogs (Score: 2.1333)	040807
15		Crayfish and Other Non-native Invertebrates (Score: 1.5333)	040806
16		Non-native birds (Not Scored)	
17	4.5667	Air Chemistry – ozone	010101
18	4.5333	Riparian Communities (springs, seeps, stream riparian communities)	041002
19	4.3333	Visitor Use, Visitor Satisfaction and Visitation	051403
20	4.2000	Soil chemistry and nutrient cycling	020506
21	4.1333	Water Chemistry – Surface water	030702
22	4.1333	Soil Hydrologic Function	020508
23	4.1000	Air Chemistry – wet and dry deposition	010102
24	4.0000	Weather – basic meteorology	010201
25	3.8667	Vegetation Change	041000
26		Riparian (Total Score: 4.5333)	041002
27		Sagebrush-grass/scrub Community(Total Score: 3.0667)	041005
28		Pinyon-juniper Woodland (Total Score: 3.0333)	041004
29		Cliff Communities (Total Score: 2.7000)	041012
30		Calicolous scrub (Total Score: 2.4667)	041006
31		Blackbrush Communities (Total Score: 2.4333)	041010

Table 29. (Con't.)

Rank	Score	MOJN Vital Sign Name/Specific	Vital Sign ID
		Cactus Communities (Total Score: 2.3000)	041011
		Dune Communities (Total Score: 2.2667)	041009
		Joshua Tree Woodland (Total Score: 2.0667)	041013
		Ponderosa Pine (Total Score: 1.3000)	041014
		Ancient bristlecone pine (Total Score: 1.2000)	041015
		Alpine/subalpine Community (Total Score: 1.0667)	041001
		Mesquite Communities (Total Score: 0.9333)	041008
		Relictual Communities (Total Score: 0.9333)	041007
		Smoke tree (Total Score: 0.9333)	041016
		Fan Palm Oases (Total Score: 0.8000)	041003
13	3.8000	Soil erosion and deposition	020501
14	3.8000	Riparian bird communities	041023
Top 20%			
15	3.7333	Disturbance - soil surface	020504
16	3.6667	Springs/Riparian Restoration	051501
16	3.6667	Air Chemistry - contaminants	010104
17	3.5333	Weather - patterns of precipitation	010202
18	3.4000	Soil biota	020503
18	3.4000	Soil compaction	020507
18	3.4000	Soil aggregate stability	020502
18	3.4000	Disturbed Sites Restoration - Linear	051502
18	3.4000	Stream / wash channel characteristics	020304
19	3.3667	Presence and Dynamics of Biological Soil Crusts	020509
20	3.3333	Reptile communities	041021
20	3.3333	Land Cover, Land Use and Landscape Pattern	061702
20	3.3333	Regional Population Growth	051402
21	3.2667	Desert pavement and mineral crusts	020510
22	3.2333	Fire and Fuel Dynamics	061601
23	3.2000	Bighorn sheep	041024
23	3.2000	Landbird Communities	041031
23	3.2000	Bats	041027
24	3.0667	Disturbance Pattern and Process	062001
25	3.0000	Small mammal communities	041022

Table 29. (Con't.)

Rank	Score	MOJN Vital Sign Name/Specific	Vital Sign ID
26	2.9667	At-risk populations	041101
		Rare plants (Not Scored)	
		Rare animals (Not Scored)	
27	2.9333	Visitor Support Facilities: Infrastructure and Maintenance	051405
28	2.8667	Chemical Contamination - Groundwater and Soil	051201
28	2.8667	State T&E species	041102
28	2.8667	Invertebrate biodiversity	041018
29	2.8333	Disturbed Sites Restoration - Non-linear	051503
		Abandoned Mine Lands (Not Scored)	
29	2.8333	Federal T&E species	041103
		Desert tortoise (Not Scored)	
		Devils Hole pupfish (Not Scored)	
		Mohave tui chub (Not Scored)	
30	2.8000	Dark night sky	051302
30	2.8000	Surface Radiation Balance	010203
31	2.7333	Hillslope features and processes	020303
32	2.6667	Aquatic Macroinvertebrates and Algae	030706
33	2.6000	Nutrient Cycling	061801
34	2.5000	Soil organic matter	020505
34	2.5000	Predators	041025
		Ravens (Total Score: 2.4333)	041029
		Coyote (Total Score: 1.9000)	041030
		Mountain lions (Not Scored)	
		Bobcats (Not Scored)	
		Raptors (Not Scored)	
35	2.2333	Amphibians	041020
36	2.2000	Caves / karst features and processes	020401
37	2.0667	Soundscapes	062101
38	2.0000	Desert tortoise disease	040902
39	1.9333	Windblown features and processes	020301
40	1.8333	Mule Deer	041026
41	1.8000	Forest Pathogens	040905
41	1.8000	Seismic activity	020403
42	1.7333	Fish Disease and Parasites	040903

Table 29. (Con't.)

Rank	Score	MOJN Vital Sign Name/Specific	Vital Sign ID
42	1.7333	Cultural Landscape Condition	051406
43	1.6667	Hantavirus and Bubonic Plague	040904
44	1.5333	Playas	020306
45	1.4000	Lake features	020305
46	1.3000	Volcanic features and processes	020402
47	1.1667	Elk	041028
48	1.0667	Domestic sheep-bighorn sheep Interactions	040901
49	1.0000	Microorganisms	030705
50	0.7000	Glacial features and processes	020302
51	0.5333	Bioaccumulation of toxins	051301

^a The original vital sign presented at the MOJN Vital Signs Scoping Workshop was Occurrence of invasive plants and animals and thus was the only general vital sign related to invasive species that was scored. This vital sign was subsequently split into 3 vital signs for the MOJN: occurrence of invasive plants – early detection, occurrence of invasive plants – status and trends and occurrence of invasive animals – status and trends. These three vital signs are presented in priority order based on discussions with the MOJN Technical Committee in July 2004.

Table 30. “Short list” of high priority vital signs for the Mojave Network.

MOJN Vital Sign	Justification for Initial Selection	Link to Conceptual Model
Groundwater dynamics and chemistry	Prioritized within top 20% at network level.	Hydrological Submodel
Surface water dynamics	Prioritized within top 20% at network level.	Hydrological Submodel
Surface water chemistry	Prioritized within top 20% at network level.	Hydrological Submodel
Occurrence of invasive plants – status and trends	Prioritized within top 20% at network level.	Fire Regime Submodel; Climate/Weather Submodel
Air chemistry – ozone	Prioritized within top 20% at network level.	
Air chemistry – visibility and particulates	Prioritized within top 20% at network level.	Soil-Water-Plant Interactions Submodel
Air chemistry – wet and dry deposition	Prioritized within top 20% at network level.	Soil-Water-Plant Interactions Submodel
Weather – basic meteorology	Prioritized within top 20% at network level.	All
Riparian communities	Prioritized within top 20% at network level.	Hydrological Submodel
Riparian bird communities	Prioritized within top 20% at network level.	Hydrological Submodel
Visitor use, visitor satisfaction, visitation	Prioritized within top 20% at network level.	N/A
Soil chemistry and nutrient cycling	Prioritized within top 20% at network level.	Soil/Geomorphology Submodel
Soil hydrologic function	Prioritized within top 20% at network level.	Soil/Geomorphology Submodel
Soil erosion and deposition	Prioritized within top 20% at network level.	Soil/Geomorphology Submodel
Soil disturbance	Prioritized within top 20% at park level (MANZ); High priority based on management significance alone at GRBA, JOTR, and LAME.	Soil Geomorphology Submodel
Biological soil crust dynamics	Prioritized within top 20% at park level (DEVA, JOTR, LAME, MOJA).	Soil Geomorphology Submodel
Vegetation change	Prioritized within top 20% at network level.	Soil-Water-Plant Interactions Submodel
At-risk populations	High priority based on management significance alone at DEVA, GRBA, and JOTR.	Hydrological Submodel
Federal T&E species	Prioritized within top 20% at park level (DEVA, JOTR, LAME, MOJA).	Hydrological Submodel
Cave and karst processes	Prioritized within top 20% at park level (GRBA).	Hydrological Submodel
Land use, land cover, and landscape pattern	#1 priority at JOTR based on ecological significance alone; prioritized as #2 ecosystem stressor; interpretive power.	All
Bighorn sheep	High priority based on management significance alone at GRBA, JOTR, and MOJA.	Hydrological Submodel
Fire and fuel dynamics	Prioritized within top 20% at park level (GRBA, JOTR); #1 priority at JOTR and LAME based on ecological significance alone.	Fire Regime Submodel
Cultural landscape condition	#1 priority at MANZ based on management significance alone; High priority based on management significance alone at LAME.	ALL
Reptile communities	High priority based on ecological significance alone at DEVA, JOTR, and LAME.	Soil-Water-Plant Interactions Submodel ?
Small mammal communities	High priority based on management significance alone at GRBA and MOJA.	Fire Regime Submodel

- 1 Table 31. Justification and monitoring questions for high priority vital signs in the Mojave Network. (Information contained in this
2 table was developed and revised at the Mojave Network Vital Signs Scoping Workshop, May 2004 – see Appendix Q).

Vital Sign	Justification and Monitoring Questions
Air and Climate	
Air Quality-Ozone	Ozone damages human health, vegetation, and many common materials. It is also a key component of urban smog. Although the only park in a Class I Airshed, JOTR exceeded the national 1- hour ozone standard on 46 days between 1992 and 1999. Most other parks only occasionally exceed this standard. JOTR also was one of nine park units that failed to meet the EPA 8-hour ozone standard based on data from 1997-1999. Most network units are in/near recently designated 8-hr O₃ non-attainment areas. In 2004, the American Lung Association State of the Air Report declared San Bernadino County, CA to have the unhealthiest air in the nation (ozone and particulates). Portions of both JOTR and MOJA are within or adjacent to San Bernadino County. DEVA, GRBA, JOTR, and LAME are part of the NPS Ozone Monitoring Network. In 2004, NPS-Air Resources Division completed a risk assessment of foliar injury to vegetation from ozone in network parks that concluded that JOTR, MANZ, and MOJA are at high risk for foliar injury to plants from elevated ozone levels. The report also identified ozone sensitive and bioindicator plant species at DEVA, GRBA, JOTR, LAME, and MOJA (NPS 2004a).
	1. Is the number of plants (individuals & species & their spatial distribution) exhibiting ozone damage increasing over time in areas subject to elevated ozone levels? 2. Are concentrations of ambient ozone increasing over time in and around network parks? 3. Is the frequency and severity of air pollution effects on sensitive resources in network parks changing over time? 4. Is plant/lichen community composition changing over time in areas subject to elevated ozone levels?
Air Quality – Wet and Dry Deposition	Sulfur and nitrogen are the principal constituents of acidic deposition, which can impact aquatic and terrestrial ecosystems as well as cultural resources. Alpine lakes and soils are particularly vulnerable to acidification due to their low buffering ability. Network ecosystems are generally adapted to low nitrogen conditions and there are potentially significant impacts associated with the continued deposition of atmospheric nitrogen (NPS 1992a). These include increasing the density and biomass of invasive plant species (particularly invasive annual grasses), decreased density, biomass, and species richness of native plant communities, and change in fire frequency. DEVA, GRBA, and JOTR are part of the National Atmospheric Deposition Program/National Trends Network (NADP/NTN) for wet deposition and the Clean Air Status and Trends Network (CASTNet) for dry deposition. Data from these sites indicates that deposition of both nitrogen and sulfur are elevated above natural levels of deposition (NPS 2004b)
	1. Are dry deposition rates in network parks changing over time (nitrate, sulfate, ammonium, sulfur dioxide, nitric acid)? 2. Are wet deposition rates in network parks changing over time (hydrogen, sulfate, nitrate, ammonium, chloride, base cations)? 3. Is total deposition (sum of wet and dry and occult (fog/cloud)) in network parks changing over time? 4. Is soil chemistry, productivity, species richness, plant community composition, and fire frequency and intensity changing over time in areas subject to increased deposition of nitrogen?

Table 31. (Con't.)

Vital Sign	Justification and Monitoring Questions
Air Quality – Visibility and Particulate Matter	Particulate matter is a human health concern and, in the form of sulfates and carbon particles, is very efficient at scattering light resulting in visibility impairment, particularly with increased humidity. Particulate matter also can combine with tropospheric ozone to produce photochemical smog. This may be of particular concern in areas of southern Nevada and California subject to thermal inversions. Particulate matter and smog degrade visitor experience by obscuring scenic vistas and night skies in addition to being linked to respiratory ailments in humans including eye irritation, bronchitis, wheezing, asthma, heart disease, premature mortality, etc. In 2004, the American Lung Association State of the Air Report declared San Bernadino County, CA to have the unhealthiest air in the nation (ozone and particulates) (ALA 2004). Portions of both JOTR and MOJA are within or adjacent to San Bernadino County. In contrast, the best visibility in the contiguous United States occurs in an area centered around GRBA. Trend analysis indicates that visibility is improving slightly on the 20 percent clearest days and worsening on the 20 percent haziest days. Visibility is specifically mentioned as an important resource in the General Management Plan for DEVA, GRBA, JOTR, and MOJA. Visibility also is considered a critical element of the cultural landscape at MANZ. Visibility is currently monitored at DEVA, GRBA, and JOTR (IMPROVE)(NPS 2004b).
	1. Are the number of days network parks fail to meet national air quality standards for particulate matter for human health increasing? 2. Is visibility in parks changing over time? 3. Is the quality of night skies changing over time? 4. Is existing monitoring adequate to characterize visibility and particulate matter within and between Parks? 5. Are the levels of gases that contribute to visibility reduction (e.g. NO₂) changing over time and what is their relative contribution to visibility reduction? 6. What is the contribution of "in-Park" emissions (fire) to particulate matter and is it changing over time?
Weather and Climate – Basic Meteorology	Climate is a primary factor controlling the structure and function of ecosystems in the Mojave Network. Key in understanding ecosystem dynamics will be an understanding of the roles of climate variability, hydrologic interactions with soils, and adaptive strategies of biota to capitalize on spatially and temporally variable moisture dynamics (Noy-Meir 1973, Rodriguez-Iturbe 2000, Reynolds et al. 2004). This information provides significant power to the interpretation of other potential vital signs and provides a basis for understanding the response of desert ecosystems to future climate variation (Hereford et al. 2004). Measurements of temperature, precipitation, wind, humidity, soil moisture and soil temperature can act as indicators of changing climatic conditions and weather patterns. DEVA, GRBA, JOTR, and LAME all monitor basic meteorological parameters such as precipitation and temperature. Weather stations in the vicinity of MOJA have been identified, mapped and data (historical and current) is being collected and summarized by the USGS. Additionally, DEVA and GRBA are accepted sites for the Climate Reference Network and long-term climate monitoring will begin between 2004-2006, including basic meteorological parameters.

Table 31. (Con't.)

Vital Sign	Justification and Monitoring Questions
	1. Is the timing, intensity, duration, and geographic distribution of precipitation events in network parks changing over time? 2. Is the annual average temperature, minimum temperature, and maximum temperature in network parks changing over time?
Geology and Soils	
Subsurface Geologic Processes – Cave/Karst Features and Processes	All network parks, except MANZ, contain natural caves. Great Basin National Park contains over 30,000 acres of karst geology and over 30 wild caves. Cave resources are listed as an exceptional natural resource in the park General Management Plan and are equally important from a visitor experience perspective. Lehman Cave, one of the primary reasons for establishment of GRBA, is famous throughout the world for an unusual concentration of cave formations and abundance of shields (NPS 1992a). Cave and karst systems are sensitive to many environmental factors including changes in hydrology (e.g. lowered water table), changes in water quality, atmospheric changes (e.g. CO₂, temperature), and altered geologic processes (e.g. erosion). Cave environments, particularly obligate cave invertebrate communities, may provide a sensitive indicator of environmental change.
	1. What are the trends in visitor use counts at selected caves over time? 2. What are the trends in dust fall and amount of lint in network caves that experience significant human use (e.g. Lehman Cave)? 3. What are the trends in species composition, abundance, and type of use by native faunal populations (vertebrate and invertebrate, obligate and facultative species)? 4. What are the short and long-term trends in water input to cave systems? 5. How is the microclimate of caves (e.g. temperature, humidity, evaporation) changing over time? 6. Is soil chemistry and sediment loading (e.g. amount, particle size) in caves changing over time? 7. What are the trends in air quality (e.g. particulates) and air flow in caves? 8. Are the structural elements of caves stable (widening fractures, joints, faults, etc.)? 9. Is water quantity and water quality in wild caves changing over time?
Soil Quality – Soil Erosion and Deposition	Loss of topsoil changes the capacity of soil to function and restricts its ability to sustain future uses. Erosion removes or redistributes topsoil, the layer of soil with the greatest amount of organic matter, biological activity and nutrients (Belnap 2003a). Erosion breaks down soil structure exposing organic matter within aggregates to accelerated decomposition and loss. Degraded soil structure reduces the rate of water infiltration and increases runoff which can lead to further erosion. Erosion of nutrient rich topsoil can cause a shift to less desirable plants including invasive plant species. The ability of a plant community to recover after topsoil is lost is restricted. The materials deposited by erosion can bury plants, cover roads and trails, accumulate in streams, rivers and reservoirs degrade water and air quality and damage or degrade cultural landscapes.

Table 31. (Con't.)

Vital Sign	Justification and Monitoring Questions
	1. Is the patch size, distribution, and degree of soil erosion and deposition in parks changing over time? 2. Are the mechanisms (e.g., wind, water) of soil erosion and deposition changing over time? 3. Is plant community composition, abundance, and distribution changing over time in areas with altered patterns of soil erosion or deposition?
Soil Quality – Soil Disturbance	Disturbance of the soil surface is a natural process (e.g. animal burrowing, flooding, etc.) that can be exacerbated by anthropogenic activities such as grazing, off-highway vehicle use, mining operations, etc. Disturbance of the soil surface results in increased invasive plant species cover, dust generation, surface runoff, erosion, increased bare ground, decreased soil organic matter and may negatively affect burrowing mammal habitat. Post-settlement changes in plant communities have caused changes in the extent of bare ground and accelerated soil loss. Research in the eastern Mojave Desert indicates that disturbed soils may produce up to 36 times more sediment when compared to undisturbed sites (Belnap 2003a). Hydrophobic soils or soils that repel water, are of most concern at GRBA due to high intensity fire events. Hydrophobic soils retard vegetative recovery and may result in increased runoff and significant erosion, subsequently affecting other park resources (e.g. water quality, spawning habitat for Bonneville Cutthroat trout). Within a given climate regime, severity of disturbance and soil texture may be the best determinants of recovery rate and soil texture the best predictor of resistance to disturbance (Belnap 2001).
	1. What are the long-term trends (rates, fluctuations) in patch size, distribution, and degree of physical soil surface disturbance in the parks? 2. Are the mechanisms of physical disturbance changing over time? 3. How do the long-term trends in disturbed soil surfaces relate to vegetation dynamics and climate variability?
Soil Quality – Soil Chemistry and Nutrient Cycling	Soil chemical properties provide the foundation for plant growth in conjunction with soil moisture. Nutrient cycles are essential ecosystem processes and the linkages to decomposition are complex and important. Ecosystems on stable trajectories have biological interactions that tend to conserve key nutrients. Significant loss or gain of elements is a good indicator of change in the system such as acidification or nitrification (Whitford 2002). Increased levels of soil nitrogen caused by atmospheric nitrogen deposition may increase the dominance (density and biomass) of invasive plant species, particularly invasive grasses, and decrease the density, biomass, and species richness of native plant communities (Brooks 1999a). Decreased soil buffering and pH affects availability of N, P, and K and thus invasive grass distribution. Soil salinity also is one of the primary factors affecting growth and distribution of plant communities in the Mojave Network. Extremes in soil chemistry have also resulted in unique landscape/plant assemblages and management problems (salinity/toxicity) in network parks.

1 Table 31. (Con't.)

2

Vital Sign	Justification and Monitoring Questions
	1. What are the long-term trends in content and concentrations of different soil nutrients? 2. How do the long-term trends in nutrient content and concentrations relate to vegetation dynamics and climate variability? 3. Is the species composition, abundance, and distribution of native plant communities changing over time in areas subject to increased atmospheric nitrogen deposition? 4. Is the cover and distribution of invasive plant species changing over time in areas subject to increased atmospheric deposition?
Soil Quality – Hydrologic Function	In deserts, geology and soils provide the template with which biota build integrated ecological systems. The availability of water is crucial, and small variations in available water can drastically alter plant and animal communities. Both physical and chemical geologic attributes commonly control important variation in water availability. Surficial geologic deposits vary in soil texture (grain size distribution and packing), bulk density, and other factors; horizontal variations are largely influenced by depositional processes and vertical variations by soil development (pedogenesis). Soil texture is critical in the moisture budget since, in general, coarse soils have higher infiltration rates, whereas finer grained soils have lower infiltration rates but higher retention capacities (Blair and McPherson, 1994). Soil type in conjunction with plant communities and their dynamics, topography, and climate regimes are primarily responsible for broad scale differences in soil moisture across the landscape. Plant-available soil moisture provides a key to understanding ecosystem maintenance in desert ecosystems. This indicator integrates soil water features with climate fluctuations.
	1. Is the vertical distribution or horizontal extent of plant-available soil moisture changing over time? 2. Is vegetative community structure change over time in response to changes in plant-available soil moisture? 3. Are observed changes in plant-available soil moisture due to background natural variability or anthropogenic disturbances?
Soil Quality – Biological Soil Crust Dynamics	Crusts generally cover most soil spaces not occupied by green plants and are concentrated in the top 1/8 inch of the soil. The main components of soil crusts are cyanobacteria, bryophytes, and lichens. In many areas, they comprise over 70% of the living ground cover and are key in reducing erosion, increasing water retention, and increasing soil fertility (Belnap 2001). Because plant cover is sparse, crusts are an important source of organic matter for desert soils. The biomass and species richness of biological soil crusts increases as the amount of precipitation increases and the temperature at which it falls decreases. The lichen and moss components of the crusts are most prevalent at locations dominated by winter precipitation, whereas warm season precipitation seems to be a limiting factor for the distribution of these organisms (Jayne Belnap, <i>pers. com.</i>). In the Mojave Desert, biological soil crusts appear to exhibit a marked preference for younger piedmont deposits with weaker pedogenic soils, and they are relatively rare on active and very old deposits. In addition, biological soil crust cover tends to be denser on substrates rich in granitic or limestone detritus and sparse on those with >85% eolian sand. Therefore, potential biological soil crust cover is predictable and these relations can be used to manage lands that have reduced crust cover. Large scale disturbance of biological soils crusts poses a significant threat to ecosystem integrity by increasing soil

Table 31. (Con't.)

Vital Sign	Justification and Monitoring Questions
	loss (erosion/dust), increasing the rate of water loss, and reducing soil fertility all of which may alter plant and animal communities. Initial studies in the Mojave Desert indicate that crusts require more than a century for recovery if significant shearing occurs. Recovery rates are most dependent on climatic history, in particular precipitation. Within a given climate regime, severity of disturbance and soil texture may be the best determinants of recovery rate and soil texture the best predictor of resistance to disturbance.
	1. Is the quality, patch size, distribution, and abundance of biological soil crusts in different vegetation communities, climate zones, disturbance regimes, and soil types changing over time? 2. Are the types of mechanisms (e.g. ORVs) that disrupt biological soil crusts changing over time?
Water - Refer to Table 32 for water resource related monitoring questions and objectives.	
Hydrology – Groundwater dynamics and chemistry	Understanding groundwater dynamics has been identified as a top management priority for network parks and increasing groundwater withdrawal has been identified as a significant ecosystem stressor within the Mojave Network. An understanding of water table levels, ground water flow paths, and the connection between groundwater and surface water resources is required for predicting the effects of natural and human-induced hydrological changes (e.g. municipal groundwater withdrawal) and the fate of contaminants (e.g. landfill leach). Precipitation events recharge the desert basin aquifers at a slow rate and this recharge feeds scattered springs and wetland habitats. Pumping a relatively small fraction of groundwater out of these basins can lower the water table and potentially dry up critical surface water resources. Subsidence of portions of the Mojave Desert by as much as four inches between 1992 and 1999 also has been linked to water-level declines of more than 100 feet between the 1950's and 1990's. In places around Las Vegas, groundwater levels have declined 300 feet since the first flowing artesian well was drilled in 1907 (Bawden et al. 2003). Land subsidence can disrupt surface drainage, reduce aquifer storage, cause earth fissures, and damage wells and other infrastructure (Bawden et al. 2003). The chemical constituents of groundwater relate to groundwater source, age, and movement. Groundwater chemistry can provide information on changes in groundwater flow paths, changes in groundwater recharge that may indicate environmental changes and contaminants. The chemical signature of groundwater changes as it flows through different types of rock. Changes in the chemical signature may indicate that a change in flow has occurred, possibly due to seismic events as observed at Pipe Springs National Monument (Truini, <i>pers. comm.</i>). The isotopic signature of groundwater (oxygen-18, deuterium) provides information about recharge. Change in the isotopic signature of groundwater can indicate environmental changes such as a shift in type of precipitation from rain to snow associated with climatic changes.

Table 31. (Con't.)

Vital Sign	Justification and Monitoring Questions
Hydrology – Surface Water Dynamics	Water is the lifeblood of the desert. Infrequent precipitation and long periods of drought are defining characteristics of the Mojave and Sonoran Deserts and water availability is the primary factor limiting plant productivity in deserts (Whitford 2002). Ninety percent of Southern Nevada's water supply comes from Lake Mead. Due primarily to recent drought conditions, the lake level dropped 60 feet between 2000 and 2003. Water management officials predict a further drops if weather and water use predictions are correct (Allen 2003). Surface waters are fed by groundwater and surface run-off (e.g. snow melt, rain events) and change in groundwater flow systems, climatic change and climate variability may have significant impacts on the availability of surface water. Pressures on groundwater resources in California and Nevada are expected to continue to increase into the future posing significant future threats to surface water availability in network parks. Hydrologic changes are of concern in relation to stream/spring high and low flows in response to weather/climatic events, impacts to special status species (67% of Federally endangered species in the network are desert fishes), impacts to recreational users (e.g. hikers, boaters), and impacts to drinking water resources for Las Vegas and surrounding areas. Required as a quantitative measurement (cfs) or qualitative estimate of flow related to bank full (stream) or level (lake).
Water Chemistry – Surface Water Chemistry	Under Section 305(b) of the Clean Water Act, each state is required to conduct water quality surveys to determine the overall health of the waters of the state, including whether or not designated uses are being met. States report to the EPA every two years. When impaired water bodies are identified through 305(b) assessments, they are included in 303(d) lists for ranking of priority sites and Total Maximum Daily Load (TMDL) development in order to limit discharges of specific pollutants to that water body (Ledder 2003). Lake Mead National Recreation Area is the only network park that contains waters designated as 303(d) or “impaired”. The Las Vegas Wash carries approximately 160 million gallons of treated sewage effluent and contaminated groundwater into Lake Mead each day. Between 1990-1994, the Las Vegas Wash received the 2nd highest amount of toxic water pollution in the state of NV. Effluent may also contain high levels of ammonia, nitrates, nitrites, and other nutrients. The addition of nutrients alters the productivity of aquatic plants and is a primary contributor to lake eutrophication. Significant levels of contaminants accumulated in organisms can lead to stress, illness, neurologic disorders, and/or death of aquatic biota (67% of Federally endangered species in the network are desert fishes). Additionally, the Clean Water Act includes a provision for the identification of Outstanding National Resource Waters (ONRW) to provide protection to the Nation’s most treasured water bodies and signifies that no lowering of water quality is allowed for that specific high quality water body and provides the maximum amount of protection under the Clean Water Act. Several ONRW are present within Great Basin National Park.

Table 31. (Con't.)

Vital Sign	Justification and Monitoring Questions
Biological Integrity	
Invasive Species – Invasive/Exotic Plants	The invasion and establishment of non-native, invasive plant species is accelerating at an unprecedented rate due to increases in global trade and transportation. This breakdown of biogeographical barriers is having profound consequences on ecosystems worldwide and is second only to habitat destruction as a threat to wildland biodiversity. Concern about ecological damage from exotic invasive species involves impacts to native flora and fauna, natural disturbance regimes, and ecosystem functions. Among these are concerns for threatened and endangered species sustainability and alteration of density, biomass, and diversity of native plant communities, species extirpation/extinction due to changes in fire regime, and alteration of basic soil processes. At least 66 non-native plant species have been identified in two or more park units within the Mojave Network with invasive annual grasses being most widespread and of greatest concern to park managers. Evaluation of patterns of habitat invisibility in the western Mojave Desert in association with varied levels of disturbance, soil nutrient levels, and precipitation suggest that early detection monitoring of annual plants should focus on regions of high rainfall and nitrogen deposition and on washes and beneath-canopy microhabitats (Brooks 1999a).
	1. Is the acreage of 'successful containment of invasive plant species' changing over time? 2. Is the number of invasive plant species (aquatic and terrestrial) in network parks and on lands adjacent to parks changing over time? 3. Is the relative abundance, % cover, and distribution of invasive plant species, particularly invasive annual grasses, changing over time? 4. Is the rate of spread of invasive species changing over time? 5. Is the ratio of native to non-native plant species in riparian and wetland habitats changing over time? 6. Is the ratio of native to non-native plant species in upland areas changing over time? 7. What are the long-term changes in native plant communities after an invasive species has been eradicated?
Focal Species and Communities - Vegetation Change	This vital sign combines the specific justifications for the individual vegetation communities that have been separated out as vital signs, as well as communities that are present but have not been considered of enough significance to have their own vital sign. Specific plant communities and species of interest are provided in Table 28. See justifications for plant related focal species and communities provided in the Mojave Network Vital Signs Scoping Report, Appendix K available at http://hrcweb.lv-hrc.nevada.edu/mojn/workshop.htm (Accessed 30 August 2005).

Table 31. (Con't.)

Vital Sign	Justification and Monitoring Questions
	1. What vegetational "units" (communities, associations, alliances, etc. based on the scale of the particular question being asked) are present in the parks and how big are they (inventory question?) 2. What species, and in what relative abundances are present in each of the vegetation "units" (species composition)? 3. Is the area and extent of the mapped vegetation communities in the parks changing over time? 4. What trends in vegetation prompt changes in near surface soil properties important for nutrient cycling and hydrologic function? 5. What trends in near surface soil properties prompt changes in vegetation? 6. How do plant communities change in response to climate change (e.g. drought, global climate change)? 7. How do faunal communities and species change in response to changes in plant community structure? 8. Determine the link between invasive species and vegetation community change. Are the changes permanent? 9. What are the effects of land use and management practices on the existing plant communities? How are these practices changing the vegetation communities? 10. What are the relative proportions of winter and summer annuals in the Mojave Network and are they changing over time? 11. For species that don't rely primarily on vegetative reproduction, are pollinator populations sufficient to ensure continued success at seed set and cross-pollination? (What are the trends in pollinator populations over time?)
Focal Species and Communities - Riparian Communities	Riparian areas comprise one of the most dramatically altered community types over the last 150 years in the western United States, however they remain the most biologically diverse. More than 75% of the species in the Mojave-Great Basin region are strongly associated with riparian vegetation, including 80% of the birds and 70% of butterflies (Brussard et al. 1998). A significant number of species of special concern are associated with riparian habitat within network parks including the Southwest willow flycatcher, Least Bell's Vireo, relict leopard frog (<i>Rana onca</i>), etc. Plant and animal communities associated with surface water, have been significantly altered across network parks due to the effects of past and current human use including water diversions, agricultural development, and livestock grazing. In many areas, riparian communities are now dominated by non-native tamarisk species that access water more easily and tolerate saline soils better than native plant species. This habitat is potentially the most significant to maintaining biological diversity and the most threatened across parks in the Mojave Network.
	1. Is the area of riparian habitat associated with perennial streams, springs, and lakes changing over time? 2. Is the species composition, community structure, and distribution of riparian habitat at springs and along streams and lakeshores changing over time? 3. What are the long-term trends in species richness and relative abundance of faunal communities in riparian habitat? 4. Is the extent and severity of surface disturbance in riparian habitats changing over time? 5. Is native tree recruitment on lake shorelines increasing over time?

Table 31. (Con't.)

Vital Sign	Justification and Monitoring Questions
Focal Species and Communities - Reptile Communities	Reptiles tend to be long-lived and abundant in arid ecosystems and may potentially serve as a good indicator of environmental change, particularly lizards. Research suggests that species richness of snakes may be a good indicator of edge effects. Reptiles also represent a vertebrate taxa group with a significant number of species of special concern (e.g. desert tortoise, Gila monster) and several species that network parks already spend a significant amount of time and money monitoring. In 1993, 19 commercial pet collectors reported a harvest of 21,794 reptiles in Nevada. Arizona has recently made the decision to allow reptile collection under a state hunting permit (with associated bag limits). Because hunting is permitted in LAME with an Arizona hunting license the potential for a significant collecting to occur within the park exists (K. Turner <i>pers. comm.</i>). Commercially popular species include chuckwallas and gila monsters, both species of concern, as well as more common reptiles such as the California King snake, long-nosed leopard lizard, and Panamint rattlesnake (Brussard et al. 1998).
	1. Is the total harvest of reptiles from LAME, associated with legal hunting, changing over time? 2. Is the total harvest of reptiles in the Mojave Desert, associated with commercial pet collecting, changing over time? 3. What are the long-term trends in reptile community species composition, relative abundance, and distribution along elevational gradients? 4. What are the long-term trends in lizard density in network parks? 5. What are the trends in snake diversity and abundance, and mortality rates on roads? 6. What is the relationship between drought/wet years and reptile populations? 7. What are trends in rock-dwelling reptiles related to rock-climbing and bouldering?
Focal Species and Communities - Small Mammal Communities	Contemporary populations of 16 montane mammal species, across the Great Basin-Mojave Desert region are presently isolated on mountains, and probably have been since the Pleistocene Epoch (Brussard et al. 1998). Research in National Park units on the Colorado Plateau, Sierra-Cascades, and Rocky Mountains indicate that the number of mammal population extinctions has exceeded the number of colonizations since park establishment and that the rate of extinction is inversely related to park area (Newmark 1995). If extirpated, relict mammal populations that are isolated on montane islands probably could not recolonize under current climatic conditions. Research suggests that five environmental variables, representing seasonal extremes in temperature, annual energy and moisture, and elevation may predict up to 88% of the variation in mammalian species density for the whole continent (Badgley and Fox 2000). The fact that a significant amount of the variation in species composition and density can be explained by environmental variables makes mammalian populations and communities a potential indicator of environmental change. Small mammals are of particular interest due to their potentially significant role in soil processes and seed distribution and germination, their relative abundance, and the fact that they are relatively cheap and easy to monitor.

1 Table 31. (Con't.)

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Vital Sign	Justification and Monitoring Questions
	1. Is the distribution of small mammal communities, along elevational gradients, changing over time? 2. Is small mammal community species composition and population density, along elevational gradients, changing over time? 3. What changes in small mammal communities are occurring over time in response to ecosystem stressors (e.g. degradation of air quality, alteration in soil quality, habitat fragmentation, etc.)? 4. Are changes in small mammal species composition correlated with changes in vegetation communities (e.g. species composition, cover of invasive species, etc.) or selected environmental variables?
Focal Species and Communities - Riparian Bird Communities	Obligate riparian bird species may be particularly good indicators of change in riparian communities. These are species that place >90% of their nests in riparian vegetation or for which >90% of their abundance occurs in riparian vegetation during the breeding season, such as the Least bell's vireo. Almost all birds in the Mojave Network depend on wetland and riparian habitats during at least some phase of their annual cycle. More than half of the breeding birds in the Great Basin are associated primarily with riparian habitat. Riparian bird communities are also significant in terms of maintaining bird species of special concern, including the federally endangered Southwest willow flycatcher (<i>Empidonax trailii</i>). Degradation and destruction of riparian areas are widely viewed as the most important causes of the decline of land bird populations in the Mojave Network (Brussard et. al. 1998). Nearly all springs sites and riparian areas across the network have been altered by human use throughout history.
	1. What are the long-term trends in species composition, abundance, and distribution riparian bird communities? 2. What are the long-term trends in abundance and distribution of obligate riparian bird species? 3. Are urbanphyilic birds being subsidized and what are the trends in abundance and distribution of these species in response to increasing urbanization? 4. What are the long-term trends abundance and distribution of breeding species and migrants? 5. How does the abundance and distribution of riparian bird communities vary seasonally and along elevational gradients?
Focal Species and Communities - Bighorn Sheep	Bighorn sheep numbers have declined significantly across their range primarily due to habitat fragmentation, habitat loss, disease, and predation. Bighorn sheep were extirpated from the south Snake Range, including GRBA, by 1940. The Nevada Department of Wildlife translocated 20 Rocky Mountain bighorn sheep (<i>Ovis canadensis canadensis</i>) from Colorado to GRBA in 1979 and 1980, but this effort has failed to establish a viable herd. Bighorn sheep populations have continued to decline and extensive searches by GRBA staff in 2001, identified 9 individuals with a total bighorn sheep population estimate of <12 individuals. Desert bighorn sheep exist in all other network parks, except MANZ. Within each of these parks they are considered a species of concern due to their sensitivity to human disturbance. They also are an important game species (LAME and MOJA) and source population for translocation to other areas of California (MOJA). Cumulative effects of human disturbance have been implicated in the abandonment of bighorn sheep habitat (and extirpation of the population) in Arizona (Etchberger et al. 1989), California (Graham 1971), and Utah (King 1985). When the limits

Table 31. (Con't.)

Vital Sign	Justification and Monitoring Questions
	Of their tolerance for disturbance is exceeded sheep may abandon an area, either temporarily or permanently (Welles and Welles 1961, Light 1971, Wehausen 1980, Papouchis et. al. 2001). Preliminary results on movement of bighorn sheep relative to concentrated recreational areas at JOTR indicates that sheep are avoiding critical habitat areas due to recreational activities (Thompson and Longshore 2004).
	1. Is the population size and distribution of bighorn sheep changing over time? Where? 2. Are the behavioral characteristics of bighorn sheep changing over time (e.g. daily and seasonal movements, habitat use) in/near concentrated recreational areas? 3. Is habitat utilization by bighorn sheep changing over time? 4. Is recruitment of lambs changing over time? 5. Is the quality of habitat in bighorn sheep summer and winter ranges changing over time (e.g. patch size, patch connectivity, visibility between patches)? 6. Is total annual harvest of bighorn sheep at LAME and MOJA changing over time? 7. Is habitat fragmentation at the metapopulation level increasing over time? 8. Is genetic diversity of populations changing over time?* 9. Determine threshold level of trends in human activities/disturbance in sheep habitat. 10. What are the trends in causes of mortality for bighorn sheep?
At-Risk Biota - At-Risk Populations	At-risk populations include species designated as rare, endemic, and NPS sensitive (e.g. Bonneville Cutthroat trout). All network parks except MANZ have species considered "at-risk" and these are often a focus of park managers and considered an important component of biodiversity in parks. Nearly 1,000 native plant species have been identified at DEVA and approximately 12% of these native plants are considered special status species, including two federally listed plant species and 12 endemic plant species. The DEVA General Management Plan lists as a park management goal, the "perpetuation of rare and endangered plants and animals and those endemic to [the park]".
	1. What are the long-term trends in abundance and distribution of at-risk populations in network parks? 2. What are the long-term trends in availability and quality of suitable habitat for at-risk species? 3. What are the long-term trends in at-risk populations in areas that have been invaded by selected non-native plant species?

Table 31. (Con't.)

Vital Sign	Justification and Monitoring Questions
At-Risk Biota - Federal T&E Species	Federally threatened and endangered species are an important aspect of biodiversity. Parks are mandated to monitor their condition and implement conservation activities to further their recovery. The desert tortoise was list by the U.S. Fish and Wildlife Service as 'Threatened' in 1990 and critical habitat was formally designated in 1994. Critical habitat, managed for the protection of the desert tortoise and their habitat, has been designated within MOJA, JOTR and LAME. Significant resources are spent on monitoring of desert tortoise populations across the Mojave Desert. The California Desert Managers Group approved integrating and evaluating all existing information related to the status/trends in desert tortoise populations, and implementing line distance sampling for all recovery units in California (including NPS lands). Sixty-seven percent of Federally listed biota are desert fishes including the Devils Hole pupfish, Mohave tui chub, bonytail chub, and razorback sucker.
	1. What are the long-term trends in population size and distribution of federally listed (threatened and endangered) species in network parks? 2. What are the long-term trends in availability and quality of suitable habitat for federally-listed species? 3. Is the genetic integrity of federally-listed fish species changing over time? 4. Is recruitment of federally-listed fish species changing over time? 5. How do populations of federally-listed threatened and endangered species change in response to selected ecosystem stressors (e.g. invasive species)? 6. Are species recovery plan goals and objectives being successfully and consistently achieved over time?
Human Use	
Visitor and Recreation Use – Visitor Use-Visitor Satisfaction-Visitation	This vital sign includes 3 components that contribute our understanding of social considerations: visitor use, visitor satisfaction and park visitation. Data on annual visitation to parks and visitor satisfaction (NPS Visitor Services Project) are already collected at the national level. <u>Visitor Use:</u> Although visitor use is unlikely to serve as a “vital sign” by itself, social aspects of park management must be considered a critical assessment in developing a comprehensive monitoring plan. Detection of trends in visitor use (e.g. change in use of caves, change in backcountry use, change from passive to active types of recreation) may provide a powerful tool to guide future park planning efforts, trigger change in current management actions and management focus (e.g. law enforcement), and provide an interpretive tool for explaining trends in other vital signs.

1 Table 31. (Con't.)

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Vital Sign	Justification and Monitoring Questions
	<u>Visitor Satisfaction:</u> Program evaluations are an important tool in analyzing the effectiveness and efficiency of NPS programs, and evaluating whether they are meeting their intended objectives. Enjoyment of the park units and their resources is a fundamental part of the visitor experience and critical to long-term preservation of park resources. Visitor enjoyment and safety are affected by the quality of park programs, management of resources, facilities, services, crowding, etc. Knowledge about the people who visit NPS areas has become increasingly important because of the need to know if visitor expectations are being met. The NPS Visitor Services Project (VSP) provides a mechanism for determining visitor satisfaction. The VSP is an ongoing research project that utilizes two main survey tools to provide the NPS with valuable visitor feedback: in-depth visitor studies and a customer satisfaction card. <u>Visitation:</u> Visitation statistics are collected using standardized protocols and maintained on-line for each National Park Service unit (www2.nature.nps.gov/stats/). Significant visitation records (> 60 years) exist for DEVA, JOTR, and LAME. In 2003, LAME experienced the 5th highest visitation in the nation. Visitation at DEVA has increased the most - between 1933 and 2003, park visitation (# of recreational visits) increased 8,930%. Mean percent increase for DEVA, JOTR, and LAME for the time during which visitation records are available (early-mid 30's-2003) is 5,021%. In the last 20 years at DEVA, JOTR, and LAME visitation has increased, on average, by 155%. This increase is similar to that observed over recent years at GRBA, MANZ, and MOJA. Visitation in network parks is expected to continue to increase into the future. Increasing visitation has numerous implications for park managers, particularly in terms of threatened and endangered species sustainability, subsidized predators, habitat fragmentation, habitat degradation, and need for additional infrastructure.
	1. Is the number of visitors to park caves increasing over time? 2. Is the incidence of cave vandalism increasing over time? 3. Is visitation to sensitive park areas increasing over time (e.g. dunes, oases)? 4. Is the number of backcountry permits issued annually changing over time? 5. Is the number of poaching incidents in network parks changing over time? 6. Is the number of hunting permits issued for take within network parks changing over time? 7. Is the number and area of concentrated recreational areas changing over time? 8. Is the total number of annual recreation visits to network parks changing over time? 9. Is the annual rate of increase in park visitation changing over time? 10. Is the seasonality of visitation in network parks changing over time? 11. Is the location and distribution of concentrated recreation sites within network parks changing over time? 12. Is the number of visitor comments related to noise levels and night sky programs changing over time (positive/ negative)? 13. Is the percentage of park visitors that express satisfaction with park facilities, services, and recreational opportunities changing over time? 14. Are changes in visitor use/visitation related to trends in soil distribution, introduction and cover of invasive plants and animals, change in emissions, and other selected vital signs?

Table 31. (Con't.)

Vital Sign	Justification and Monitoring Questions
Cultural Landscapes – Cultural Landscape Condition	All network parks have significant cultural landscape elements. The entire park at MANZ is considered a cultural landscape and management of this resource is the #1 park management priority. Elements of the cultural landscape that are important include species composition, land cover, visibility/viewshed, soundscape, and structural elements such as orchards, gardens, spring boxes, historic roads, etc. that parks are mandated to preserve. In addition to relatively small scale features, cultural landscapes may include broader scale issues such as visibility, soundscape, and land cover. Natural resources, within the context of a cultural landscape, are managed as cultural resources. Occasionally, goals related to cultural landscape restoration conflict with those of natural resource management (e.g. related to invasive species). Information gained through the network monitoring program may contribute to resolution of conflicts between cultural and natural resource management in parks and produce information related to natural features and processes critical to both natural and cultural resource managers (e.g. change in rate of erosion). Monitoring of cultural landscapes will be addressed through monitoring of other vital signs and identification of cultural landscape elements within the sampling design as appropriate.
Landscapes (Ecosystem Pattern and Processes)	
Fire and Fuel Dynamics – Fire and Fuel Dynamics	The annual area burned in wildfires has generally increased in the Western United States, an increase attributable partly to build-up of woody fuels, partly to drought, and partly to the invasion of non-native plant species such as <i>Bromus</i> spp. An understanding of fire and fuel dynamics is critical to science-based management of shrubland, woodland, and forested ecosystems. Change in fire regime (size, frequency, intensity) is a significant threat to parks in the Mojave Network. Fire is considered a critical element in maintenance of natural ecosystems, particularly patch mosaic dynamics, at GRBA. In recent years, GRBA has experienced a greater number of large, high intensity, stand-replacing fires that have threatened significant park resources such as ancient bristlecone pine stands. Change in fire regime at GRBA is primarily attributed to fire suppression activities and grazing over the last century. Fire history developed from pinyon-juniper woodlands at GRBA in 1990, showed a complex and variable fire history at GRBA that largely took place before 1860 and only 3% of fires occurring post-1900. Initial fire history in mixed-conifer stands at GRBA, reveal mean fire interval of 5.6 years prior to Euro-American settlement (1859), and no record of fire from 1881 to 2001 (Eddleman and Jaindle 1994). A fuel characteristic class map is currently being developed for GRBA. Fire in the Mojave Desert is considered historically infrequent and desert shrublands were once considered 'fire-proof'. The invasion of the alien annual grasses such as red brome and cheatgrass (Salo 2004 and Mack 1986, respectively) has increased fire frequencies and intensities and fire has become a resource management problem throughout low elevations in the Sonoran, Mojave, and Great Basin deserts alike (Brooks and Pyke 2001). In the Mojave Desert, recurrent fire may have devastating impacts on native plants that are poorly adapted to fire, leading to loss of native species, transitional shifts in communities, and potentially permanent replacement of native plant communities by alien annual grasslands (Brooks et. al. 2003). Fuels modeling can provide information useful in predicting fire behavior, monitoring fuel condition changes, providing a means for fuel assessments, and developing fuels management plans.

Table 31. (Con't.)

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Vital Sign	Justification and Monitoring Questions
	1. Is fire size, frequency, and intensity changing over time? 2. What are the long-term trends in fire return interval and effects in predominant native plant communities? 3. What are the long-term trends in cause of wildland fire in network parks (e.g. natural vs human caused)? 4. What are the trends in fuel loading and fuel continuity in predominant native plant communities along elevational gradients in the Great Basin-Mojave Desert Region? 5. Is the continuity of fine fuels in Mojave Desert shrublands changing over time? 6. Is plant productivity in GRBA and PARA changing over time? 7. Are invasive annual grasses (% cover and distribution) in parks changing over time in and around burned areas?
Landscape Dynamics – Land Use, Land Cover, and Landscape Pattern	<u>Land Use:</u> Over three quarters of the Mojave Desert is in federal jurisdiction (77%). The three main federal land administrators are the BLM (34%), National Park Service (28%), and Department of Defense (14%). The U.S. Forest Service and BLM also administer significant lands adjacent to GRBA. Private lands, comprising 21% of the Mojave, are held primarily by ranchers, farmers, utility companies, mining interests, and urban development. Private and state lands occur in a checkerboard pattern embedded in a matrix of federal properties (Davis et. al. 1998). Human population in the Great Basin-Mojave Desert region is predicted to experience continued growth into the future with the highest probability of future development on private undeveloped lands near existing development. These areas are often located near military bases in the Mojave Desert. Changes in land use are expected to be most significant in and around 29 Palms, CA (JOTR), Barstow, CA (MOJA), and Las Vegas, NV (LAME). Land-use practices at the local and regional scale can dramatically affect soil quality, water quality and quantity, air pollution, level of habitat fragmentation, habitat loss, and contribute to the spread and introduction of invasive species. Understanding changes in land use lends interpretive power to other vital signs and may contribute to early detection and prediction of future resource issues. <u>Land Cover:</u> Three vegetation types contribute to 75% of the land cover in the Mojave region, Mojave Creosote Bush Scrub (57%), Mojave Mixed Woody Scrub (13%), and Desert Saltbush Scrub (5%)(Davis et. al. 1998). Land cover at GRBA and in portions of LAME (e.g. PARA) are dominated by woodland and forest cover. Land cover is affected by natural events, including climate variation, flooding, vegetation succession, and fire, all of which can be changed in character or magnitude by human activities. Today, land cover is altered primarily by direct human use. Human-induced change in land cover is a primary factor in habitat loss, the most significant contributor in the listing of plant and animal species. A sustainable ecosystem maintains characteristic processes (geomorphic, hydrologic, soil, biological and atmospheric), allowing the system to deliver ecosystem services (Christensen et. al. 1996). Understanding of change in land cover provides critical insights into current or future changes in ecosystem services (habitat, recreation, stabilizing soils, etc.).

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Table 31. (Con't.)

Vital Sign	Justification and Monitoring Questions
	<u>Landscape Pattern:</u> Spatial heterogeneity in desert ecosystems has significant effects on basic ecological processes. Landscape mosaics are created by repeating units of several patch types across the landscape. Landscape-level processes such as habitat patch mosaic structure may strongly influence local populations. The character of a landscape's pattern (patch size and structure, distribution, shape, dispersion, connection, etc.) directly influences the distribution, abundance, and movement of animals, and distribution, abundance, germination, and dispersal of plants. In deserts, where many of the organisms are living at or near the threshold for surviving the climatic extremes, the availability of resources in patches is a critical variable (Whitford 2002). In the Great Basin, fire can be an important element in maintaining patch mosaic dynamics. Patch mosaic dynamics is of special interest in GRBA related to the management of habitat, including patch size, composition, and structure for bighorn sheep. Changes in climate, fragmentation, change in fire regime, and grazing have had the greatest past and current impacts on landscape pattern in the Great Basin-Mojave Desert region.
	1. Where is land use changing in and around network parks, over what time scale? 2. Is the extent and rate of land use change in and around network parks changing over time? 3. Is the number grazing allotments, allotment stocking rates, and patterns of livestock use within allotments changing over time? 4. Is the rate of land acquisition and number inholdings within parks changing over time? 5. How is the type/distribution/intensity/frequency of land use changing over time? 6. Where is land cover changing in and around network parks and over what time scale? 7. Is the extent and rate of change in land cover in and around network parks changing over time? 8. Is patch size (e. g. mean, minimum) in woodland and forested habitat at DEVA, GRBA, and LAME changing over time? 9. Is the size and distribution of vegetation patch types across the Great Basin-Mojave Desert landscape changing over time? 10. Is the distance between resource patches changing over time? 11. What are the long-term trends in structure and composition of resource patches?

3.2.6 Final Selection of Vital Signs (Step 8)

The network “short list” of high priority vital signs will be used to guide future long-term planning and design of the network vital signs monitoring program and provide focus for park-level monitoring efforts. FY 2006 activities related to high priority vital signs will include the identification, cataloging, conversion, and analysis of existing monitoring data/information, development of specific, measurable monitoring objectives, and continued development of conceptual model components. These efforts will focus on high priority vital signs selected by the network as the focus of initial funding for long-term monitoring in early FY 2006. The network will develop evaluation criteria for vital signs selection (i.e. partnership and cost-sharing information, status of baseline information, cost of implementation, etc.) and implement the selection process through a small workshop (or series of workshops) involving park and network staff. A structured group decision-making process will be used to take all of the information and ideas available, and then produce judgments, manage conflict, and enable consensus.

3.2.6.1 2005 Mojave Network Water Resources Monitoring Workshop

Although the Mojave Network has not selected their final list of vital signs it is assumed given the importance of water in arid systems (as evidenced by network prioritization, stressor prioritization, etc.) that water resources will be a focus of monitoring. Therefore, the MOJN moved forward with the Mojave Network Water Resources Monitoring Workshop on April 5-6, 2005 in Henderson, NV. A total of 16 individuals participated, representing network and park staff, regional and national NPS hydrologists, and selected subject matter experts. The workshop objectives were to: (1) provide understanding of the guidance, requirements and planning process described by NPS-Water Resources Division for the development of network water resources monitoring plans; (2) summarize and review existing information related to water resources and water-related vital signs; (3) review and revise existing, water-related monitoring questions developed through the 2004 MOJN Vital Signs Scoping Workshop; (4) develop and prioritize monitoring objectives for each water-related vital sign; and (5) identify and describe high priority information needs (e.g. baseline data, evaluation of existing datasets, etc.) for network parks.

Workshop participants remained in one working group and information was presented and comments/results captured within an Excel spreadsheet. Due to the small number of monitoring objectives developed, prioritization of objectives occurred through discussion and unanimous agreement. Workshop products were: (1) decision to develop a network vital signs monitoring plan that integrates water quality monitoring rather than a stand-alone plan; (2) list of revised monitoring questions for water-related vital signs; (3) prioritized list of monitoring objectives for each water-related vital sign (Table 32); and (4) list of data gaps for each network park. The final workshop report is provided in Appendix R and report appendices are available on-line at: <http://hrcweb.lv-hrc.nevada.edu/mojn/workshop.htm> (Accessed 30 August 2005).

Similar workshops will be scheduled to develop monitoring objectives, etc. for additional high priority and ‘selected’ vital signs in FY 2006.

Table 32. Monitoring questions, monitoring objectives, and objective ranking for high priority water-related vital signs in the Mojave Network.

MOJN Vital Sign	Monitoring Question	Monitoring Objective	Rank
Groundwater dynamics and chemistry	How do groundwater levels change in space and time?	To detect changes in volumetric rate in areas across the Mojave Network with potential for groundwater development compared with control sites on a continuous basis (monthly realistically).	1
	How is groundwater withdrawal in and around network parks changing over time?	To detect changes in water level in both space and time across the Mojave Network in areas with potential for groundwater development compared with control sites on a continuous basis (initially continuous, monthly thereafter).	2
	How do biotic communities respond to changes in groundwater conditions (quality and quantity) over time?	To detect changes in community structure, demography, water level, and other selected parameters for selected biological communities across network parks associated with shallow groundwater conditions for a given time period.	3
	What are the trends in groundwater quality across network parks and regionally?	To detect changes in major ions, trace elements, nutrients, organics, radionuclides, and other selected pollutants in groundwater at selected individual sites across network parks with a high potential for degradation on a quarterly basis.	4
	How are water levels, flows, and water quality in caves changing over time?	To detect changes in water level, flow, and selected water quality parameters (e.g. pH, temperature, conductivity, dissolved oxygen) in selected cave systems at GRBA and PARA for a given period of time (either continuous or event based).	5
Surface water dynamics	How is spring discharge changing over time?	To detect changes in stage and discharge in selected perennial and ephemeral springs across network parks on a continuous basis.	1
	How is stream discharge and/or the timing of stream discharge changing over time?	To detect changes in stage and discharge in perennial streams (at DEVA, GRBA, LAME, and MOJA) and selected intermittent streams (at MANZ) across network parks on a continuous basis.	2
	How do aquatic and riparian communities respond to changes in surface water conditions (quality and quantity) over time?	To detect changes in aquatic and riparian community structure and demography in relation to selected surface water parameters (e.g. core water quality parameters) at selected springs, streams, and lakes across network parks for a given period of time.	3
	How is water volume/lake level changing over time?	To detect changes in water volume and/or lake level in Lake Mead, Lake Mojave, and Devils Hole on a continuous basis.	4
		To detect changes in water volume and/or lake level in alpine lakes at GRBA on a continuous basis between May and October.	5

Table 32. (Con't.)

MOJN Vital Sign	Monitoring Question	Monitoring Objective	Rank
Water chemistry – surface water	What are the trends in input of nutrients(wastewater input and atmospheric), pollutants, sediments, etc. into lakes, streams, springs, and caves?	To detect changes in selected pollutants (e.g. nutrients, suspended sediment, endocrine disruptors, perchlorate, etc.) in selected springs, streams, and lakes across the network on a monthly basis (minimally on a quarterly basis). Sampling priorities include 303d-listed and ONRW waters, concentrated recreation areas, and tributaries to Lake Mead.	1
	How is water quality (core parameters) in selected water bodies changing over time?	To detect changes in pH, dissolved oxygen, conductance, and temperature in selected springs, streams, and lakes across the network on a continuous basis (minimally on a monthly basis). Sampling priorities include 303d-listed and ONRW waters, concentrated recreation areas, and tributaries to Lake Mead.	2
	Is level of compliance with national drinking water standards changing over time?	To detect changes in the frequency that selected water quality parameters (e.g. fecal coliform) fail to meet national standards for drinking water at Lake Mead, Lake Mojave, and other water sources designated for public consumption across the network as required by law.	3

Chapter 4. Sampling Design**Chapter 5. Sampling Protocols****Chapter 6. Data Management and Archiving****Chapter 7. Data Analysis and Report Writing****Chapter 8. Administration/Implementation of the Monitoring Program****Chapter 9. Schedule****Chapter 10. Budget**

Chapter 11. Literature Cited

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Reference A. Scientific and common names for species listed in Mojave Network Phase I Report.

Scientific Name	Common Name
<i>Plants</i>	
<i>Abies concolor</i>	White fir
<i>Abies lasiocarpa</i>	Subalpine fir
<i>Acacia greggii</i>	Catclaw
<i>Acer glabrum</i>	Rocky Mountain Maple
<i>Achnatherum</i> spp.	Needlegrass
<i>Achnatherum hymenoides</i>	Indian ricegrass
<i>Allenrolfea occidentalis</i>	Pickle weed
<i>Ambrosia dumosa</i>	White bursage
<i>Artemisia</i> spp.	Sagebrush
<i>Artemisia tridentata</i>	Big sagebrush
<i>Atriplex</i> spp.	Saltbush
<i>Baccharis sarothroides</i>	Desert broom (eastern Mojave)
<i>Brassica tournefortii</i>	Sahara mustard
<i>Bromus madritensis rubens</i>	Red brome
<i>Bromus tectorum</i>	Cheatgrass
<i>Calochortus kennedyi</i>	Desert Mariposa lily
<i>Carex</i> spp.	Sedges
<i>Centaurea</i> spp.	Knapweeds and star thistles
<i>Cercocarpus</i> spp.	Mountain mahogany
<i>Chilopsis linearis</i>	Desert willow
<i>Coleogyne ramosissima</i>	Blackbrush
<i>Cucurbita palmate</i>	Palmate-leaved gourd
<i>Distichlis</i> spp.	Saltgrass
<i>Echinocactus polycephalus</i>	Cottontop cactus
<i>Erodium cicutarium</i>	Redstem filaree
<i>Fouquieria splendens</i>	Ocotillo
<i>Juncus</i> spp.	Rushes
<i>Juniperus osteosperma</i>	Utah juniper
<i>Juniperus scopularum</i>	Rocky Mountain juniper
<i>Larrea tridentata</i>	Creosote bush
<i>Lepidium latifolium</i>	Tall white top
<i>Lepidospartum squamatum</i>	Desert broom (western Mojave)
<i>Lycium andersonii</i>	Wolfberry
<i>Oenothera</i> spp.	Evening primrose
<i>Opuntia basilaris</i>	Beavertail cactus
<i>Picea engelmannii</i>	Engelmann spruce
<i>Pennisetum setaceum</i>	Fountain grass
<i>Pinus contorta</i>	Lodgepole pine
<i>Pinus edulis</i>	Two-needle pinyon pine
<i>Pinus flexilis</i>	Limber pine

Species list. (Con't.)

Scientific Name	Common Name
<i>Pinus longaeva</i>	Bristlecone pine
<i>Pinus monophylla</i>	Single-needle pinyon pine
<i>Pinus ponderosa</i>	Ponderosa pine
<i>Pleuraphis jamesii</i>	Evergreen plantain
<i>Pleuraphis rigida</i>	Big galleta
<i>Populus angustifolia</i>	Narrowleaf cottonwood
<i>Populus fremontii</i>	Fremont cottonwood
<i>Populus tremuloides</i>	Quaking aspen
<i>Prosopis velutina</i>	Velvet mesquite
<i>Pseudotsuga menziesii</i>	Douglas fir
<i>Psoralea arguta</i>	Smoke tree
<i>Purshia glandulosa</i>	Bitterbrush
<i>Rosa woodsii</i>	Mountain rose
<i>Salix</i> spp.	Willow
<i>Sarcobatus vermiculatus</i>	Greasewood
<i>Schismus</i> spp.	Mediterranean grass
<i>Schismus arabicus</i>	Mediterranean grass
<i>Schismus barbatus</i>	Mediterranean grass
<i>Stanleya elata</i>	Panamint prince's plume
<i>Tamarix athel</i>	Athel tree
<i>Tamarix ramosissima</i>	Salt cedar
<i>Tessaria sericea</i>	Arrowweed
<i>Yucca brevifolia</i>	Joshua tree
<i>Yucca schidigera</i>	Mojave yucca
Animals	
<i>Acrididae</i> (Family)	Grasshoppers
<i>Ammospermophilus</i> spp.	Ground squirrel
<i>Anabrus simplex</i>	Mormon cricket
<i>Antilocarpa</i>	Pronghorn
<i>Aphonopelma chalcodes</i>	Tarantula
<i>Auriparus flaviceps</i>	Verdin
<i>Bothrioccephalus achelognathii</i>	Asian tape worm
<i>Brachylagus idahoensis</i>	Pygmy rabbit
<i>Canis latrans</i>	Coyotes
<i>Castor Canadensis</i>	Beaver
<i>Centruroids exilicauda</i>	Scorpion
<i>Cervus elaphus</i>	Elk
<i>Charadrius vociferous</i>	Killdeer
<i>Clethrionomys gapperi</i>	Red-backed vole
<i>Cottus bairdi</i>	Mottled sculpin
<i>Cyprinodon diabolis</i>	Devils Hole pupfish

1 Species list. (Con't.)

2

Scientific Name	Common Name
<i>Cyprinodon nevadensis nevadensis</i>	Saratoga pupfish
<i>Dendroica petechia</i>	Yellow warbler
<i>Dipodomys microps</i>	Kangaroo rat
<i>Dipsosaurus dorsalis</i>	Desert iguana
<i>Empidonax trailii</i>	Southwestern willow flycatcher
<i>Equus asinus</i>	Wild burro
<i>Equus caballus</i>	Wild horse
<i>Erethizon dorsatum</i>	Porcupine
<i>Euphagus cyanocephalus</i>	Brewers blackbird
<i>Falco peregrinus</i>	Peregrine falcon
<i>Felis concolor</i>	Mountain lion
<i>Gambusia affinis</i>	Mosquitofish
<i>Siphateles bicolor mojavenis</i>	Mohave tui chub
<i>Gila elegans</i>	Bonytail chub
<i>Glaucomys sabrinus</i>	Northern flying squirrel
<i>Gopherus agassizii</i>	Desert tortoise
<i>Hadrurus arizonensis</i>	Scorpion
<i>Haliaeetus leucocephalus</i>	Bald eagle
<i>Hyles lineate</i>	White-lined sphinx caterpillar
<i>Hymenoptera</i> (Order)	Ants
<i>Isoptera</i> (Order)	Termites
<i>Latrodectus hesperus</i>	Black widow spider
<i>Lepus californicus</i>	Black-tailed hares
<i>Lynx rufus</i>	Bobcat
<i>Melospiza melodia</i>	Song sparrow
<i>Molothrus ater</i>	Brown-headed cowbird
<i>Microtus</i> spp.	Voles
<i>Microtus richardsoni</i>	Water vole
<i>Neotoma</i> spp.	Woodrats
<i>Odocoileus hemionus</i>	Mule deer
<i>Oncorhynchus clarki utah</i>	Bonneville cutthroat trout
<i>Oncorhynchus mykiss</i>	Rainbow trout
<i>Ovis canadensis</i>	Desert bighorn sheep
<i>Ovis canadensis canadensis</i>	Rocky mountain bighorn sheep
<i>Passerculus sandwichensis</i>	Savannah sparrow
<i>Passer domesticus</i>	House sparrow
<i>Passerina amoena</i>	Lazuli bunting
<i>Phainopepla</i> spp.	Silky flycatcher
<i>Phrynosoma desertii</i>	Horned lizard
<i>Rana catsbeiana</i>	American bullfrog
<i>Richardsonius balteatus</i>	Red-sided shiner
<i>Rhinichthys osculus</i>	Speckled dace

Species list. (Con't.)

Scientific Name	Common Name
<i>Sauromalus obesus</i>	Chuckwalla
<i>Sorex vagrans</i>	Vagrant shrew
<i>Spermophilus variegates</i>	Rock squirrel
<i>Sturnus vulgaris</i>	European starling
<i>Sylvalagus</i> spp.	Cottontail rabbit
<i>Tachycineta thalassina</i>	Violet-green swallow
<i>Tamiasciurus hudsonicus</i>	Red squirrel
<i>Tegeticula</i> spp.	Yucca moths
<i>Thomomys talpoides</i>	Pocket gopher
<i>Uma</i> spp.	Fringe toed lizard
<i>Vireo gilvus</i>	Warbling vireo
<i>Vulpes</i> spp.	Fox
<i>Zapus princeps</i>	Woodland jumping mouse

Reference B. Glossary of Key Terms and Concepts

Alluvium – a general term for detrital deposits made by streams on riverbeds, flood plains, and alluvial fans.

Alluvial fan – an outspread, gently sloping mass of alluvium deposited by a stream, especially in an arid region where a stream issues from a narrow canyon onto a plain or valley floor.

Anthropogenic effects – are caused by or attributed to humans. As used here, they are human influenced factors that cause stress in natural systems.

Attributes – any living or nonliving feature or process of the environment that can be measured or estimated and that provide insights into the state of the ecosystem. The term indicator is reserved for a subset of attributes that is particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong (Noon 2003; <http://science.nature.nps.gov/im/monitor/Glossary.htm>).

Bajada – a broad, gently inclined, detrital surface extending from the base of mountain ranges into an in-land basin.

Biological integrity – the ability to maintain and support a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region.

Biome – a climax community that characterizes a particular natural region.

Biota – the animal and plant life of a region.

C₄ – a set of photosynthetic reactions through which carbon dioxide is fixed to yield a 4 carbon intermediate (a reaction often associated with desert grasses, adaptation to save water)

CAM – a variant of the C₄ pathway in which carbon dioxide is fixed at night (often associated with succulents such as cactus, processes done at night to avoid extreme heat during that day, an adaptation to curtail water loss).

Carbonate rock – rock sediment formed from the carbonates of calcium, magnesium, and/ or iron (e.g. limestone or dolomite).

Caudex – a thickened underground base of stem from which new leaves may arise.

Colluvium – a general term applied to loose deposits, usually at the foot of a cliff, and brought there by gravity.

Community – is a group of populations of different species occupying a given place at a given time that are viewed as interdependent, an aggregation of interacting species.

1 **Corm** – a thickened underground stem in which plant storage products are accumulated.

2
3 **Composition** – defined as the identity and variety of elements within an ecosystem, including
4 species present and their population structure, abundance, and genetic diversity (Noss 1990).

5
6 **Degradation** – an anthropogenic reduction in the capacity of a particular ecosystem or
7 ecosystem component to perform desired ecosystem functions (e.g., degraded capacity for
8 conserving soil and water resources). Human actions may degrade desired ecosystem functions
9 directly, or they may do so indirectly by damaging the capacity of ecosystem functions to resist
10 or recover from natural disturbances and/or anthropogenic stressors (derived from concepts of
11 Whisenant 1999, Archer and Stokes 2000, and Whitford 2002).

12
13 **Disturbance** – “...any relatively discrete event in time that disrupts ecosystem, community, or
14 population structure and changes resources, substrate availability, or the physical environment”
15 (White and Pickett 1985:7). In relation to monitoring, disturbances are considered to be
16 ecological factors that are within the evolutionary history of the ecosystem (e.g., drought). These
17 are differentiated from anthropogenic factors that are outside the range of disturbances naturally
18 experienced by the ecosystem (Whitford 2002).

19
20 **Driver** – a natural agent responsible for causing temporal changes or variability in quantitative
21 measures of structural and functional attributes of ecosystems.

22
23 **Ecological indicator** – see *indicator*.

24
25 **Ecological integrity** – a concept that expresses the degree to which the physical, chemical, and
26 biological components (including composition, structure, and process) of an ecosystem and their
27 relationships are present, functioning, and capable of self-renewal. Ecological integrity implies
28 the presence of appropriate species, populations and communities and the occurrence of
29 ecological processes at appropriate rates and scales as well as the environmental conditions that
30 support these taxa and processes (<http://science.nature.nps.gov/im/monitor/Glossary.htm>).

31
32 **Ecoregion** – an area over which the climate is sufficiently uniform to permit development of
33 similar ecosystems on sites having similar properties. Ecoregions contain many landscapes with
34 different spatial patterns of ecosystems.

35
36 **Ecosystem** – a spatially explicit unit of the Earth that includes all of the organisms, along with
37 all components of the abiotic environment within its boundaries (Likens 1992, cited by
38 Christensen et al. 1996:670).

39
40 **Ecosystem functioning** – the flow of energy and materials through the arrangement of biotic and
41 abiotic components of an ecosystem. Includes many ecosystem processes such as primary
42 production, trophic transfer from plants to animals, nutrient cycling, water dynamics and heat
43 transfer. In a broad sense, ecosystem functioning includes two components: ecosystem resource
44 dynamics and ecosystem stability (Díaz and Cabido 2001).

Ecosystem health – a metaphor pertaining to the assessment and monitoring of ecosystem structure, function, and resilience in relation to the notion of ecosystem “sustainability” (following Rapport 1998 and Costanza et al. 1998). A healthy ecosystem is sustainable (see *Sustainable ecosystem*, below).

Ecosystem integrity – see *ecological integrity*.

Ecosystem management – the process of land-use decision making and land-management practice that takes into account the full suite of organisms and processes that characterize and comprise the ecosystem and is based on the best understanding currently available as to how the ecosystem works. Ecosystem management includes a primary goal of sustainability of ecosystem structure and function, recognition that ecosystems are spatially and temporally dynamic, and acceptance of the dictum that ecosystem function depends on ecosystem structure and diversity (Dale et al. 2000:642).

Edaphic – related to or caused by particular soil conditions, as of texture or drainage, rather than by physiographic or climate factors.

Endemic species – any species naturally confined to a particular area or region.

Endolithic – within the soil or rock layer.

Eolian – pertaining to the wind, esp. said of such deposits as loess and dune sand.

Equilibrium – a condition of balance between two opposing forces.

Evapotranspiration – the portion of precipitation returned to the area through evaporation and transpiration.

Focal resources – are park resources that, by virtue of their special protection, public appeal, or other management significance, have paramount importance for monitoring regardless of current threats or whether they would be monitored as an indication of ecosystem integrity. Focal resources might include ecological processes, such as deposition rates of nitrates and sulfates in certain parks; or they may be a species that is harvested, endemic, alien, or has protected status.

Focal species / organisms – species and/or organisms that play significant functional roles in ecological systems by their disproportionate contribution to the transfer of matter and energy, by structuring the environment and creating opportunities for additional species and/or organisms, or by exercising control over competitive dominants and thereby promoting increased biological diversity (derived from Noon 2003:37). [Encompasses concepts of keystone species, umbrella species, and ecosystem engineers.]

Forcing functions – a natural agent external to the processes being modeled responsible for causing temporal changes or variability in quantitative measures of structural and functional attributes of ecosystems. Examples include solar radiation, N and P loading, turbidity, and temperature (Culver 1999).

Functional groups – groups of species that have similar effects on ecosystem processes (Chapin et al. 1996) – frequently applied interchangeably with *functional types*.

Functional types –sets of organisms sharing similar responses to environmental factors such as temperature, resource availability, and disturbance (= functional *response* types) and/or similar effects on ecosystem functions such as productivity, nutrient cycling, flammability, and resistance / resilience (= functional *effect* types) (Díaz and Cabido 2001).

Genotype – the genetic constitution, latent or expressed, of an organism, the sum total of all genes present in an organism.

Geomorphic – pertaining to the shape of the earth or its surface features.

Geophyte – plants that expend major part of their growth in the soil.

Hydrologic function (lotic and lentic systems) – capacity of an area to: dissipate energies associated with (1) high stream flow (lotic); or (2) wind action, wave action, and overland flow (lentic); thereby reducing erosion and improving water quality; filter sediment, capture bedload, and aid floodplain development; improve flood-water retention and groundwater recharge; develop root masses that stabilize streambanks against cutting action; develop diverse ponding and channel characteristics to provide the habitat and the water depth, duration, and temperature necessary for fish production, waterfowl breeding, and other uses; support greater biodiversity (from Prichard et al. 1998, 1999).

Hydrologic function (upland systems/soils) – capacity of a site to capture, store, and safely release water from rainfall, run-on, and snowmelt, to resist a reduction in this capacity, and to recover this capacity following degradation (Pellant et al. 2000).

Iteroparous - producing offspring at more than one time during a lifetime.

Indicator (general use of term) – a term reserved for a subset of environmental attributes that is particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong (Noon 2003; <http://science.nature.nps.gov/im/monitor/Glossary.htm>).

Indicators of ecosystem health – see *vital sign*.

Inherent soil properties – soil properties that are relatively unaffected by management activities, climatic fluctuations, and natural disturbances (e.g., texture, color, depth, mineralogy, horizonation).

Inventory – is an extensive point-in-time effort to determine location or condition of a resource, including the presence, class, distribution, and status of plants, animals, and abiotic components such as water, soils, landforms, and climate.

1 **Karst** – an area of limestone formations characterized by sinks, ravines, and underground
2 streams.

4 **Landscape** – a spatially structured mosaic of different types of ecosystems interconnected by
5 flows of materials (e.g., water, sediments), energy, and organisms.

7 **Lentic** – referring to standing freshwater habitats, such as ponds and lakes.

9 **Lotic** – referring to running freshwater habitats.

11 **Measures** – the specific variables used to quantify the condition or state of an attribute or
12 indicator (or vital sign). These are specified in definitive sampling protocols. For example,
13 stream acidity may be the indicator, while pH units are the measure (from NPS Inventory and
14 Monitoring website, <http://science.nature.nps.gov/im/monitor/vsm.htm#Definitions>).

16 **Mesic** – of or pertaining to a relatively moist and benign environment.

18 **Microclimate** – variations of climate within a given area.

20 **Monitoring** – is the systematic, consistent, and simultaneous measurements of physical,
21 chemical, biological, and human-use variables of different landscape compartments, through
22 time and at specified locations. In theory, by monitoring a wide range of variables at long-term
23 sites, it is possible to gain an understanding of how ecosystems function and respond to change.

25 **Natural variability** – the ecological conditions, and the spatial and temporal variation in these
26 conditions, that are relatively unaffected by people, within a period of time and geographical area
27 appropriate to an expressed goal (Landres et al. 1999).

29 **Orographic** – of or pertaining to mountains or mountain ranges.

31 **Paleobotany** – the study of fossil plants.

33 **Pediment** – a broad gently sloping erosion surface or plain of relief, typically developed by
34 running water, in an arid region at the base of an abrupt and receding mountain front.

36 **Pedogenesis** – the process of soil formation.

38 **Phenology** – term referring to the timing of an organisms lifecycle (ex: producing flowers only
39 with certain periods of light).

41 **Phreatophytes** – a plant species which extends its roots into the saturated zone of the water
42 table.

44 **Piedmont** – lying or formed at the base of a mountain or mountain range.

Playa – a term used in the Southwestern US for a dry, barren area in the lowest part of an undrained desert basin, underlain by clay, silt, or sand and commonly by soluble salts. It may be marked by an ephemeral lake.

Reference conditions – the range of historic (or natural) variability in ecological structures and processes, reflecting recent evolutionary history and the dynamic interplay of biotic and abiotic conditions and disturbance patterns (Morgan et al 1994; Swanson et al. 1994).

Research – the objective of understanding ecological processes and, in some cases, determining the cause of changes observed by monitoring.

Resilience – the capacity of a particular ecological attribute or process to recover to its former reference state or dynamic after exposure to a temporary disturbance and/or stressor (adapted from Grimm and Wissel 1997). The ability of a natural ecosystem to restore its structure following acute or chronic disturbance (Westman 1978). Resilience is a dynamic property that varies in relation to environmental conditions (Scheffer et al. 2001).

Resistance – the capacity of a particular ecological attribute or process to remain essentially unchanged from its reference state or dynamic despite exposure to a disturbance and/or stressor (adapted from Grimm and Wissel 1997). Resistance is a dynamic property that varies in relation to environmental conditions (Scheffer et al. 2001).

Rhizome – a more or less horizontal underground stem.

Riparian – pertaining to or situated on the banks of a body of water, esp. a river.

Saturated zone – a sub-surface zone in which all the soil interstices are filled with water, under pressure greater than that of the atmosphere.

Semelparous – species which reproduce only once during their lifetime.

Soil / site stability – the capacity of a site to limit redistribution and loss of soil resources (including nutrients and organic matter) by wind and water (Pellant et al. 2000).

Soil quality – the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation (Karlen et al. 1997:6). From an NPS perspective, soil quality is defined by a soil's capacity to perform the following ecological functions: (a) regulate hydrologic processes; (b) capture, retain, and cycle mineral nutrients; (c) support characteristic native communities of plants and animals. Soil quality can be regarded as having (1) an inherent component defined by the soil's inherent soil properties as determined by the five factors of soil formation, and (2) a dynamic component defined by the change in soil function that is influenced by human use and management of the soil (Seybold et al. 1999).

Speleothem - a mineral deposit formed in a cave by the action of water.

State – as applied to state-and-transition models, a *state* is defined as “a recognizable, resistant and resilient complex of two components, the soil [or geomorphic] base and the vegetation structure” (Stringham et al. 2003:109). These two ecosystem components interactively determine the functional status of the primary ecosystem processes of energy flow, nutrient cycling, and hydrology. States are dynamic and “... are distinguished from other states by relatively large differences in plant functional groups and ecosystem processes [including disturbance and hydrologic regimes] and, consequently, in vegetation structure, biodiversity, and management requirements” (Bestelmeyer et al. 2003:116). (Also see *threshold* and *transition*.)

Stressor: any physical, chemical, or biological entity or process that can induce an adverse response (modified from EMAP Master Glossary,

Structure – the spatial organization of the constituent parts of the ecosystem, including large-scale patterns.

Succulent – a plant with fleshy, water storing, stems and leaves.

Threshold – as applied to state-and-transition models, a *threshold* is a point “...in space and time at which one or more of the primary ecological processes responsible for maintaining the sustained [dynamic] equilibrium of the state degrades beyond the point of self-repair. These processes must be actively restored before the return to the previous state is possible. In the absence of active restoration, a new state is formed” (Stringham et al. 2003:109). Thresholds are defined in terms of the functional status of key ecosystem processes and are crossed when capacities for resistance and resilience are exceeded. (Also see *state* and *transition*.)

Transition – as applied to state-and-transition models, a *transition* is a trajectory of change that is precipitated by natural events and/or management actions which degrade the integrity of one or more of the primary ecological processes responsible for maintaining the dynamic equilibrium of the state. Transitions are vectors of system change that will lead to a new state without abatement of the stressor(s) and/or disturbance(s) prior to exceeding the system’s capacities for resistance and resilience (adapted from Stringham et al. 2003). (Also see *state* and *threshold*.)

Trend – a unidirectional change.

Unsaturated zones – a sub-surface zone in which soil interstices are not filled with water.

Variable – any quantitative aspect of an object of concern.

Vital signs – a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. The elements and processes that are monitored are a subset of the total suite of natural resources that park managers are directed to preserve “unimpaired for future generations,” including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources. Vital signs may occur at any level of organization including landscape, community, population, or genetic level, and may be compositional

(referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes) (from NPS Inventory and Monitoring website, <http://science.nature.nps.gov/im/monitor/vsm.htm#Definitions>).

Watershed – a drainage basin, usually described as into a river or lake.

Xeric – of or pertaining to a relatively dry, often stressful environment.

Xerophytic – used to describe plants with very low water requirements.

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