The Southern Nevada Agency Partnership Science and Research Synthesis:

Science to Support Land Management in Southern Nevada

Executive Summary

United States Department of Agriculture / Forest Service

Rocky Mountain Research Station

General Technical Report RMRS-GTR-304

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Abstract

This synthesis provides information related to the Southern Nevada Agency Partnership (SNAP) Science and Research Strategy Goal 1 – to restore, sustain and enhance southern Nevada's ecosystems – and Goal 2 – to provide for responsible use of southern Nevada's lands in a manner that preserves heritage resources and promotes an understanding of human interaction with the landscape. The Science and Research Strategy has nine Sub-goals that address the topics of water and water use, fire, invasive species, biological diversity, restoration, cultural resources, historic content, recreation, and science-based management. This synthesis summarizes the state-of-knowledge related to each of these Sub-goals, addresses knowledge gaps, and provides management implications. It builds on previous efforts to develop the necessary scientific understanding for adaptive management of southern Nevada ecosystems.

Keywords: Mojave, Great Basin, anthropogenic disturbance, climate change, invasive species, altered fire regimes, water resources, species of conservation concern, restoration, heritage resources, recreation, ecosystem resilience, science-based management

Editors

Jeanne C. Chambers is a Research Ecologist with the U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station in Reno, Nevada, and an Adjunct Professor at the University of Nevada, Reno. Her research focuses on the restoration of disturbed or degraded upland and riparian ecosystems in the western United States. Since 1992, much of her work has been on understanding disturbance processes in the arid Great Basin and developing concepts and methods for maintaining or restoring ecosystem resilience.

Matthew L. Brooks is a Research Botanist with the Department of the Interior, U.S. Geological Survey, Western Ecological Research Center, Yosemite Field Station in Oakhurst, California. His primary research interest is the ecology and management of invasive species and wildfire in western North America. He has studied Mojave Desert ecosystems and evaluated effects of land use practices in that region since 1988.

Burton K. Pendleton is a Research Ecologist with the U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station in Albuquerque, New Mexico. His primary research interest is the ecology of desert shrub communities, with an emphasis on the blackbrush community. He is co-leader of the Comprehensive Inventory and Monitoring Project for the Spring Mountains National Recreation Area, Humboldt-Toiyabe National Forest from 2010-2013.

Carol B. Raish is a Research Social Scientist with the U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station in Albuquerque, New Mexico. Her primary research interests include examining resource use on public land and exploring the role of traditional economic practices, such as small-scale ranching, in maintaining cultural heritage. Other projects have included working with communities to understand their preferences concerning fire and fuels management on public land.

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Authors

Wayne R. Belcher
U.S. Geological Survey
Nevada Water Science Center
Henderson, NV 89074
wbelcher@usgs.gov

Matthew L. Brooks
U.S. Geological Survey
Western Ecological Research Center
Yosemite Field Station
Oakhurst, CA 93644
matt_brooks@usgs.gov

Jeanne C. Chambers
U.S. Department of Agriculture, Forest Service
Rocky Mountain Research Station
Reno, Nevada 89512
jchambers@fs.fed.us

Steven M. Ostoja
U.S. Geological Survey
Western Ecological Research Center
Yosemite Field Station
Oakhurst, CA 93644
sostoja@usgs.gov

Randy A. McKinley
U.S. Geological Survey
Earth Resources Observation and Science Center
Sioux Falls, SD 57198-0001
rmckinley@usgs.gov

Alice M. McSweeney
U.S. Department of Agriculture, Forest Service
Rocky Mountain Research Station
Albuquerque, NM 87102-3497
Current Address:
Box 24
Glorietta, NM 87535
amcsweeney@cybermesa.com

Michael J. Moran
U.S. Geological Survey
Nevada Water Science Center
Henderson, NV 89074
mjmoran@usgs.gov

Burton K. Pendleton
U.S. Department of Agriculture, Forest Service
Rocky Mountain Research Station
Albuquerque, NM 87102-3497
bpendleton01@fs.fed.us

Carol B. Raish
U.S. Department of Agriculture, Forest Service
Rocky Mountain Research Station
Albuquerque, NM 87102-3497
craish@fs.fed.us

Megan E. Rogers
U.S. Geological Survey
Nevada Water Science Center
Henderson, NV 89074
mrogers@usgs.gov

Donald W. Sada,
Desert Research Institute
Division of Hydrologic Sciences
Reno, NV 89509
don.sada@dri.edu

Kent Turner
National Park Service
Lake Mead National Recreation Area
Boulder City, NV 89005
kent_turner@nps.gov

Contents

Chapter 1

An Overview of the Southern Nevada Agency Partnership Science and Research Synthesis

Jeanne C. Chambers, Matthew L. Brooks, Kent Turner, Carol B. Raish, and Steven M. Ostoja

Executive Summary

Maintaining and restoring the diverse ecosystems and resources that occur in southern Nevada in the face of rapid socio-economic and ecological change presents numerous challenges to Federal land managers. Rapid population growth since the1980s, the land uses associated with that growth, and the interactions of those uses with the generally dry and highly variable climate result in numerous stresses to ecosystems, species, and cultural resources. In addition, climate models predict that the rate of temperature increase and, thus, changes in ecological processes, will be highest for ecosystems like the Mojave Desert. The Southern Nevada Agency Partnership (SNAP; http://www.SNAP.gov) was established in 1999 to address common issues pertaining to public lands in southern Nevada. Partners include the Bureau of Land Management, National Park Service, U.S. Fish and Wildlife Service, and USDA Forest Service and they work with each other, the local community, and other partners. SNAP agencies manage more than seven million acres of public lands in southern Nevada (95% of the land area). Federal land includes two national recreation areas, two national conservation areas, four national wildlife refuges, 18 congressionally designated wilderness areas, five wilderness study areas, and 22 areas of critical environmental concern. The partnership's activities are mainly centered in Southern Nevada's Clark County (fig. 1.1), but lands managed by SNAP partner agencies also include portions of the Lake Mead National Recreation Area in Mohave County, Arizona, U.S. Fish and Wildlife Service, and USDA Forest Service-managed lands in Lincoln and Nye Counties, Nevada, and all lands and activities managed by the Southern Nevada District Office of the Bureau of Land Management. These lands encompass nine distinct ecosystem types (fig. 1.2), support multiple species of management concern and 17 listed species, and are rich in cultural and historic resources. This introductory executive summary discusses the Science and Research Strategy developed by the SNAP agencies, the Science and Research Report, and need for science-based management in southern Nevada.

Science and Research Strategy

The SNAP agencies are interested in developing an interagency science program that is consistent across agency boundaries and that can inform management decisions regarding natural resources, cultural resources, and human use of public lands. A science and research team was established by the SNAP agencies to develop the interagency science program. This team published the SNAP Science and Research Strategy (Strategy) in 2009. The Strategy is designed to integrate and coordinate scientific research programs in southern Nevada and to improve the efficiency and effectiveness of these programs.

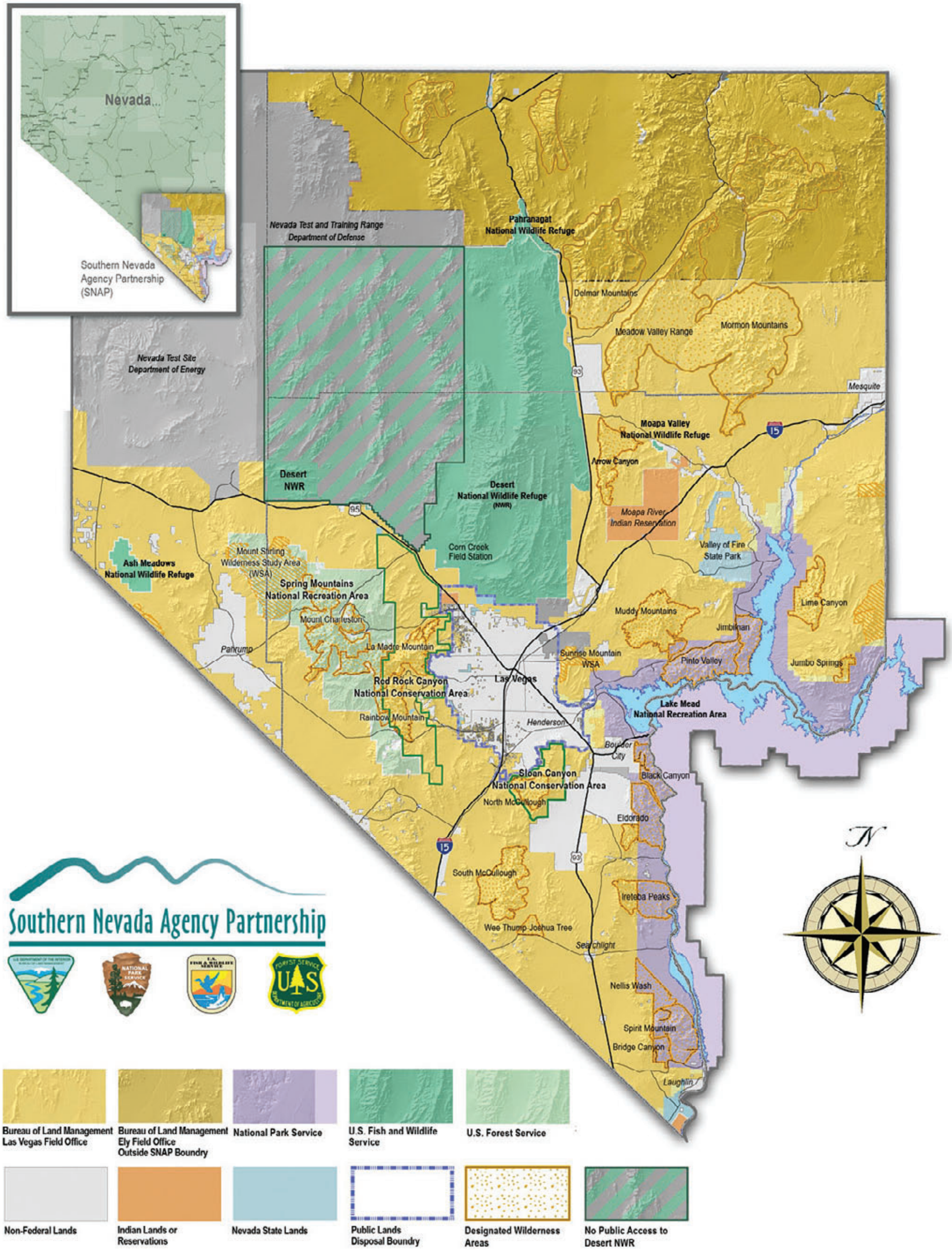

Figure 1.1—Map of the SNAP area illustrating land ownership within the region.

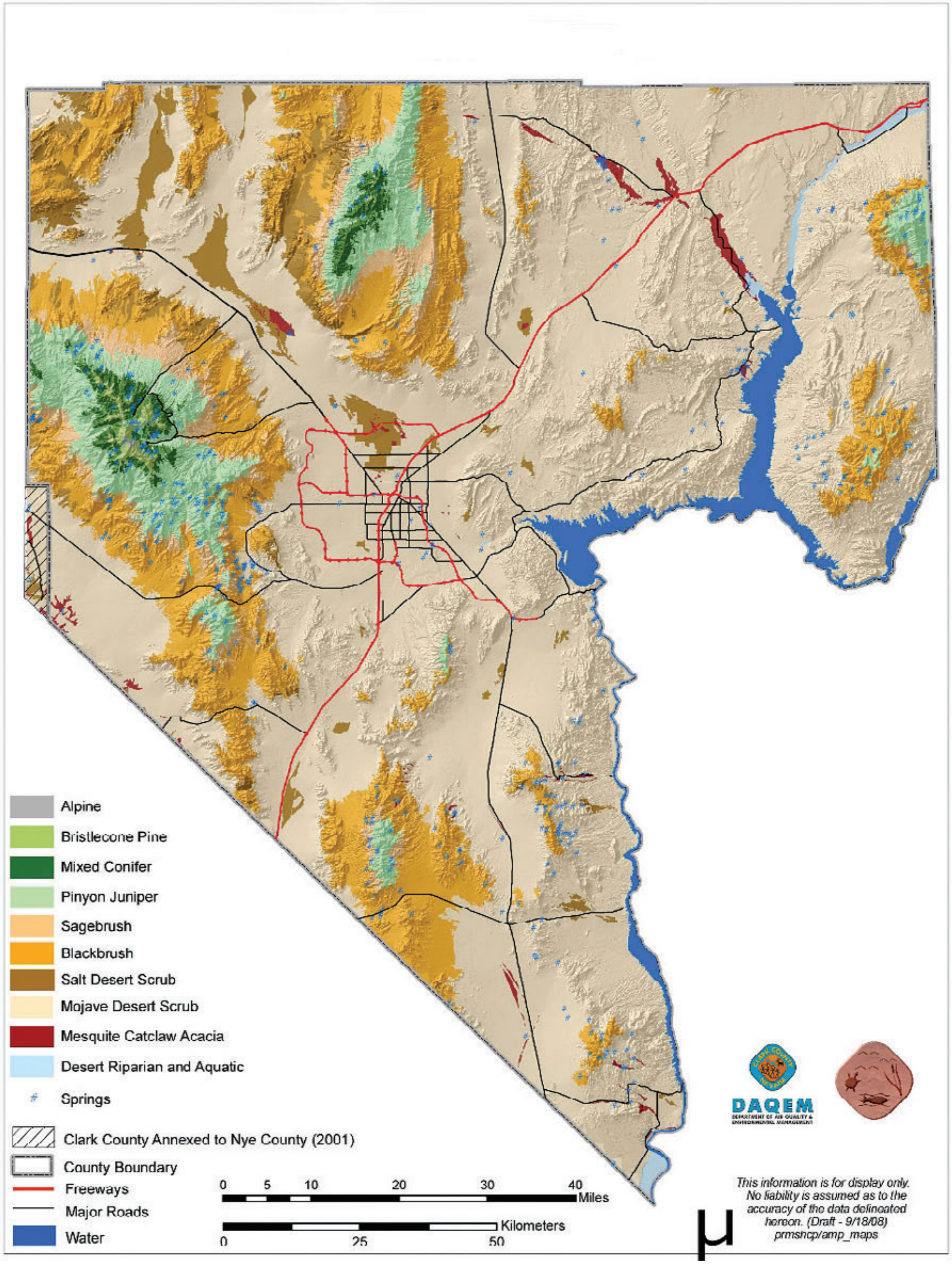

Figure 1.2—Map of the SNAP area illustrating the southern Nevada ecosystem types recognized in the Clark County MSHCP.

The Strategy's purpose is to inform and guide SNAP agencies in identifying the highest priority science and research needs, sharing resources and funds to implement needed research, communicating research needs to potential research partners, and eliminating redundancy between agency research programs.

Key components of the Strategy are an annual SNAP science needs assessment and a SNAP Science and Research Synthesis Report (Synthesis Report). The needs assessment is used to communicate SNAP's science and research needs to the broader scientific research community and to potential research partners. It documents high priority regional and management needs, is prepared by the SNAP science and research team, and is based on input of agency managers, resource staff, and scientists. The Synthesis Report summarizes the state of knowledge and key science findings related to the SNAP Science and Research Strategy Goals, identifies knowledge gaps, and provides management implications. The Synthesis Report is prepared on a 5-year basis and is used to guide the annual SNAP science needs assessments. The first Synthesis Report is comprised of two General Technical Reports; one that has chapters with detailed reviews and one that includes these Executive Summaries of the more detailed chapters.

The SNAP Science and Research Strategy established several Goals for interagency science and research that is conducted in support of resource management in southern Nevada. Development of the Goals was based on individual agency goals, the SNAP Board vision, the interagency science and research team's charter goals, the input of individual agency specialists, and input from interdisciplinary scientists that was obtained during several planning workshops. Each Goal has a set of Sub-goals and questions that address specific science needs. The three main Goals are:

Goal 1. Restore, sustain, and enhance Southern Nevada's ecosystems.

Goal 2. Provide for responsible use of Southern Nevada's lands in a manner that preserves heritage resources and promotes an understanding of human interaction with the landscape.

Goal 3. Promote scientifically informed and integrated approaches to effective, efficient, and adaptive management.

Science and Research Synthesis Report

The Goals and Sub-goals of the SNAP Science and Research Strategy provide key focal areas for both the annual science needs assessments and the science and research Synthesis Report. This Synthesis Report addresses information related to Goals 1 and 2 and their associated Sub-goals (table 1.1). The Sub-goals address the topics of fire, invasive species, landscapes and watersheds, biological diversity, cultural resources, historic content, recreation, land uses, and education. This Synthesis Report provides a summary of the state of knowledge related to each of the nine Sub-goals, addresses knowledge gaps, and provides management implications. It builds on previous efforts to develop the necessary scientific understanding for adaptive management of southern Nevada ecosystems including the Multi Species Habitat Conservation Plan (MSHCP), and a 2007 workshop that was organized by the Desert Research Institute on the characteristics of southern Nevada ecosystems and the threats to ecosystem health. The Synthesis Report is organized around the topics addressed in the Sub-goals, and table 1.1 provides a crosswalk between the chapters in this document and the Goals and Sub-goals in the SNAP Strategy.

Table 1.1—A crosswalk relating the chapters in this document to the Goals and Sub-goals in the SNAP Science and Research Strategy.

Goal/Chapter	Sub-goal
Goal 1. Restore, sustain, and enhance southern Nevada's ecosystems	
Chapter 1. An Overview of the Southern Nevada Agency Partnership Science and Research Synthesis	
Chapter 2. Southern Nevada Ecosystem Stressors	
Chapter 3. Water and Water Use in Southern Nevada	*Sub-Goal 1.3.* Restore and sustain proper function of southern Nevada's watersheds and landscapes
Chapter 4. Invasive Species in Southern Nevada	*Sub-Goal 1.2.* Protect southern Nevada's ecosystems from the adverse impacts of invasive species
Chapter 5. Fire History, Effects, and Management in Southern Nevada	*Sub-Goal 1.1.* Manage wildland fire to sustain southern Nevada's ecosystems
Chapter 6. Species of Conservation Concern and Environmental Stressors: Local, Regional, and Global Effects	*Sub-Goal 1.4.* Sustain and enhance southern Nevada's biotic communities to preserve biodiversity and maintain viable populations
Chapter 7. Maintaining and Restoring, Sustainable Ecosystems in Southern Nevada	*Sub-Goal 1.3.* Restore and sustain proper function of southern Nevada's watersheds and landscapes
Goal 2. Provide for responsible use of southern Nevada's lands in a manner that preserves heritage resources and promotes an understanding of human interaction with the landscape	
Chapter 8. Human Interactions with the Environment through Time in Southern Nevada	*Sub-Goal 2.1.* Develop an understanding of human interactions with the environment through time
Chapter 9. Preserving Heritage Resources through Responsible Use of Southern Nevada's Lands	*Sub-Goal 2.2*. Preserve heritage resources through responsible use of southern Nevada's lands
Chapter 10. Recreation Use on Federal Lands in Southern Nevada	*Sub-Goal 2.4.* Provide for appropriate (type and location), quality, and diverse recreational experiences, resulting in responsible visitor use on federal lands in southern Nevada
*Chapter 11***.** Science-based Management of Public Lands in Southern Nevada	*Sub-Goal 2.3.* Manage current and future authorized southern Nevada land uses in a manner that balances public need and ecosystem sustainability
	Sub-Goal 2.5. Promote an effective conservation education and interpretation program to improve the quality of resources and enhance public use and enjoyment of southern Nevada public lands

Science-Based Management

Science-based management aimed at maintaining sustainable ecosystems is essential if public lands in southern Nevada are to continue to support both multiple land uses and habitat for the region's diverse assemblage of plants and animals. Sustainable or "healthy" ecosystems exhibit resilience to stressors and disturbances and resistance to invasives and supply important ecological services and goods. Due to the strong elevation/climate gradients in the region and the large differences in the abiotic and biotic characteristics of southern Nevada ecosystems, the different ecosystem types exhibit varying levels of ecological resilience. In general, ecosystems that receive the highest levels of precipitation or that are the most productive are the most resilient to stressors and disturbances in the Great Basin and Mojave deserts. For example, among the least resilient are Mojave Desert scrub ecosystems at low elevations and alpine ecosystems at high elevations, while the most resilient are mixed conifer and piñon and juniper ecosystems. In contrast, resistance to invasives tends to be higher in the most stressful environments (salt desert shrub and alpine ecosystems) because only a limited suite of species are adapted to establish and persist under the harsh conditions. Several interacting factors influence both resilience to disturbance and stressors and resistance to invasives in arid and semi-arid ecosystems including the climatic regime and other environmental characteristics of the ecosystem, its ecological condition, the severity and frequency of disturbance, and feedbacks among invasive species and disturbance regimes.

Adaptive management that is aimed at maintaining or increasing resistance and resilience can reduce the uncertainty associated with management decisions and increase the region's capacity to deal with stressors without losing options for the future. Key aspects of adaptive management are a scientific understanding of the underlying processes structuring southern Nevada ecosystems, the effects of the numerous stressors on these ecosystems and their associated species, and the factors that influence their ecological resistance and resilience. Routine assessment of the ecological conditions of the different ecosystem types and monitoring the effects of the region's stressors and of management actions to maintain or restore ecosystem resistance and resilience provides feedback for adaptive management. Periodic science syntheses, like the ones in this GTR, give information on the current state of knowledge and the ecological trajectories of the region's ecosystems and species, and identify needed information for effective management.

For a complete discussion of topics in this executive summary, see Chapter 1, *An Overview of the Southern Nevada Agency Partnership Science and Research Synthesis*, in "The Southern Nevada Agency Partnership Science and Research Synthesis—Science to Support Land Management in Southern Nevada" (RMRS GTR-303).

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Chapter 2

Ecosystem Stressors in Southern Nevada

Burton K. Pendleton, Jeanne C. Chambers, Matthew L. Brooks, and Steven M. Ostoja

Executive Summary

Southern Nevada ecosystems are subject to a number of stressors that range in scope from local to regional to global. At the regional scale, human population growth and related activities constitute a major stressor. Nevada has undergone significant change due to unprecedented population growth and ongoing global change processes. Nevada's growth rate has been the highest in the nation for the last five decades. Clark County has experienced particularly rapid growth with a population increase of more than 40 percent since the 2000 census. Other regional or local stressors, many of which are related to human population growth, include invasive species, changes in land use, and altered fire regimes. Global stressors affecting southern Nevada ecosystems include elevated carbon dioxide (CO_2) concentrations, nitrogen (N) deposition, and changes in temperature and precipitation patterns. This chapter provides background information on the stressors affecting southern Nevada's ecosystems that is needed to address Goal 1.0 in the SNAP Science Research Strategy, which is "Restore, sustain, and enhance southern Nevada's ecosystems."

Global Stressors

Atmospheric CO_2 increased approximately 32 percent during the last century and is expected to double by the end of this century. Concentrations of CO_2 are closely linked to global warming and climate change. Over the last 150 years, global temperatures have risen in tandem with increasing CO_2. Data for Nevada show that temperatures have risen 2.0 °C since 1908, with a projected increase of 2-6 °C by 2100. Increases in nighttime temperatures will likely lead to an expansion of desert species northward. Precipitation patterns also are influenced by rising levels of atmospheric CO_2 through changes in ocean temperatures and global circulation patterns. In addition to expected changes in the amount and timing of precipitation, rising temperatures will likely decrease snow pack levels and increase the rate of snow-melt, resulting in lower mid-summer stream flows. Longer and more intense droughts are expected to occur throughout the west. Drought and reduced runoff will result in increased competition for the limited water resources of southern Nevada.

Local and Regional Stressors

Population Growth and Urbanization

Until the recent economic downturn, Nevada was the fastest growing state in the country for five straight decades. The vast majority of urban development has taken place in the Mojave Desert scrub ecosystem. Associated issues include dust generation, dumping, off-road travel and unauthorized roads, destruction of cultural resources, creation of dispersal corridors for exotic species, and land degradation caused by uncontrolled recreation and ORV use. Vegetation communities at higher elevations are impacted by recreational activities of the large urban population. Pollution and dust from energy development, housing development, and recreation affect air quality through increases in airborne particulate matter. Of particular concern are particles smaller than 10 micrometers in diameter (PM-10), which can cause serious health effects. Windblown dust accounts for 89-90 percent of the PM-10 occurring in Clark County.

Control measures currently being implemented are expected to offset increases in vehicular emissions that accompany population growth.

Nitrogen Deposition

Industrial and urban pollution have led to increased levels of atmospheric nitrogen deposition. Nitrogen deposition generally occurs as dust. Increased levels of nitrogen may result in higher biomass production if accompanied by sufficient moisture; however, potential gains in productivity will likely be mitigated by changes in climate. Unfortunately, exotic annual grasses are particularly responsive to increased levels of nitrogen, potentially causing a community shift from shrubland to one dominated by invasive grasses. Increased levels of soil N are also expected to alter nutrient cycling.

Energy Development

In southern Nevada, renewable energy is in the form of solar and wind energy development. The BLM has identified five solar energy zones in southern Nevada. These areas have high solar radiation and limited environmental concerns. Solar energy facilities are planned, under construction, or in operation in Boulder City and Amargosa Valley. Limited experience with large-scale solar facilities means that there is little on-the-ground capacity to mitigate potential impacts. Attention during the planning, construction and operation phases could help to minimize potential environmental impacts.

The technology to develop energy from wind on a large scale is more mature than that for large-scale solar development, but our understanding of potential impacts of proposed large-scale wind farms in southern Nevada is severely lacking. Potential effects of wind turbines on wildlife include avoidance behavior, and bird and bat mortality.

Recreation

As the population in southern Nevada continues to grow, so too will the use of public lands for recreation. Meeting recreational needs of both citizens and visitors to the area must be balanced with maintaining natural resources and conserving the unique biodiversity of southern Nevada's ecosystems.

Water Development

Water is a very critical issue throughout the Southwest. The Southern Nevada Water Authority (SNWA) was formed in 1991 with the goal of managing existing water resources, developing new ones, and promoting conservation. Ninety percent of the water provided by the Las Vegas Valley Water District is from Colorado River water impounded in Lake Mead. Ten percent of the water budget comes from approximately 100 municipal groundwater wells. Based on current and projected demands, a long-term water supply other than the Colorado River is needed. The Water Resource Plan projects the need for additional groundwater resources to be brought on-line by 2020.

Springs are home for many rare species and the presence of non-native species, both animal and plant, constitute a major stressor. Stressors on springs include animal and human trampling, water diversion and groundwater pumping, seasonal freezing and drying, contamination, and scouring by flooding.

Insects and Disease

Insect and disease issues in southern Nevada are limited at present. Chronic wasting disease in deer, white nose syndrome in bats, and respiratory infections in desert bighorn sheep have the potential to occur in southern Nevada, but are not currently found within the state. In 2009, the Humboldt-Toiyabe National Forest conducted an aerial survey of bark beetle damage. Over 200,000 acres were surveyed, with only minimal damage observed. Drought, warmer winter temperatures, and changes in precipitation amount and timing will certainly affect the type and extent of insect and disease outbreaks, but what these might be is currently unknown.

Grazing

Permitted grazing by domestic livestock in southern Nevada is minimal, although trespass grazing is an issue in some areas. There is a legacy of effects from grazing of large numbers of cattle and sheep in previous decades. Very few records of past use are available and that makes determining the amount of disturbance and recovery rates difficult. Currently, the major grazing impacts in southern Nevada come from wild horses and burros. The annual population increase since 2006 is estimated to be 17 to 20 percent for wild horses and 20 percent for burros, a fact that makes maintenance of appropriate population size difficult. Wild horses and burros consume herbaceous vegetation and some parts of woody vegetation in a wide variety of vegetation types, with use concentrating at springs/seeps. Ground disturbance caused by trampling, particularly in areas surrounding sensitive springs and seeps, creates conditions favorable for invasive non-native species and may harm rare species. Large scale fires, which are a fairly recent phenomenon, and the projected increases in temperature and drought frequency will reduce available water and forage.

Invasive Species

Invasive species present a number of management issues. In the Mojave Desert, management of invasive plants and management of fire must be integrated due to the linkage between the two issues. Invasive plants produce biomass and fine fuels that will carry fire in the interspaces between shrubs, resulting in large, relatively frequent wildfires in desert shrub ecosystems that are not fire adapted. Wetland and aquatic invasives are also on the rise. Riparian weeds reduce the biodiversity of critical wetland communities. Also, the release of nonnative fish into springs, quagga mussels into lakes, and nonnative bullfrogs and crayfish into lakes and rivers are impacting the native and endemic fish, amphibians, and snail species.

Altered Fire Regimes

Wildfire is a growing concern to managers in southern Nevada. The shrub communities of the Mojave Desert are not adapted to large-scale fire. Shrub seedbanks of many species are not sufficient for natural regeneration to occur after fire. The post-fire shrub community is less diverse, and has increased fine fuel loads that are prone to more frequent fire. Thus, the fire cycle is reset outside of the timeframe under which these communities developed. Restoration of the post-fire landscape is problematic due to lack of predictable moisture, unavailability of native seed, and other issues. Suppression of naturally occurring fires at upper-elevation ecosystems that are fire-adapted has also created a problem for land managers.

Knowledge Gaps and Management Implications

Southern Nevada is experiencing both a novel suite of stressors and an unprecedented rate of climate change. With the introduction of new stressors, rapid climate change, and increased and larger disturbances, ecosystems will change in new and difficult to predict directions. Managers are faced with situations for which we have no current answers. What can be done to control the influx of invasive species? How can we manage the increasing frequency and intensity of wildfires? Of particular concern are endemic species that exhibit specific habitat requirements. Are they resilient enough, genetically variable enough, or are their specialized habitats protected enough for them to persist in place? These questions constitute some of the big issues facing managers and provide a general overview of knowledge gaps, which are discussed in more detail in subsequent chapters. Additional information needs are:

- Species-specific climate profiles and projected ranges under different climate change scenarios; methods to detect geographic shifts in plant communities and individual species.
- Effects of drought, warmer winter temperatures, and changes in precipitation amount and timing on the type and extent of insect and disease outbreaks.
- Interactive effects of naturally occurring disturbances with global change drivers such as rising levels of CO_2 and N deposition.
- Effects of N deposition and increased CO_2 levels on biogeochemical cycles including biological soil crust function.
- Appropriate plant materials and planting techniques for use in reclamation and restoration of disturbed sites under expected climate change scenarios.
- Criteria for selecting the most appropriate and least deleterious sites for energy development.
- Information on the environmental impacts of large-scale power development, including wind and solar, on animal mortality, migration corridors, seed movement, and potential off-site effects of dust and chemical dust control agents.
- Improved techniques for tracking available forage given the increase in the biomass of exotic annual grasses and the accompanying changes in the size and frequency of wildfires.

Human caused stressors can be mitigated through educational programs. Dust control and reduction, energy savings to reduce energy sprawl, reduction of soil surface disturbance, and reduction of the impact of recreational activities are among many areas in which existing and new educational programs could reduce human impacts. All educational programs should stress how these steps increase ecosystem integrity. For a complete discussion of topics in this executive summary, see *Chapter 2, Southern Nevada Ecosystem Stressors* in “The Southern Nevada Agency Partnership Science and Research Synthesis – Science to Support Land Management in Southern Nevada” (RMRS GTR-303).

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Chapter 3

Water and Water Use in Southern Nevada

Wayne R. Belcher, Michael J. Moran, and Megan E. Rogers

Executive Summary

Water and water use in southern Nevada is an important issue. The scarcity of water resources for both human and biologic communities often leads to intense competition for both surface and ground waters. Anthropogenic and climate change impacts on scarce water resources need to be understood to assess human and ecosystem health for southern Nevada. Chapter 3 outlines the state of the knowledge for hydrology in southern Nevada − ground water, surface water, and water quality − and provides recommendations for filling knowledge gaps. Information is presented that will help land managers develop strategies to achieve Sub-goal 1.3 in the SNAP Science Research Strategy, which is to "Restore and sustain proper function of southern Nevada's Watersheds and Landscapes" (see table 1.1).

Groundwater

In southern Nevada, groundwater flow is strongly influenced by the physical framework of the system, which is characterized by aquifers, confining units, and flow barriers. Groundwater flows through a diverse assemblage of rocks and sediments in the region, and geologic structures exert significant control on groundwater movement.

The groundwater hydrology of southern Nevada, as in all flow systems, is influenced by geology and climate and varies with time. In general, groundwater moves through permeable zones under the influence of hydraulic gradients from areas of recharge to areas of discharge in the regional system. The topography produces numerous local subsystems within the major flow system. Water that enters the flow system in a recharge area may be discharged in the nearest topographic low, or it may be transmitted to a regional discharge area.

Three principal aquifer types exist within southern Nevada: (1) volcanic-rock aquifers, which are primarily tuff, rhyolite, or basalt of Tertiary age; (2) carbonate-rock aquifers, which are primarily limestones and dolomites of Mesozoic and Paleozoic age; and (3) basin-fill aquifers, which are primarily unconsolidated sand and gravel of Quaternary and Tertiary age. Any or all three aquifer types may be in, or underlie, a particular basin and constitute three separate sources of water; however, the aquifers may be hydraulically connected to form a single source. Other rock types within the region have low permeability and act as boundaries to the flow of fresh ground water.

In the prevailing conceptual model of interbasin flow, water enters the system as interbasin underflow and as recharge from precipitation in upland areas. Because of present-day arid conditions, recharge currently is restricted to higher altitudes; virtually no recharge occurs and no perennial surface water flows in the lowlands and valley floors (except the Colorado River and its tributaries). Ground-water flow paths within the system diverge from the highlands and are superimposed on deeper regional flow paths that are controlled largely by flow in the regional carbonate-rock aquifer. The

SNAP area is contained within two regional groundwater flow systems: the Death Valley flow system and the Colorado flow system. The Death Valley flow system is located in the southern part of the Great Basin province and is approximately 100,000 sq. km. in area. It consists of recharge areas in the mountains of central and southern Nevada and discharge areas of wet playas and springs south and west of the Nevada National Security Site and in Death Valley, California. The Colorado flow system is located in the Colorado River drainage system just east of the southern part of the Great Basin and is approximately 42,000 sq. km. in area. Recharge areas are in some mountainous areas within the flow system, but recharge to the system is also from groundwater flow from adjacent river systems. The Virgin and Colorado Rivers are the major discharge areas of the system.

Current sources of groundwater flow in the region are (1) recharge from precipitation in the mountains (usually winter storms) within the model domain; and (2) lateral flow into the area, predominantly through the carbonate-rock aquifer. Most groundwater recharge results from infiltration of precipitation and runoff on the mountain ranges. Water may infiltrate from melting snowpack in the mountains primarily on volcanic or carbonate rocks or adjacent to the mountains from streams flowing over alluvium (fans and channels).

Groundwater discharge in the region is from (1) seeps and spring flow from the regional carbonate-rock aquifer and local systems; (2) evapotranspiration (ET); (3) pumpage for irrigation, mining, public supply, commercial, and domestic uses; and (4) subsurface flow in or out of the area.

Surface Water

In southern Nevada, perennial streamflow is sparse, except in the Colorado River drainage. Most surface water in the region is either runoff or spring discharge. Precipitation falling on the slopes of the mountains forms small, intermittent streams that quickly disappear and infiltrate as groundwater recharge. In addition, several streams originate from snowmelt in the high altitudes of the Spring Mountains. Both of these types of streams have highly variable base flows and in dry years have almost imperceptible discharges. Springs maintain perennial flow for short distances in some of the drainages.

In most of Nevada, nearly all the streams that originate in the mountains are ephemeral and lose flow to alluvial aquifers as the streams emerge onto the valley floors. In southern Nevada, there are three main fluvial systems: the Colorado River (Lake Mead), the Virgin and Muddy Rivers, and the Las Vegas Wash. The Colorado River is supplied primarily by runoff from the Rocky Mountains. The Virgin and Muddy Rivers and the Las Vegas Wash are all tributaries to the Colorado River. The Muddy River begins as a series of regional springs in Moapa Valley and drains into the northern arm of Lake Mead (Colorado River). The Virgin River originates in Navajo Reservoir in southwestern Utah and enters Lake Mead from the north (forming the northern arm of the lake). Prior to the construction of Hoover Dam, the Muddy River joined the Virgin River. The Las Vegas Wash, which supports a large wetland, drains Las Vegas Valley and largely contains urban runoff, shallow ground water, reclaimed water, and storm water runoff. USGS measures discharge on all four of these rivers.

Ground-water discharges at Ash Meadows National Wildlife Refuge, Pahranagat National Wildlife Refuge, the Moapa Valley, at numerous springs and seeps in the mountainous areas, and along parts of the Amargosa River. Additionally, ground water is intersected at Devils Hole, a fissure in the regional carbonate-rock aquifer in the Ash Meadows area. Most springs can be classified as local (low discharge and cool temperatures) or regional (high discharge and warmer temperatures).

Knowledge Gaps and Management Implications

There are many actual and potential water-quality issues on and within the Federal lands of southern Nevada with respect to consumptive use, anthropogenic impacts, and preservation of habitat for endangered and threatened species. Desert Research Institute (DRI) has conducted extensive work assessing the water quality of local springs in southern Nevada as it relates to the viability of biologic communities. USGS, the U.S. Environmental Protection Agency, the National Park Service, U.S. Fish and Wildlife Service, the Bureau of Land Management, and other Federal, state, and local agencies collect water quality information on a somewhat routine basis.

As climate change and increasing population potentially reduce available water supplies for both human and biologic communities, the collection and interpretation of information to define and assess local and regional hydrologic conditions becomes vital. Assessing the information that is regularly collected by Federal agencies in southern Nevada has indicated that there are several gaps in data collection. Since there tends to be a project-by-project approach to data collection, at times there is no long-term program(s) to collect data. Data are collected for the goals of a certain project and once the project is completed, data collection ends. There is very little long-term continuity or planning on basic data collection that could be used to assess the hydrologic and biologic health of southern Nevada. A long-term consistent data collection effort will ensure that the right data are collected for evaluation of baseline conditions and assessment of long-term trends.

Recommendations for long-term data collection include: pumping inventories, evapotranspiration, recharge, spring discharge, and stream flow.

For a complete discussion of topics in this executive summary, see *Chapter 3, Water and Water Use in Southern Nevada*, in "The Southern Nevada Agency Partnership Science and Research Synthesis—Science to Support Land Management in Southern Nevada" (RMRS GTR-303).

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Chapter 4

Invasive Species in Southern Nevada

Matthew L. Brooks, Steven M. Ostoja, and Jeanne C. Chambers

Executive Summary

Southern Nevada contains a wide range of topographies, elevations, and climatic zones that are emblematic of its position at the ecotone between the Mojave Desert, Great Basin, and Colorado Plateau ecoregions. These varied environmental conditions support a high degree of biological diversity, but they also provide opportunities for a wide range of invasive species. In addition, the population center of Las Vegas valley and agricultural areas scattered throughout Clark, Lincoln, and Nye counties, all connected by a network of roads and highways, plus ephemeral and perennial watercourses, provide abundant opportunities for new invaders to be transported into and within southern Nevada. Invasive species are a major concern for land managers because of their capacity to compete with native species, change habitat conditions, and alter ecosystem properties.

Executive Order 13112 issued by President Clinton in 1999 called for the establishment of the inter-departmental National Invasive Species Council (NISC) and creation of a national plan to serve as a comprehensive blueprint for Federal actions on invasive species. This plan identifies five strategic goals: prevention, early detection and rapid response, control and management, restoration, and organizational collaboration. It defines an invasive species as "a species that is 1) non-native (or alien) to the ecosystem under consideration and 2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health." Many non-native species do not cause harm and are actually beneficial to humans (e.g., crop species). Others are clearly invasive and harmful outside of their native range (e.g., European starling). Still other non-native species are considered invasive by some, but beneficial or otherwise desirable by others (e.g., some ornamental plants, wild horses, and burros). Land managers, policy makers, and society in general must determine which non-native species are invasive and pose the greatest threats. This chapter provides information that will help land managers develop strategies to achieve Sub-goal 1.2 in the SNAP Science Research Strategy, which is to "Protect southern Nevada's ecosystems from the adverse impacts of invasive species" (see table 1.1).

Invasive Plants

Uplands

The majority of invasive plant species that dominate upland areas in southern Nevada are annuals. Annuals complete their entire lifecycle in 1 year—germinating, growing, reproducing, and dying—typically from winter to spring. They are ideally suited to avoid the most inhospitable arid conditions that characterize most of the year by remaining dormant as seeds in the seedbank. Seeds also provide an ideal mechanism for dispersal, allowing annual species to spread both within and among areas. Major species of concern include cheatgrass (*Bromus tectorum*), red brome (*Bromus rubens*), Mediterranean split-grass (*Schismus barbatus*, *Schismus arabicus*), red-stemmed filaree (*Erodium cicutarium*), and various mustard species (*Brassica tournefortii, Hirshfeldia incana, Sisymbrium irio, Sisymbrium altissimum*, *Malcomia africana*).

The greatest threat that invasive plants pose to upland areas of southern Nevada is the alteration of fire regimes. Invasive plants also outcompete native plants for limiting resources. In addition, the seeds of some invasive plants (e.g., red brome, red-stemmed filaree) are eaten and dispersed by native granivores. The desert tortoise will consume red brome if there is little else to eat, and this may cause physiological problems associated with potassium levels.

Annual plants are notoriously difficult to manage. Their seeds are easily dispersed and often remain viable for many years. Preventing their transport into new areas of southern Nevada is the best first line of defense, followed by eradication or containment of nascent populations. Washing of equipment and removal of propagules from shoes and clothing before leaving infested areas also can help reduce dispersal rates. Repeated treatment over a period of years is generally required until the soil seedbank becomes exhausted.

Riparian/Aquatic and Springs

Riparian and spring ecosystems are characterized by both annual and perennial invasive plant species. Perennial species that have clonal or rhizomatous life forms or that are capable of root sprouting are ideally suited to survive the scouring floods and sediment deposition that often typify arid riparian ecosystems. These species are also often highly competitive with native riparian species. Facultative or obligate riparian species include the perennials, giant reed (*Arundo donax*), Russian olive (*Elaeagnus angustifolia*), camelthorn (*Alhagi pseudalhagi*), and perennial pepperweed (*Lepidium latifolium*), and the annual rabbitsfoot grass (*Polypogon monspeliensis*). Upland species that utilize seasonal increases in water availability or that occur at the periphery of these ecosystems include Russian knapweed (*Acroptilon repens*), invasive annual grasses such as ripgut brome (*Bromus diandrus*), red brome, and cheatgrass, and invasive mustards.

Perennial species can attain large size, displace native vegetation, and significantly affect the physiographic structure of vegetation stands. Tamarisk (*Tamarix* spp.) is perhaps the most infamous of these species in southern Nevada. Conversion of native riparian vegetation to tamarisk stands can affect wildlife habitat quality and ecosystem properties associated with fire and hydrologic regimes. Even so, this ecosystem continues to support a diversity of species including two birds of conservation concern.

Challenges associated with controlling and managing riparian invasive plants differ from those of uplands. Many perennial species have persistent below-ground roots and rhizomes that make eradicating populations difficult (e.g., giant reed, perennial pepperweed). Also, seeds and other propagules are readily transported in flowing water and by the animals that utilize these ecosystems. Mechanical or prescribed fire treatments often are used initially to reduce aboveground biomass and stimulate resource re-allocation from belowground to aboveground tissue. Then, after regrowth has occurred, chemical treatments are used as a follow-up to kill the plants. Treatment of resprouts may be necessary during subsequent years. Long-term of success of these treatments is dependent on restoration with native species and continued monitoring to detect reoccurring or new invasions.

There are few aquatic plant invaders in southern Nevada, and those that are currently present do not pose serious threats. However, there are a few that pose real threats and are poised to invade southern Nevada. Eurasian water-milfoil (*Myriophyllum spicatum*) occurs along the Colorado River in the vicinity of Parker Arizona and giant salvinia (*Salvinia molesta*) has been reported farther downstream at the Imperial National Wildlife Refuge. Both species have the potential to choke out waterways, increase eutrophication, disrupt food webs, and otherwise significantly alter aquatic habitats of southern Nevada. These changes could threaten everything from endemic animals such as pupfish and spring snails, to game species such as sunfish, bass, and trout. Options for controlling aquatic plants are limited once the species have established. Educational programs promoting watercraft washing and periodic inspections at entry points are potentially the most effective way to prevent transport and colonization of new waterways.

Invasive Animals

Terrestrial

While perhaps less conspicuous and less abundant than invasive plants, invasive animals can have significant ecological and economic consequences in southern Nevada. Species of concern include Argentine ants (*Linepithema humile*), imported red fire ants (*Solenopsis* spp.), and feral dogs (*Canis familiaris*), cats (*Felis catus*), and cattle (*Bos primigenius*). Wild horses (*Equus ferus*) and burros (*Equus asinus*) also can impact natural resources and could be considered an invasive species as defined by the National Invasive Species Council. However, these species also are viewed by many as a national cultural treasure, emblematic of the pioneer spirit of the West, and are specifically protected by the 1971 Wild Free-Roaming Horse and Burro Act (Public Law 92-195).

Argentine ants are successful and voracious predators in part because they will combine territories and attack other insects including native ant colonies, lizards, snakes and small mammals. Red imported fire ants compete with native fire ants, prey on invertebrates and vertebrates, and may affect plant assemblages through selective seed removal. Wild horse, burros, and cattle can cause damage by trampling vegetation, soil compaction, and overgrazing, especially near watering sites. Feral cats and dogs prey on birds and other wildlife and are among the main predators of the Federally protected desert tortoise.

Control of invasive ants can be difficult. Aside from baiting and chemical control, few options exist and even these may have some residual impact on non-target groups. Trapping and other removal techniques are effective control strategies for wild horses, burros, cattle, and feral cats and dogs. However, these methods are generally not implemented due to animal rights concerns, and comprehensive feral dog and cat programs can be very difficult to implement.

Aquatic

Several notable aquatic invasive species exist in southern Nevada including the quagga mussel (*Dreissena rostriformis*), American bullfrogs (*Rana catesbeiana*), red swamp crayfish (*Procambarus clarkii*), mosquitofish (*Gambusia* spp.), red shiner (*Notropis leutrensis*), shortfin molly (*Poecilia mexicana*), cichlids (*Oreochromis* spp.), and tilapia (*Tilapia* spp.).

Quagga mussels can clog pipes and compromise water intake systems, encrust boats, docks and associated facilities, alter the aquatic food web, impact sport fishing and litter beaches with their small sharp shells. Bullfrogs are aggressive and voracious predators of native toads and frogs, reptiles, small mammals, and birds, some of which are listed under the Endangered Species Act. Mosquitofish, red shiner, and cichlids have adversely affected native invertebrates, amphibians, and fishes. Shortfin mollies prey on larval fish including the Federally Endangered Moapa dace (*Moapa coriacea*) and Moapa White River springfish (*Crenichthys baileyi moapae*).

Prevention is the key to quagga mussel control because even if adults are killed the larvae have the ability to evade control measures and later recolonize. Physical methods for control of bullfrogs and crayfish include de-watering and temporary habitat removal, but this can affect native species. Chemical control methods for fish include picicides (e.g., rotenone); however, the effective dosage required will also kill most other co-occurring organisms.

Knowledge Gaps and Management Implications

Prevention is clearly the first line of defense against invasive species. The most effectively managed invasive species are those that are kept from being transported to, and colonizing within, southern Nevada. Species can be transported accidentally by people and equipment, and this mode of transport can be minimized by washing tools and vehicles, especially when leaving sites with known local infestations. Other species can be transported purposefully into a region, and then spread on their own into wildland areas. These purposeful introductions can be discouraged by preventative regulations for state and Federal noxious species, and by public education and partnerships with the agricultural and ornamental horticultural community for other high priority species to help find less invasive alternatives.

Early detection and rapid response requires significant pre-planning to be effective. Because there are more species than can be managed, a prioritization process is key to refine early detection plans to improve their detectability. Depending on the types of existing information and resources available to process the information, a generalized, prioritized, or optimized monitoring plan can be developed to improve the efficacy of monitoring efforts (fig. 4.1).

Control and management also require prioritization to triage nascent populations for rapid response control actions, and the same prioritization concepts can be used as those applied to early detection (fig. 4.1). It is also important to continue monitoring and retreating these areas for a few years to ensure that there are no surviving individuals. Ideally, monitoring should be designed to evaluate the efficacy of control treatments, and adjust them accordingly in the future. If the ultimate objectives of control treatments are to benefit other species (e.g., natives), biological diversity (e.g., native species diversity), or ecosystem properties (e.g., reduce fire spread potential), then those factors should also be targeted for monitoring.

Restoration of robust native ecosystems can improve the resilience of degraded areas to subsequent biological invasions. Unfortunately, the specific factors that increase resistance to invasion are poorly understood. As a result, restoration guidelines are generally focused on maximizing characteristics like abundance and diversity of native species, diversity of functional types, and groups of species important for critical aspects of ecosystem function (e.g., nutrient cycling). All restoration projects should be carefully monitored to both determine if their restoration targets are achieved and to evaluate their effects on invasion resistance.

Organizational collaboration is required to effectively manage invasive species because they truly know no political boundaries, and if neighboring land owners are not doing their part, then efforts to prevent invasions and the problems that follow will often be in vain. Sharing resources and expertise by Federal and local agencies through

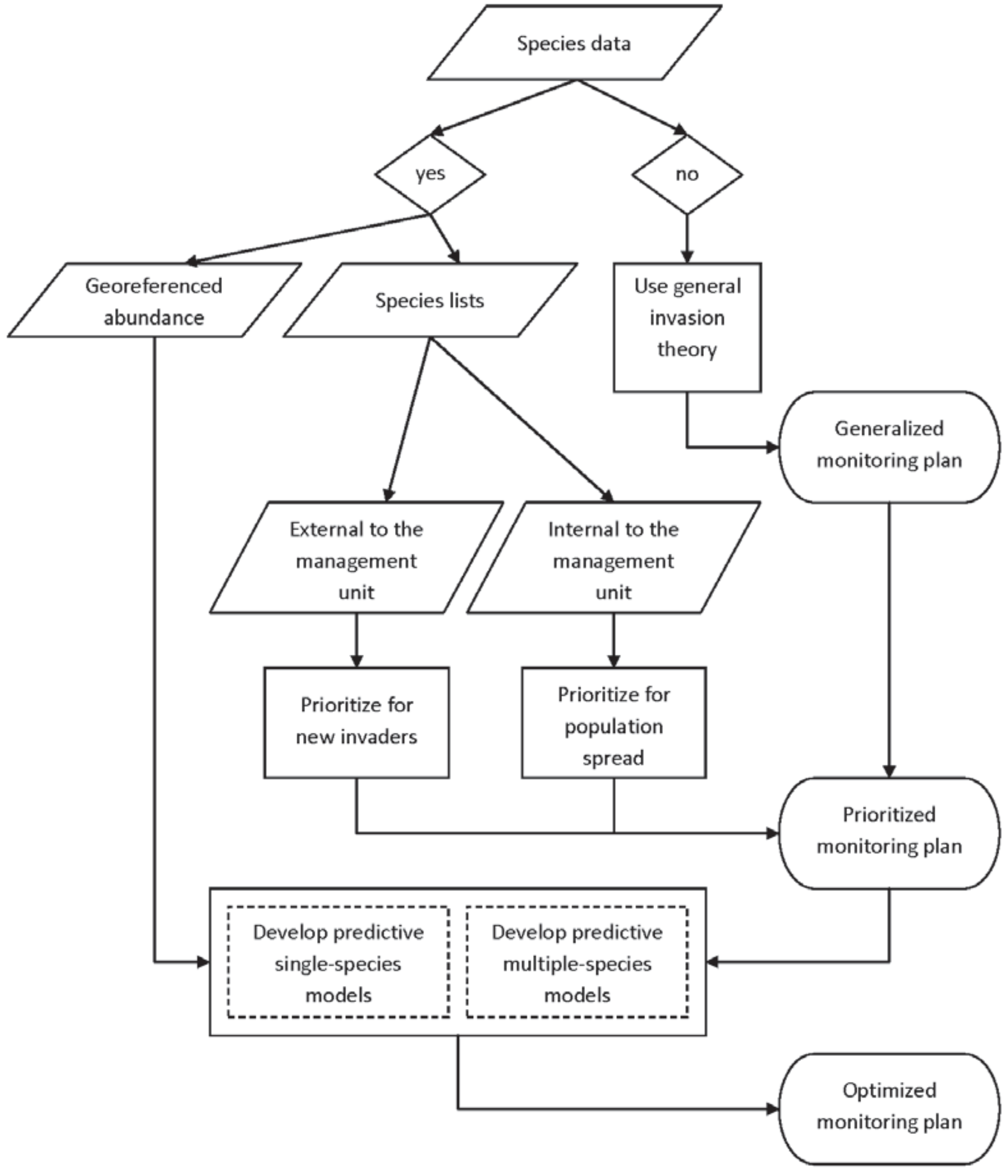

Figure 4.1–Steps for developing early detection monitoring plans (reprinted with permission from Brooks and Klinger 2009)

cooperative agreements and through the interagency Southern Nevada Restoration Team can assist with the process of collaboration. Cooperative Weed Management Areas (CWMA) are formal groups that also can facilitate this process, especially by ensuring that species priorities are consistent across land management units and that coordinated management plans are maintained over time. For a complete discussion of topics in this executive summary, see *Chapter 4, Invasive Species in Southern Nevada,* in "The Southern Nevada Agency Partnership Science and Research Synthesis—Science to Support Land Management in Southern Nevada" (RMRS-GTR-303).

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Chapter 5

Fire History, Effects, and Management in Southern Nevada

Matthew L. Brooks, Jeanne C. Chambers, and Randy A. McKinley

Executive Summary

Fire can be both an ecosystem stressor and a critical ecosystem process, depending on when, where, and under what conditions it occurs on the southern Nevada landscape. Fire can also pose hazards to human life and property, particularly in the wildland/urban interface (WUI). The challenge faced by land managers is to prevent fires from occurring where they are likely to threaten ecosystem integrity or human developments, while allowing fires to occur where they will provide ecosystem benefits. This chapter provides information that will help land managers develop strategies to achieve Sub-goal 1.1 in the SNAP Science Research Strategy, which is to "Manage wildland fire to sustain southern Nevada's ecosystems" (see table 1.1).

Fire History and Patterns of Burning

Since the last glacial period at the beginning of the Holocene approximately 10,000 years ago, the Mojave Desert and southern Great Basin Desert landscapes of southern Nevada have experienced continuous arid to semi-arid conditions. A general trend towards increased aridity has resulted in an upslope shift in vegetation associations and their associated fire regimes during prehistoric times (i.e., pre-settlement). With increased aridity and decreased productivity, the spatial extent of fire across southern Nevada undoubtedly declined and became increasingly isolated within disjunct mixed conifer, piñon and juniper, sagebrush, and riparian ecosystem types.

The first accounting of extensive historic fire in southern Nevada was in the late 1930s and early 1940s when it was estimated that fires burned 20 percent (approximately 80,000 acres, 32,375 ha) of the total extent of blackbrush that occurred in the region at that time. During the mid-century drought from 1942 to 1975 there were relatively few fires, but significant burning occurred after precipitation began to increase in 1976. Between 1972 and 2007, approximately one million acres (404,686 ha) burned in 116 large fires (≥1,000 acres) in Lincoln and Clark counties, primarily within the blackbrush/shadscale and Mojave Desert scrub ecosystems (fig. 5.1). Most of that burned acreage (90%) occurred in areas that had not previously burned during the 36-year study period, 8 percent occurred in areas that had burned once before, and 2 percent occurred in areas that had burned two or three times before (fig. 5.2). The largest areas burned in the 2005 and 2006 fire seasons and appear to have been unprecedented during the past century. There was a general increase in number of large fires and area burned between 1972 and 2007, largely due to the 2005 and 2006 fires (fig. 5.3). Trend analyses that only span a few decades can be suspect, so the conclusion that fire activity has recently increased beyond historical conditions is somewhat tenuous.

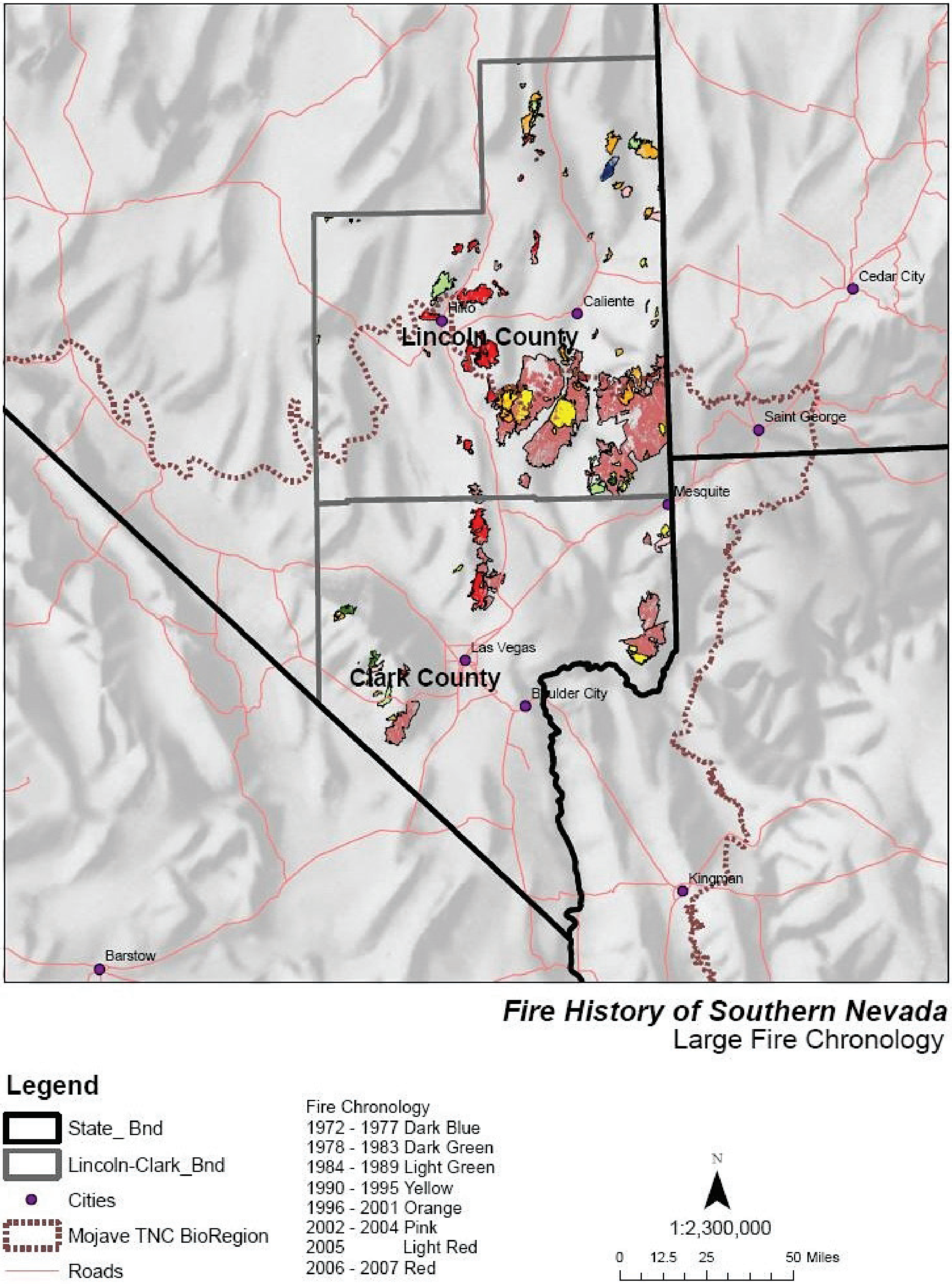

Figure 5.1—Large fire chronology 1972 through 2007 inclusive (≥1,000 acres). Shades from cool to warm colors represent the chronology of fire occurrence beginning with the oldest fires (blue) and ending with the recent fires (red) (reprinted with permission from McKinley and others, in press).

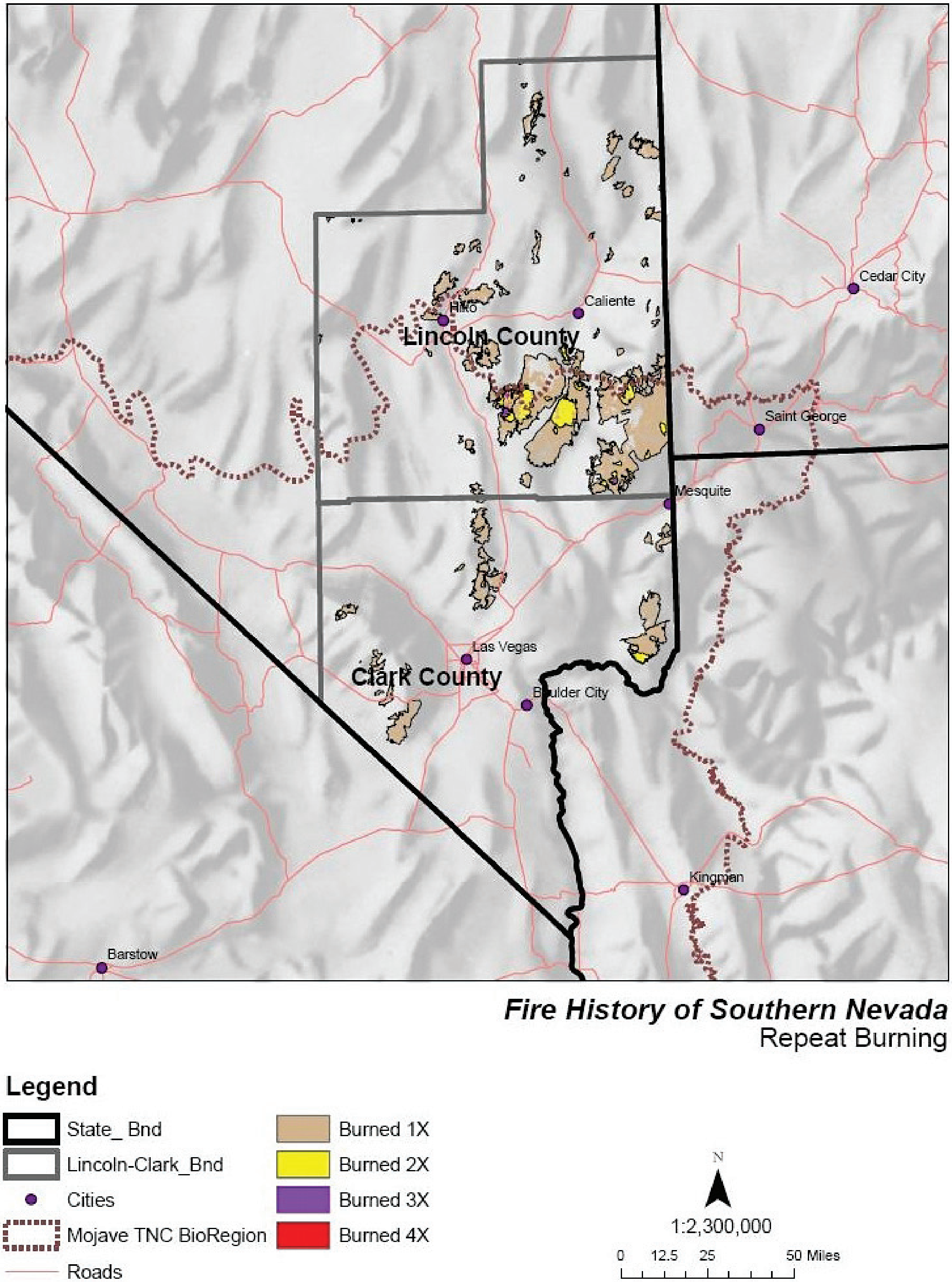

Figure 5.2—Fire frequency of large fires 1972 through 2007 inclusive (≥1,000 acres) (reprinted with permission from McKinley and others, in press).

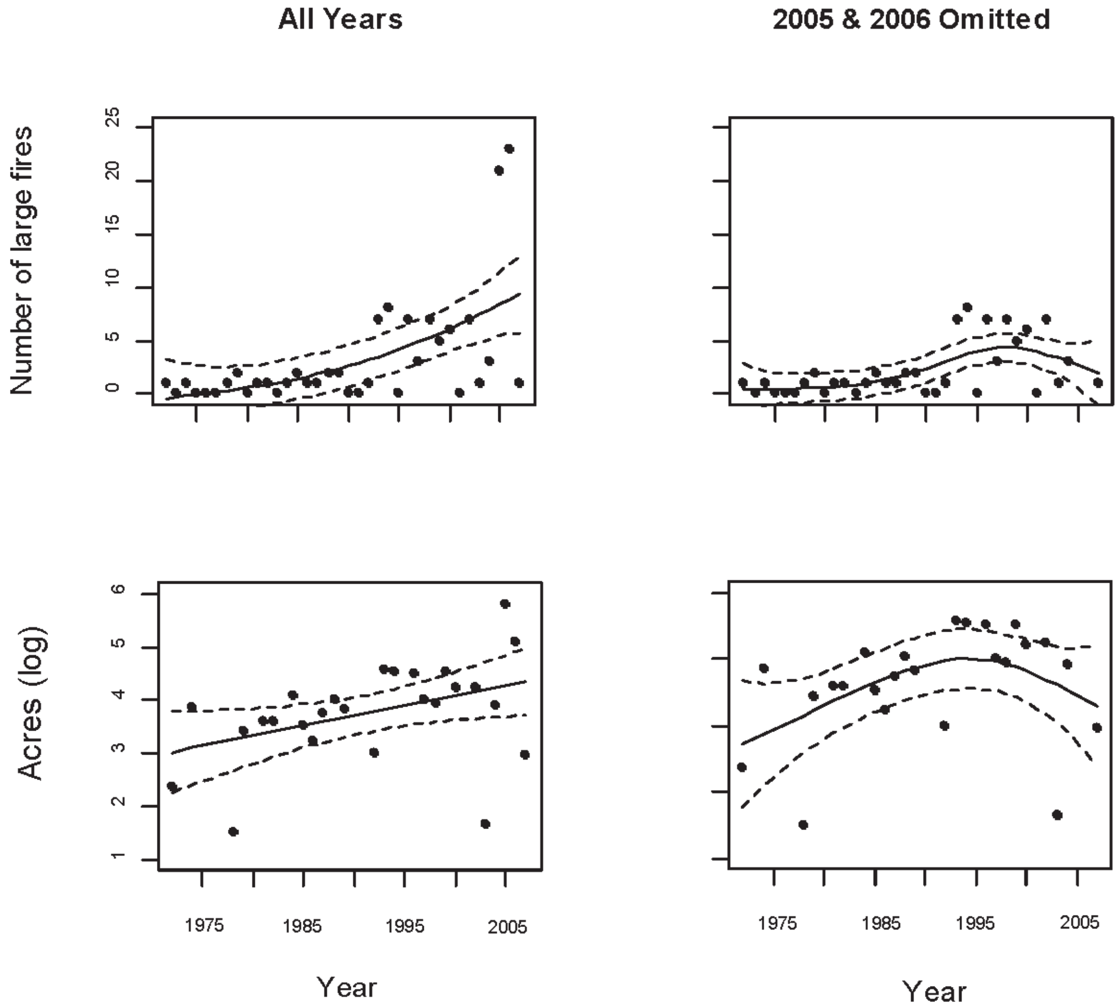

Figure 5.3—Patterns over time (1972-2007) for the number of large fires (≥1,000 acres), total area burned (log_{10} acres), mean fire size (log_{10} acres), and the proportion of burned area classified as high severity in Clark and Lincoln counties, Nevada. The shape of the relationship was derived from generalized additive models. Dotted lines are 95% confidence bands (modified with permission from McKinley and others, in press).

During the past century, fire activity in southern Nevada has been primarily associated with the warm (positive) phase of the multi-decadal Pacific Decadal Oscillation (PDO) cycle during which perennial fuels increase, and secondarily with the El Niño phase of the interannual El Niño-Southern Oscillation (ENSO) cycle during which fine ephemeral fuels increase due to increased precipitation. The El Niño effect alone may not be sufficient to promote large fires, and may only kick in during the latter part of or soon after a multi-decadal period of high rainfall associated with the PDO (e.g., after 1993, and especially during 2005 and 2006). Although intentional burning by humans has at times added significantly to acres burned, these fires likely remain small when climatic conditions result in sparse fuels.

Plant species in the genus *Bromus* are directly associated with changes in temporal and spatial patterns of burning in upland areas of the Mojave and Great Basin deserts. Although these species can undoubtedly alter fire regimes, their influence is ultimately tied to the PDO and ENSO cycles. Warm PDO phases are associated with exponential population growth of non-native annual grasses, such as that documented for *Bromus rubens* from the late 1970s through 1990. Increasing populations lead to high propagule production and dispersal into new areas, potentially increasing the regional scope of the grass/fire cycle. The El Niño ENSO phase is associated with years of extremely high rainfall that lead to episodic spikes in fuel loads created by invasive annual grasses and result in heightened fire hazards, especially in lower and middle elevation shrublands. The hallmark of the grass/fire cycle is a landscape dominated by invasive annual plants, with low abundance of native woody species, and continuous fuelbeds of ephemeral fine fuels that promote short fire return intervals (fig. 5.4). These conditions are most prevalent in Lincoln County.

Fire Effects and Management Actions

Although land management actions focus on individual fires, the ultimate influence of fire across landscapes and over time is attributed to fire regimes. The type (ground, surface, or crown fire), frequency (i.e., return interval), intensity (heat released), severity (ecological response), size, spatial complexity, and seasonality of fire define the fire regime. When fire regimes are altered (e.g., by plant invasions or land management practices) the recovery of the resident species following fire can be compromised and landscapes can be converted to new vegetation types.

All fires are not the same, although most published studies on fire effects report the effects of "fire" as if it is a univariate factor. The ultimate effects of fire are influenced by fire behavior, seasonality, and spatial pattern, in addition to the predominant life forms of plants and animals, the time elapsed since the previous fire, and the historical and current land uses and weather patterns.

Fire effects and appropriate management actions vary among the various ecosystem types in southern Nevada (table 5.1). Fire management is not a one-size-fits-all proposition, and the typical fire management concerns and guidelines for appropriate management actions must be examined in the context of each major ecosystem type.

Figure 5.4—A section of the 2005 Southern Nevada Fire Complex in the Tule Desert region of Lincoln County, NV. This is an area that had burned within the past few decades and was dominated by standing dead *Bromus* spp. biomass at the time of the fire (photo credit, Bureau of Land Management, Ely Field Office files).

Table 5.1—Typical fire management concerns associated with site and fire characteristics and guidelines for appropriate fuels management, fires suppression, and Emergency Stabilization and Rehabilitation (ES&R) actions in the major ecosystem types of southern Nevada.

Ecosystem type burned	Typical fire management concerns	Guidelines for appropriate management actions
Alpine and Bristlecone pine	*Fire* – Fires that burn more than a few acres and/or completely consume multiple trees. *Site* – Tree mortality and increased down woody fuels. Low tree recruitment post-burn and increased dominance of *Bromus* spp. could alter fire regime.	*Fuels* – Rarely warranted *Suppression* – Rarely warranted except to protect small and/or isolated stands if excessive fire spread is likely. *ES&R* – Rarely warranted unless perhaps to control invasive plants or following excessively large and severe fires.
Mixed conifer	*Fire* – High severity crown fire. Long fire return interval that allow excessive fuel accumulation. *Site* – Heavy surface and ladder fuel loads could lead to high severity crown fire. Wildland/urban interface (WUI) limits fire management options.	*Fuels* – Periodically warranted in the WUI, egress routes, and where surface and ladder fuels have accumulated increasing the risk of large fires. Mechanical treatments may be initially needed, but subsequent treatments should utilize low severity, surface prescribed fire. Follow-up control of invasive plants may be needed during the first few post-treatment years. *Suppression* – Rarely warranted except in the WUI, egress routes, and where surface and ladder fuels have accumulated increasing the risk of large fires. Low severity surface fire with minimal crowning should be allowed as a natural fire regime component for vegetation management benefits. Follow-up control of invasive plants may be needed during the first few post-fire years. *ES&R* – May be warranted to stabilize slopes near the WUI or following excessively large and severe fires.
Piñon and Juniper	*Fire* – High severity crown fire. Short fire return interval that does not allow re-establishment of shrub understory or trees. *Site* – Dominant invasive annuals. Short fire return intervals (≤60 years).	*Fuels* – Rarely warranted except in the WUI and egress routes and in shrub-dominated areas exhibiting tree expansion. Prescribed fire may be the more cost-effective over large areas. Follow-up control of invasive plants may be needed during the first few post-fire years. *Suppression* – Warranted in the WUI, and to prevent large, high severity crown fires, but low severity surface fire in areas of undesirable tree expansion may be allowed as a natural fire regime component for vegetation management benefits. Follow-up control of invasive plants may be needed during the first few post-fire years. *ES&R* –Warranted to reestablish native plant community characteristics and to control invasive plants if inadequate perennial herbaceous species and shrubs exist for recovery. Herbicides may allow short-term control, but long-term control requires a wider array of management actions, aerial seedings have low to moderate establishment rates.
Sagebrush	*Fire* – Large, homogenous fires *Site* – Dominant invasive annuals. Short fire return intervals (≤40 years).	*Fuels* – Rarely warranted, except in the WUI and egress routes and perhaps to increase the competitive ability of perennial herbaceous species and prevent invasive annual grass dominance. Prescribed fire rarely warranted except perhaps to create a stand-age mosaic in very old late-successional contiguous stands. Follow-up control of invasive plants may be needed during the first few post-treatment years. *Suppression* – Warranted in the WUI, and in areas with low abundance of perennial herbaceous species and high risk of conversion to annual invasive grasses. *ES&R* – May be warranted to reestablish the native community and to control invasive plants if inadequate perennial herbaceous species and shrubs exist for recovery. Herbicides may allow short-term control but long-term control requires a wider array of management actions, aerial seedings have low to moderate establishment rates.

(continued)

Table 5.1—(Continued)

Ecosystem type burned	Typical fire management concerns	Guidelines for appropriate management actions
Blackbrush/shadscale	*Fire* – Large, homogenous fires. *Site* – Dominant invasive annuals. Short to moderate fire return intervals (≤100 years).	*Fuels* – May be warranted to reduce non-native annual grass fuels, perhaps centered on roads, to facilitate fire suppression. Follow-up treatments may be needed on an annual basis. *Suppression* – Warranted under most circumstances. Prescribed fire is never warranted except perhaps for experimental purposes. *ES&R* – May be warranted to reestablish the native community and to control invasive plants if inadequate perennial herbaceous species and shrubs exist for recovery. Herbicides may allow short-term control of non-native annual grasses, but long-term control requires a wider array of management actions including reestablishment of native perennial species. Aerial seedings have low establishment rates. Livestock closures are necessary post-fire to facilitate recovery of native perennial plants.
Mojave desert scrub	*Fire* – High severity, large, homogenous fires *Site* – dominant invasive annuals, short to moderate fire return intervals (≤100 years)	*Fuels* – May be warranted to reduce non-native annual grass fuels, perhaps centered on roads, to facilitate fire suppression. Follow-up treatments may be needed on an annual basis. *Suppression* – Warranted under most circumstances. Prescribed fire is never warranted except perhaps for experimental purposes. *ES&R* – May be warranted to reestablish the native community and to control invasive plants if inadequate perennial herbaceous species and shrubs exist for recovery. Herbicides may allow short-term control but long-term control requires a wider array of management actions including reestablishment of native perennial species. Aerial seedings have low establishment rates. Livestock closures are necessary post-fire to facilitate recovery of native perennial plants.
Riparian and Spring	*Fire* – High severity crown, large homogeneous fire. *Site* – Dominant invasive perennials. Heavy surface and ladder fuel loads could lead to high severity crown fire. Flood disturbance may have larger effects than fire especially in unregulated riverine systems (e.g. Virgin River)	*Fuels* – May be warranted to reduce non-native tamarisk and Russian olive fuels to reduce high severity fire. Prescribed fire may be the most cost-effective way to reduce invasive plan biomass over large areas, but follow-up control of surviving invasive plants will always be needed during the first few post-fire years, potentially followed by native plant revegetation. *Suppression* – May be warranted in the WUI or where tamarisk and native vegetation are intermixed, otherwise low to moderate severity fire may be allowed where native fuels predominate as a natural fire regime component for vegetation management benefits, or moderate severity fire may be allowed where tamarisk dominates to remove above-ground biomass as a prelude to other tamarisk control actions such as herbicide treatments followed by native plant revegetation. *ES&R* – May be warranted to control tamarisk, herbicides may allow short-term control but long-term control requires a wider array of management actions including native plant revegetation which may be accomplished by seedings or outplantings.

Alpine and bristlecone pine ecosystem fires that burn more than a few acres and/or completely consume multiple trees are the primary management concern. Due to a warming climate, tree mortality and down woody fuels may increase, tree recruitment post-burn may decrease, and *Bromus* spp. may increase to the point that the fire regime is altered. Fuels management and fire suppression are currently not warranted, but may be in the future. Postfire Emergency Stabilization and Rehabilitation (ES&R) actions are rarely warranted, except to reduce the threat of future type conversion mediated by invasive plants or excessively large fires.

High severity crown fire is the primary management concern in the mixed conifer ecosystem. This type of fire can result from long fire return intervals that allow excessive accumulation of surface and ladder fuels. Fuels management in the form of wildland fire use in resilient tree communities with low risk of high severity fire may be warranted to maintain low levels of ladder fuels. Moderate intensity surface fires at appropriate intervals can help maintain managed fuel zones and provide ecosystem benefits in many mixed conifer communities. However, in communities with low resilience to fire and resistance to invasive species or that are at risk of high severity fires, mechanical thinning may be required. Fire suppression is warranted to prevent high severity fires and protect the loss of human life and property at the (WUI). Postfire ES&R actions are warranted to stabilize slopes in the WUI following large and/or high severity fires, and in areas that lack the necessary understory species for ecosystem recovery. Concerns about land management activities within the WUI often limit management options, especially the use of managed fire. However, these tools are necessary to ultimately reduce threats to human life, infrastructure, and ecosystem integrity.

High severity crown fire is also the primary management concern in the piñon-juniper ecosystem. Piñon and juniper species are actively expanding into sagebrush and other shrub dominated ecosystems in southern Nevada. Progressive increases in fuel loads due to tree infilling are increasing the risk of large, high severity fires. In addition, invasion of annual grasses (*Bromus* spp.) at low to mid elevations can shorten fire return intervals below levels where either sagebrush species or piñon and juniper trees can reestablish (≤60 years). Wildland fire use is warranted in communities that are resilient to fire and have sufficient understory species (fire-tolerant shrubs and perennial grasses and forbs) for natural recovery. Mechanical thinning is the preferred tool in areas that have low resilience to fire and/or insufficient understory species for recovery. Fire suppression is warranted to prevent high severity fire and protect the loss of human life and property at the WUI. Postfire ES&R actions are warranted to reestablish native communities and to control invasive plants if inadequate perennial herbaceous species and shrubs exist for recovery. Herbicides may allow short-term control but long-term control requires a wider array of management actions, and aerial seedings have low to moderate establishment rates.

Large fires that encompass a majority of stands and the initiation of a grass/fire cycle, shorter fire return-intervals, and vegetation type-conversion are the primary management concerns in the sagebrush ecosystem. Fuels management is rarely warranted, except in the WUI and perhaps to increase the competitive ability of perennial herbaceous species and prevent invasive annual grass dominance. Fire suppression is warranted in the WUI and in areas with low abundance of perennial herbaceous species and high risk of conversion to annual invasive grasses. Postfire ES&R actions may be warranted to reestablish the native community and to control invasive plants if inadequate perennial herbaceous species and shrubs exist for recovery. Herbicides may allow short-term control but long-term control, requires a wider array of management actions, and aerial seedings have low to moderate establishment rates.

Blackbrush/shadscale and Mojave Desert scrub fires of most any type, but especially large, homogenous fires, are a primary management concern. Increased dominance of invasive annual grasses that lead to short to moderate fire return intervals (≤100 years) is also a management concern. Fuels management may be warranted to reduce invasive annual grass fuels, perhaps focused on roadsides, to facilitate fire suppression. Fire suppression is warranted under most circumstances. Postfire ES&R may be warranted to reestablish the native community and to control invasive plants if inadequate perennial herbaceous species and shrubs exist for recovery. Herbicides may allow short-term control, but long-term control requires a wider array of management actions. Aerial seedings have very low establishment rates and are not a solution. Postfire closures of livestock, wild horses, and burros may be necessary to facilitate recovery of native perennial plants.

Riparian and spring ecosystem fires that are large, homogenous, high severity crown fire are the primary management concern. Increased dominance of invasive tamarisk and accumulation of heavy surface and ladder fuels can lead to high severity crown fire. The non-native Russian olive may produce similar results in the future if it becomes more dominant. Fuels management may be warranted to reduce invasive tamarisk and Russian olive fuel loads. Fire suppression may be warranted in the WUI or where invasive and native vegetation are heavily intermixed. Low to moderate severity fire similar to the natural fire regime may be warranted where native fuels predominate for vegetation management benefits. Moderate severity fire also may be warranted where tamarisk dominates to remove above-ground biomass as a prelude to other control and restoration actions. Postfire ES&R actions may be warranted to control tamarisk and other invasive plants. Herbicides may provide short-term control but long-term control requires a wider array of management actions. Native plant revegetation may be accomplished by seedings or outplantings.

Knowledge Gaps and Management Implications

Important take home messages for land managers are that: (1) the effect of an individual fire event should be evaluated within the context of the ecosystem type in which it occurs, the characteristics of the fire, and characteristics of the site; (2) fire suppression is the most cost effective way to manage fires across most of southern Nevada, except in those ecosystem types where fire is part of the natural disturbance regime and wildland fire use can be used to achieve management objectives; and (3) the current range of post-fire mitigation tools are either ineffective or their effectiveness is poorly documented. Like all aspects of land management, fire management must ultimately be placed in the broader context of all the other factors associated with managing landscapes in southern Nevada. In some cases, decisions may need to be made regarding where to allocate limited resources; in other cases, conflicting objectives may need to be resolved between fire management and those focused on other management topics (especially natural and cultural resources). For a complete discussion of topics in this executive summary, see *Chapter 5, Fire History, Effects and Management in Southern Nevada*, in "The Southern Nevada Agency Partnership Science and Research Synthesis—Science to Support Land Management in Southern Nevada" (RMRS-GTR-303).

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Chapter 6

Species of Conservation Concern and Environmental Stressors: Local, Regional and Global Effects

Steven M. Ostoja, Matthew L. Brooks, Jeanne C. Chambers, and Burton K. Pendleton

Executive Summary

Southern Nevada's unique landscapes and landforms provide habitat for a diversity of plant and wildlife species of conservation concern including many locally and regionally endemic species. The high population density and urbanization of the Las Vegas metropolitan area is the source of many local and regional stressors that affect these species and their habitats: nitrogen deposition; solar and wind energy and water development; recreation, insects and disease; livestock, wild horse, burro, and elk grazing; invasive species; and altered fire regimes. Global stressors also affect these species and include climate change and CO_2 enrichment.

Resource managers must simultaneously consider local, regional, and/or global scale stressors for effective management of species of conservation concern. In the sections below we provide specific examples of how stressors can affect the range and/or habitat of select species of conservation concern within the major ecosystem types of southern Nevada. We also provide suggestions for targeted management of southern Nevada's species of conservation concern. This information addresses Sub-goal 1.4 in the SNAP Science Research Strategy, which is to "Sustain and enhance southern Nevada's biotic communities to preserve biodiversity and maintain viable populations" (see table 1.1).

Alpine and Bristlecone Pine Ecosystems

Alpine and bristlecone pine ecosystems are susceptible to various stressors and disturbances. Global and regional stressors include climate change and atmospheric nitrogen deposition. Local stressors include recreation (e.g., snow skiing, rock climbing), invasive species (e.g., dandelion), and stochastic disturbance events (e.g., avalanches). The limited amount of habitat available in these ecosystems limits the degree to which species—especially plants—can respond to stressors. Changes in plant communities can affect the habitats of animal species that depend on these ecosystems. Management options include monitoring the changes occurring in these ecosystems and developing approaches for preventing establishment of invasive species and assisting the migration of plant species like bristlecone pine. Minimizing the effects of recreation can be important for species of conservation concern.

Mixed Conifer Ecosystem

The mixed conifer ecosystem is affected by a suite of local and regional stressors including invasive species, altered fire regimes, fire and fuels management activities, recreation, and urban and water development. The effect of climate change on episodic and stochastic weather events coupled with long-term effects associated with fire suppression, invasive species, and recreation may combine to affect the persistence of endemic butterfly species in the Spring Mountains. Four species have been identified as conservation priorities including a candidate species for Federal listing including the Mt. Charleston blue butterfly (*Plebejus shasta charlestonensis*). Extreme climate events potentially linked to climate change may be adversely affecting butterflies with small restricted populations. Ongoing climate change and historical fire suppression have promoted fuel accumulation, which can lead to high intensity fires that burn large areas and compromise habitat integrity. Also, various forms of recreational use, including hiking, rock climbing, and skiing, may be affecting habitat in this ecosystem. The mixed conifer ecosystem is the focus of a diverse and varied set of management programs including vegetation and fuels management, rare species conservation, invasive species management, endemic butterfly research, and more. Increased pressure from urbanization and recreation will continue to challenge resource managers to find compromises between various user groups and species conservation in this ecosystem type.

Piñon-Juniper Ecosystem

The expansion of the piñon and juniper trees into other ecosystem types (e.g., sagebrush)—due to climate change, increased CO_2 concentrations, livestock grazing, and fire suppression—is occurring in southern Nevada. Progressive infilling of the trees following expansion causes reduced dominance or loss of understory plant species, increased fuel loads, and a greater risk of larger and higher severity fires. Lower elevation ecosystems with depleted understories are highly susceptible to invasion and dominance by annual grasses following fire. These changes can significantly affect species of conservation concern within these ecosystems, including the desert bighorn sheep and select species of birds. Pinyon jay, gray vireo, and gray flycatcher are experiencing significant population reductions due to stand in-filling and piñon die-off in piñon-juniper ecosystems. Resource managers should consider using fire, tree-thinning, invasive species management, and restriction of recreational uses when managing this ecosystem. Dynamics brought about by a changing climate, including drought and associated interactions with insects or other pathogens, will continue to challenge local resource managers.

Sagebrush Ecosystem

The sagebrush ecosystem is subject to a variety of stressors. Sagebrush types at intermediate to high elevations are exhibiting piñon and juniper expansion and progressive increases in tree dominance have the potential to compromise the integrity of sagebrush ecosystem for specific species or guilds. Sagebrush types at low to intermediate elevations are highly susceptible to invasion by annual grasses, including cheatgrass (*Bromus tectorum*) and red brome (*B. madritensis*). Conversion to annual grass dominance alters soil morphology, soil biota, and native plant diversity, as well as diversity of invertebrates, small mammals, reptiles, and birds. Bird species of conservation concern in the sagebrush ecosystem include the sage thrasher, sage sparrow, burrowing owl, and others. Each of these species is negatively affected by habitat degradation and loss due not only to invasive species and altered fire regimes but also urbanization, energy, and other development. Management actions for species of concern should consider climate model projections of species range expansion. Also, because so little of this ecosystem type naturally occurs in the region, protection of what remains should be a land management priority.

Blackbrush/Shadscale Ecosystem

The blackbrush/shadescale ecosystem is used as winter forage by deer and bighorn sheep and is habitat for numerous species of birds and small mammals. Blackbrush is one of the most flammable vegetation types in the Mojave Desert, and fires typically burn plants to ground level and deplete soil seedbanks. Because natural recruitment is low for most plant species in blackbrush vegetation, it may take centuries for natural recovery to occur following fire. Disturbances including grazing and recreation facilitate establishment of invasive annual grasses (e.g., *Bromus* spp.), the initiation of a grass-fire cycle and, ultimately, type-conversion to invasive annual dominance. Management should focus on protecting the remaining remnant patches of the blackbrush/shadscale ecosystem by controlling recreation and grazing and preventing fire. Because natural regeneration is so limited, especially for blackbrush, it is feared that this ecosystem could disappear without both restoration and active management.

Mojave Desert Scrub Ecosystem

The Mojave Desert scrub ecosystem is the most widespread and diverse of all ecosystems in southern Nevada. It is represented by several subtypes, including bajadas, sand dunes, and gypsum soils. Increased urbanization promotes human activities that have placed this ecosystem type and the habitat it provides for species of concern, like the desert tortoise and burrowing owl, at risk. Recreation and associated human activities such as target shooting and vehicle impacts are known to directly kill or injure desert tortoises. Off-highway vehicles (OHV) use and livestock grazing also have direct effects on desert tortoise and also affect tortoise habitat through reductions in native vegetation and increases in invasive species. Desert tortoises are subject to diseases including upper respiratory tract disease and a shell disease. The Mojave Desert scrub ecosystem will be subjected to increased threats from local, regional, and global stressors over time. Management efforts should concentrate on large landscape scales to maintain natural shrub densities, soil crusts, and healthy native vegetation where disturbance has been minimal.

Riparian/Aquatic Ecosystem

The riparian/aquatic ecosystem occurs along the Virgin, Muddy, and Colorado rivers and Las Vegas Wash, and may be the most degraded and manipulated ecosystem in southern Nevada. Stressors to this ecosystem include climate change, invasive species, altered fire regimes, recreation, and water diversion and extraction. Tamarisk (*Tamarix* spp.), an invasive tree, is highly competitive with native species and in many cases is the dominant species. Efforts to control tamarisk include the use of chemicals, mechanical methods, and fire and, most recently, the release of a biocontrol agent, the northern tamarisk beetle (*Diorhabda carinulata*), which is native to Eurasia. The riparian/aquatic ecosystem is home to numerous species of conservation concern including the Federally endangered southwestern willow flycatcher, which was listed due to small population sizes, population declines, and habitat threats. Concern exists about the direct and indirect effects of the biocontrol beetle on the southwest willow flycatcher. Management should consider protecting and potentially enhancing large to medium patches of habitat for species of conservation concern with the goal of maintaining a heterogeneous habitat complex of open, varied age canopy, shrub thickets dominated by native trees, shrubs, and forbs with floodplain and wetland sites intermixed.

Spring Ecosystems

Spring ecosystems are comprised of a range of biophysically diverse sites due to differences in water chemistry, slope, substrate type, persistence, morphology, and size. These ecosystems are highly sensitive to environmental stressors. Most springs have been invaded by invasive aquatic and terrestrial species that can affect ecosystem properties. Springs provide habitat for many spring-obligate species including invertebrates and vertebrates. Some of these species have highly limited distributions like the relict leopard frog (*Rana onca*), which is a candidate for Federal listing under the Endangered Species Act. The decrease in relict leopard frog populations occurred concurrently with the loss or alteration of aquatic habitat due to spring drainage and/or water development for agricultural and urban applications. Feral burros also have been implicated in the reduction of frog populations due to overgrazing of shoreline vegetation, trampling, and urination and defecation into the water. Chytrid fungus is an infectious disease of amphibians, and reports suggest that the fungus is most virulent at temperatures ≤23 °C, but that its pathogenicity and virulence decline significantly at ≥27 °C. It appears that thermal springs in the region provide critical habitat where frogs can persist despite the presence of chytrid fungus, and that the relict leopard frog occurs naturally only in thermal springs that all have source temperatures >30 °C. The habitats that support these spring-dependent species are highly imperiled due to direct effects of historical and ongoing manipulation of spring sites and the water sources that supply them.

Knowledge Gaps, Research Guidance, and Management Implications

Actions such as limiting grazing or closing OHV trails have historically been some of the primary tools used by land managers in southern Nevada to reduce the effects of anthropogenic stressors on species of conservation concern. However, managers are increasingly faced with complex and wider spanning issues that are often beyond the reach of regionally or locally based management plans. Research that can help disentangle local or regional effects from global effects is needed for conservation planning and management of species of conservation concern. This information could help focus management toward factors and actions most likely to make a difference.

The overview of species of conservation concern provided here is not a complete review of all species and stressor effects, but it is a good representation of the nature of single species research in southern Nevada. It is evident from this body of research that very little is known about the relative threats posed to, or the mitigation actions needed to protect, virtually any species, except perhaps the desert tortoise. Too often research jumps immediately to mitigation strategies without first determining what specific factors pose the greatest threats and are the most important to mitigate. In addition, the evaluation of potential threats typically focuses upon the usual anthropogenic suspects (e.g. OHVs, livestock grazing, invasive species, and climate change) without first carefully considering which factors are most likely to pose the greatest threats. Finally, fundamental science associated with the life history characteristics and habitat requirements of species typically receives the least attention, even though these topics are where research programs should actually start. For a complete discussion of topics in this executive summary, see *Chapter 6, Species of Conservation Concern and Environmental Stressors: Local, Regional, and Global Effects*, in “The Southern Nevada Agency Partnership Science and Research Synthesis—Science to Support Land Management in Southern Nevada” (RMRS-GTR-303).

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Chapter 7

Maintaining and Restoring Sustainable Ecosystems in Southern Nevada

Jeanne C. Chambers, Burton K. Pendleton, Donald W. Sada, Steven M. Ostoja, and Matthew L. Brooks

Executive Summary

Resource managers in southern Nevada are faced with the challenge of determining appropriate goals and objectives and developing viable approaches for maintaining and restoring sustainable ecosystems in the face of rapid socio-ecological and environmental change. Many of southern Nevada's ecosystems are being subjected to anthropogenic stressors that span global, regional, and local scales (Chapter 2), and are crossing ecological thresholds to new and often undesirable alternative states (Chapters 4 and 5). Protection, prevention, and restoration are integral parts of managing for sustainable ecosystems that can supply both ecosystem services and habitat for the diversity of plants and animals that occupy the region. This summary addresses the restoration aspects of Sub-goal 1.3 in the SNAP Science Research Strategy, which is to "Restore and sustain proper function of southern Nevada's watersheds and landscapes" (see table 1.1).

Managing for Resilience and Resistance

The overarching objective for restoration and management of southern Nevada ecosystems is to maintain and restore sustainable ecosystems that are resilient to disturbance and resistant to invasion. Resilience is the capacity of an ecosystem to regain its fundamental structure and functioning when subjected to stresses like drought, species invasions, or wildfire. It is a function of the underlying ecosystem attributes and processes that determine ecosystem recovery. Resistance is the capacity of an ecosystem to retain its fundamental structure and functioning (or remain largely unchanged) despite stresses, disturbances or invasive species. Resistance to invasion is a function of the biotic and abiotic factors and ecological processes in an ecosystem that limit the establishment and population growth of an invading species

The abiotic and biotic attributes and ecosystem processes that determine resilience to stressors and resistance to invasion can be illustrated with a simple conceptual model (fig. 7.1). Environmental characteristics as defined by climate, topography, and soils determine the abiotic and biotic attributes and processes of an ecosystem. In turn, the abiotic and biotic attributes and processes provide feedbacks to one another and determine the inherent potential of an ecosystem to support a given set of ecological conditions and plant species. Over time, climate, disturbance, and stressors affect the abiotic and biotic attributes and processes and determine the current ecological conditions of the system. The current ecological conditions, as influenced by the legacy of past disturbances and stressors, determine resilience to disturbance and resistance to invaders at any point in time.

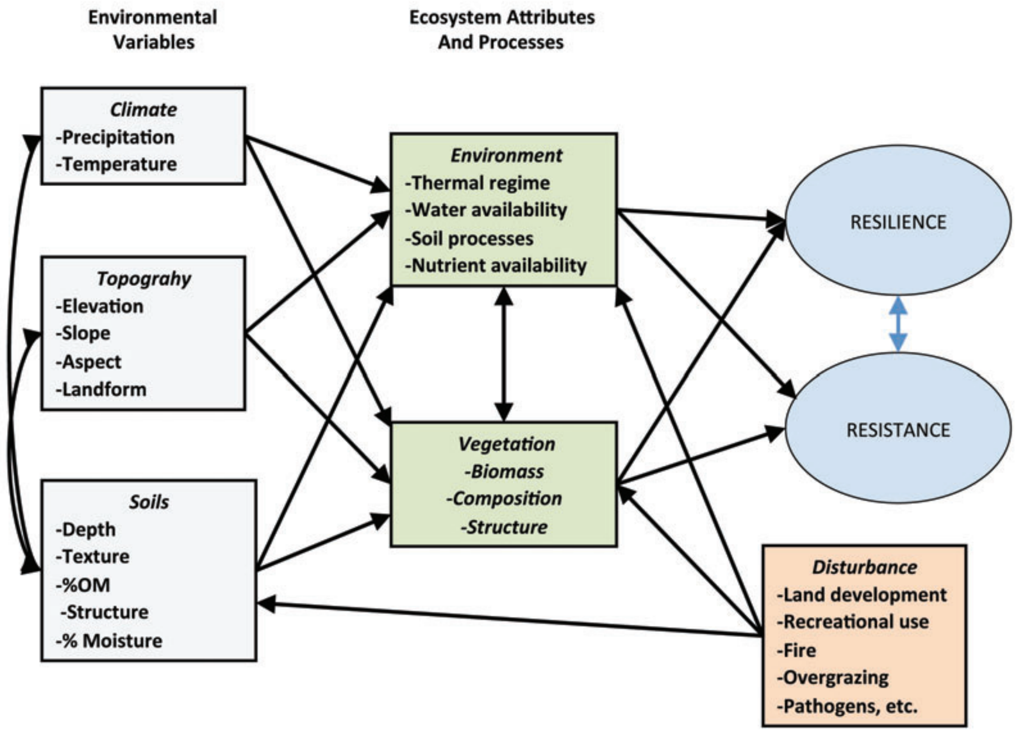

Figure 7.1–The environmental variables and the ecosystem attributes that influence resilience to disturbance and resistance to invasion. Disturbances can decrease ecological site conditions and negatively affect resilience and resistance.

Southern Nevada ecosystems differ in ecological resilience and resistance because of strong elevation/climate gradients and large differences in their environmental characteristics. The Clark County MSHCP categorizes 11 ecosystems based on elevation and soil moisture (fig. 7.2). In general, temperature regimes and effective precipitation are the primary drivers of ecological processes because they determine overall resource availability and ecosystem productivity. The resilience of southern Nevada ecosystems to disturbance and stress typically increases along these environmental/productivity gradients. These gradients also determine the likelihood that climate conditions are suitable for establishment of invasive annual grasses and other invaders. Ecosystems influenced by elevated water tables and high levels of soil moisture are in a separate category, as environmental conditions can vary considerably among these ecosystems, and factors like soil and water chemistry are important drivers of ecosystem processes.

Restoration Considerations

Restoration and management priorities and activities differ significantly among southern Nevada ecosystems because of the large variation in their environmental characteristics and, consequently, resilience to disturbance and resistance to invasive species. Overarching strategies are protection, prevention and restoration (table 7.1). Passive restoration to eliminate or minimize stress is a component of protection and prevention; active restoration is a component of prevention and restoration. Guidelines for the restoration and management of the diverse ecosystems in southern Nevada can be developed based on an understanding of their relative resilience and resistance, the dominant stressors affecting them, and the most appropriate actions to maintain and restore them (table 7.2).

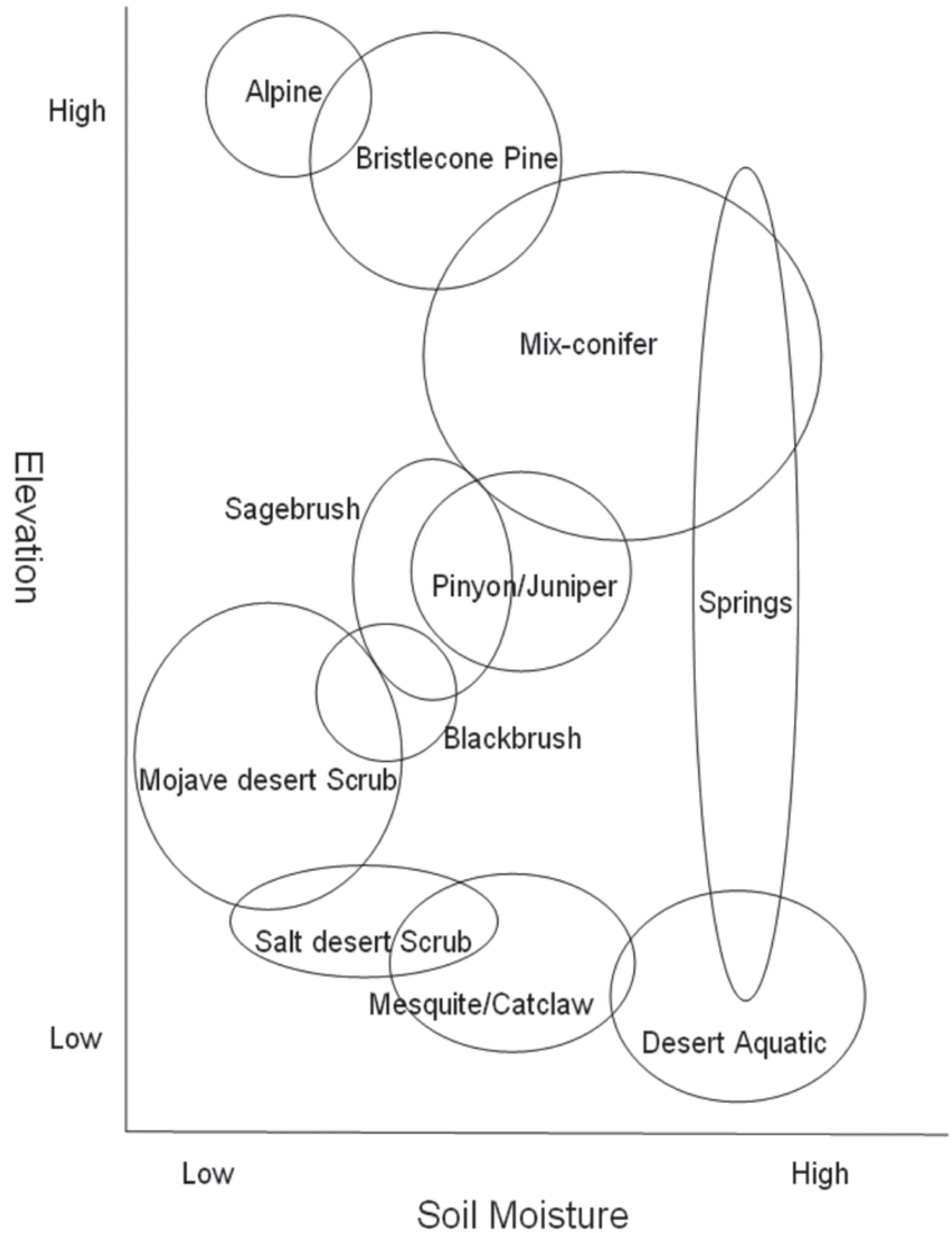

Figure 7.2–A conceptual model that categorizes 11 ecosystems of the Clark County MSHCP along two environmental gradients: elevation and soil moisture. This model is based on general knowledge of the environmental gradients that influence southern Nevada ecosystems. The shape, size, and relative position of the ellipses and circles are hypothetical (from Desert Research Institute 2008).

Table 7.1—An approach for categorizing management activities in southern Nevada ecosystems based on protection, prevention and restoration (modified from D'Antonio and Chambers 2006; Brooks and Chambers 2011).

Protection	
Focus	Ecosystems with low resilience and/or resistance, ecosystems of high conservation concern, and ecosystems at risk of crossing ecological thresholds to new alternative states.
Objectives	Eliminate or minimize current and future stressors.
Activities	Closure or active control of recreational use and burro and cattle grazing to allow natural regeneration; fire suppression in Mojave Desert scrub, blackbrush and lower elevation sagebrush and piñon and juniper ecosystems to prevent an invasive annual grass-fire cycle; control of placement and development of road and utility corridors, urban expansion, and solar energy projects to minimize fragmentation and surface disturbance.
Prevention	
Focus	Ecosystems with inherently higher resilience and/or resistance and ecosystems in moderate to high ecological condition.
Objectives	Maintain or increase resilience and resistance of areas with declining ecological conditions.
Activities	Vegetation management to decrease risk of high severity fires, maintain understory composition, and prevent invasion; mechanical vegetation management treatments to decrease decadent or over-dense shrubs and increase perennial herbaceous vegetation.
Restoration	
Focus	Ecosystems known to respond favorably to restoration treatments and ecosystems of conservation concern.
Objectives	Increase resilience and resistance of ecosystems by revegetating or rehabilitating areas disturbed by fire, recreational activities, road and utility corridors, urban expansion, solar energy projects, and other surface disturbances. Provide assisted migration for species being displaced by climate change.
Activities	Soil surface stabilization to curtail dust; seedbed preparation to mitigate soil physical and chemical disturbance and provide favorable conditions for plant establishment; transplanting or seeding native species adapted to the local environment and climate warming.

Consideration of the predicted effects of climate change on the different ecosystems and the implications for management will be needed to maintain and restore southern Nevada ecosystems. Climate change models predict high rates of temperature increase for desert ecosystems like the Mojave. By 2100, climate change is likely to result in the disappearance of some existing climate conditions, the appearance of some novel climatic conditions, and the formation of new communities with no past or present analogs. Bioclimatic envelope models predict shifts in the distributions of keystone species like creosote bush and Joshua tree, and of invasive species like cheatgrass. Due to the rapid rate of change, many species may require assisted migration, and "transformative" restoration may be needed in areas that no longer have the climate conditions necessary to support the current set of species.

Table 7.2—Resilience and resistance characteristics of the major ecosystem types in southern Nevada and guidelines for appropriate management actions.

Ecosystem	Resilience and resistance	Guidelines for appropriate management actions
Alpine and Bristlecone pine	*Resilience* – Very low to low. Extreme temperatures, short growing seasons, slow growth, and low establishment rates. Low capacity to adapt/migrate with climate warming. *Resistance* – Moderate to high. Few annual species are adapted to the extreme environment; resistance may decrease as climate warms.	*Protection* – Primary emphasis. Minimize stress from recreational activities, including firewood gathering. Monitor changes in temperature and precipitation and in species distributions and community composition. *Prevention* – Rarely warranted except to suppress fires with potential to spread. *Restoration* – Rarely warranted except for assisted migration of trees or revegetation of areas with die-off. Information on species environmental and establishment requirements is required.
Mixed conifer	*Resilience* – Moderate to high. Relatively high precipitation, long growing seasons, and moderate growth and establishment rates. Potential to migrate upslope with climate warming. *Resistance* – Moderate to low. Multiple non-native invaders adapted to environmental conditions; competition with invaders from established native plants can be high.	*Protection* – Control inappropriate recreational activities and overgrazing; detect and eradicate invasive species. *Prevention* – Warranted to decrease fuel loads, restore understory composition, and decrease invasion. Potential for Wildland Fire Use and prescribed fire where risk of large or high severity fire is low and fire spread can be controlled, and for tree thinning followed by surface fire or pile burning in WUI and areas with higher fuel loads. However, more information is needed on the responses of southern Nevada ecosystems. *Restoration* – Warranted following surface disturbance or in areas with insufficient fire tolerant understory species for site recovery after fire. Seed burial (drilling) or transplanting natives adapted to local site conditions and climate warming preferred.
Piñon and Juniper	*Resilience* – Moderate. Moderate precipitation, long growing seasons, moderate to slow growth and establishment. Potential for die-off at lower elevations with climate warming. *Resistance* – Low. Many non-native invaders adapted to environmental conditions; competition from established shrubs and herbaceous species dependent on site productivity and ecological condition.	*Protection*- Control inappropriate recreational activities and overgrazing; detect and eradicate invasive species; suppress fires at lower elevations and that threaten ecosystem integrity. *Prevention*-Warranted to decrease fuel loads, restore understory composition, and decrease invasion. Focus is on mesic sites in early to intermediate stages of tree expansion, and in moderate to high ecological condition. Potential for Wildland Fire Use and prescribed fire on productive sites at high elevation; mechanical treatments more appropriate on sites with low productivity. *Restoration* – Warranted following surface disturbance and in areas with insufficient fire tolerant understory species for site recovery after fire. Seed burial (drilling) or transplanting natives adapted to local site conditions and climate warming preferred.
Sagebrush	*Resilience* – Moderate to low. Types at higher elevations and with deeper soils have moderate resilience; types at lower elevations and on shallow soils have low resilience. *Resistance* – Moderate to low. Types at higher elevations are more resistant to annuals invaders than those at lower elevations. Resistance generally decreases as site productivity or herbaceous perennial species and ecological condition decreases.	*Protection*- Control inappropriate recreational activities and overgrazing, detect and eradicate invasive species, suppress fires at lower elevations and that threaten ecosystem integrity. *Prevention*– Warranted to restore or maintain sagebrush types, and increase understory species and resistance to invaders. Focus is on resilient and resistant sites. Potential for Wildland Fire Use and prescribed fire to control tree expansion, and shrub mowing and selective herbicides to decrease competition from overstory sagebrush. Information on ecosystem response is needed. *Restoration* – Warranted following surface disturbance and in areas with insufficient fire tolerant understory species for site recovery after fire. Seed burial (drilling) or transplanting natives adapted to local site conditions and climate warming preferred. Livestock closures required post-restoration to facilitate recovery.

(continued)

Table 7.2—(Continued)		
Ecosystem	**Resilience and resistance**	**Guidelines for appropriate management actions**
Blackbrush	*Resilience* – Low to very low. Low precipitation, moderately high temperatures, episodic recruitment. Potential to migrate upslope with climate warming. *Resistance* – Low to very low. Environmental conditions conducive to establishment of invasive annual bromes. Low competition from native species due to low productivity.	*Protection* – Primary emphasis. Suppress fires, actively control cattle and burro grazing and inappropriate recreational activities, detect and eradicate new invaders. *Prevention* – Not warranted under most circumstances. *Restoration* – Warranted following surface disturbance and in areas with insufficient fire tolerant understory species for site recovery after fire. Seed burial (drilling) or transplanting natives adapted to local site conditions and climate warming preferred. Livestock closures required after fire and restoration activities to facilitate recovery of native perennial plants.
Mojave Desert scrub	*Resilience* – Very low. Extreme environmental conditions, episodic recruitment, slow ecosystem recovery. *Resistance*– Low. Environmental conditions of more mesic systems conducive to establishment of annual grasses; few species adapted to most extreme conditions. Low competition from natives due to low productivity.	*Protection* – Primary emphasis. Suppress fires, actively control inappropriate recreational activities and overgrazing by cattle, horses and burros, detect and eradicate new invaders. *Prevention* – Not warranted under most circumstances. *Restoration* – Warranted following surface disturbance and in areas with insufficient fire tolerant understory species for site recovery after fire. Seed burial (drilling) or transplanting natives adapted to local site conditions and climate warming preferred. Livestock closures required after fire and restoration to facilitate recovery of native perennial plants.
Riparian and Spring	*Resilience* –Low to moderately high. High water availability but high water temperatures, harsh water chemistry, and scouring floods. Water availability likely to decrease with climate warming. *Resistance* – Low. Many invasive species in a variety of taxa adapted to high availability of water.	*Protection*– Maintain or increase current water allocations and in stream flows, actively control inappropriate land uses, recreational activities and overgrazing, detect and eradicate new invaders. *Prevention*- Warranted to reduce non-native tamarisk and Russian olive and to manage fuels. Biocontrol, prescribed fire, mechanical treatments, or herbicides can be used, but restoration of native species must follow. *Restoration*– Warranted to maintain river and stream channels by manipulating flow regimes, and to restore or create habitat for native species of concern. Methods include manipulating water depths, velocities and temperatures to meet requirements for species establishment and persistence, and revegetating with native species adapted to the site conditions.

Knowledge Gaps

Cross-cutting information needs for restoration and management of southern Nevada's diverse ecosystems include a better understanding of the factors that determine resilience and resistance and of the interacting effects of the region's stressors. Knowledge of the environmental conditions required for establishment and persistence of native plant species and methods for their restoration also is needed. Information needs relative to the region's major stressors follow:

<u>Climate Change</u>. More accurate predictions of changes in both temperature and precipitation; ecosystem specific information on the effects of climate change on species distributions, disturbance regimes and recovery processes.

Land Use. Knowledge of the distribution and extent of current and future land uses and their effects on current and future ecosystem resilience; information on the minimum patch sizes and degree of fragmentation that ecosystems can tolerate and still persist; land use planning tools to ensure land use is consistent with maintaining and restoring ecosystems.

Invasive Species. Increased knowledge of feedbacks to invasion from regional stressors like increased CO_2, altered fire regimes, and overgrazing; knowledge of the environmental conditions required for establishment and persistence of invasive plants and of their capacities to adapt and migrate in a warming environment; methods for controlling invaders and restoring natives that are consistent with ecosystem restoration and maintenance.

Fire. Increased knowledge of fire effectson annual species invasion and ecosystem recovery for the different ecological sites that characterize Mojave Desert scrub and blackbrush ecosystems; increased knowledge of the interacting effects of precipitation, ecosystem productivity, and understory species composition on fire return intervals for southern Nevada mixed conifer and piñon and juniper ecosystems; fire and fire surrogate tools for mixed conifer, piñon and juniper, and sagebrush ecosystems.

Management Implications

Protection is a critical component of restoring and maintaining southern Nevada ecosystems due to the arid environment and numerous stressors. Preventative management is a viable option only in more mesic or higher elevations ecosystems that do not comprise much of the total land area. Restoration is challenging in all ecosystems. Maintaining sustainable ecosystems will require a greater focus on assessing ecological condition, prioritizing restoration and management activities, and selecting the most appropriate treatments. Monitoring and adaptive management will be essential.

Assessment and Prioritization

An integrated and consistent assessment of southern Nevada ecosystems and their relative resilience and resistance is necessary to categorize and prioritize management and restoration activities. Addressing the widespread stressors affecting these ecosystems and providing habitat for species of concern requires a broad scale approach that crosses administrative boundaries. Most management plans now encompass landscapes with multiple project areas and are developed in consultation with partner agencies. Several tools already exist for developing landscape-scale and cross-boundary assessments. Soil surveys exist for most of southern Nevada including spring systems and lands managed by the BLM, most of the Desert National Wildlife Refuge, and Lake Mead and are available from the USDA Natural Resources Conservation Service (NRCS). Soil characteristics, along with climate and topography, determine the potential to support a given ecological site type (fig. 7.1). Draft ecological site descriptions (ESDs) exist for most of the region that has soil surveys and are available from the Nevada State Office, NRCS. Soil types and ESDs can be used in a GIS environment as the basis for evaluating the relative resilience and resistance of the ecosystems in the region, and the degree to which current ecological conditions deviate from potential conditions. Recent research has developed geospatial tools for identifying critical habitat for species of concern in the Great Basin that could be used in southern Nevada. Methods also have been developed to examine linkages among adjacent ESDs and the interacting effects of landforms and disturbances.

Restoration and Management Approaches

Once an area has been prioritized for active restoration and/or management, a series of logical steps can be used to develop the restoration plan: identifying landscape priorities and ecological sites, determining the current state of the site, selecting the appropriate action(s), and determining post-treatment management. A useful approach that asks questions to identify the information required in each step is provided in table 7.3. These questions can be modified to include the specific information needed for restoration of different ecosystem types.

Table 7.3—General guidelines for conducting a restoration project in southern Nevada (modified from Miller and others 2007; Pyke 2011; Tausch and others 2009).

Steps in the process	Questions to be addressed
I. Identify landscape priorities and ecological sites	1. Where are priority sites for protection, prevention and restoration? Consider the landscape context.
	2. What are the topographic characteristics and soils of the site? Verify soils mapped to the location and collect information on soil texture, depth and basic chemistry (pH, calcium carbonate, etc.)
	3. How will topographic characteristics and soils affect vegetation establishment and erosion? Evaluate erosion risk based on topography and soil characteristics.
	4. What is the potential native plant community for the site? Match soil components to their correlated ESD. This provides a list of potential species for the site.
II. Determine current state of the site	5. Is the site still within the reference state of the state and transition model for this ecological site?
III. Select appropriate action	6. How far does the site deviate from the reference state?
	7. Do sufficient perennial shrubs and herbaceous species exist to facilitate recovery? No action is needed.
	8. Are invasive species a minor component? Protection or preventative management may prevent conversion.
	9. Do invasive species dominate the site while native life forms are missing or severely under represented? Active restoration is required to restore habitat.
	10. Are species from drier or warmer ecological sites present? Restoration with species from the drier or warmer site should be considered.
	11. Have soils or other aspects of the physical environment been altered? The site may have crossed a threshold and represent a new ecological site type requiring new site-specific restoration approaches.
IV. Determine post-treatment management	12. How long should the site be protected before land uses begin? In general, sites with lower resilience and resistance should be protected for longer periods.
	13. How will monitoring be performed? Restoration effectiveness monitoring includes a complete set of measurements, analyses, and a report.
	14. Are adjustments to the restoration approach needed? Adaptive management is applied to future projects by compiling information based on consistent findings from multiple locations.

Monitoring Activities

Monitoring programs designed to track ecosystem changes in response to both stressors and management actions can be used to increase understanding of ecosystem resilience and resistance, realign restoration and management approaches, and implement adaptive management. Information is increasing on likely changes in southern Nevada ecosystems with additional stress and climate warming, but a large degree of uncertainty still exits. Strategic placement of monitoring sites and repeated measurements of key abiotic (precipitation, temperature, evaporation) and biotic (dominant native and exotic species) variables and ecological conditions can be used to decrease uncertainty and increase the effectiveness of management decisions. Monitoring sites should span the environmental/ productivity gradients and ecosystem types that occur in southern Nevada. In addition, areas of high priority should be monitored including (1) ecosystem types of small extent under development pressure like mesquite/catclaw and salt desert shrub; (2) ecosystems that support numerous species of conservation concern like springs and riparian areas; (3) ecotones between ecosystem types where changes in response to climate are expected to be largest; (4) ecological sites with different climatic conditions and soils that are exhibiting invasion and repeated fires; and (5) ecological sites with different climatic conditions and soils that are exhibiting tree expansion and increased fire risk. Monitoring the response of ecosystems to management actions and active restoration also is of high priority as it provides information on treatment effectiveness that can be used to adjust methodologies.

Monitoring activities are most beneficial when consistent approaches are used among and within agencies to collect, analyze, and report monitoring data. Common databases can be used by agency partners to record and share monitoring data, like the USGS Land Treatment Digital Library, to facilitate this process.

For a complete discussion of topics in this executive summary, see *Chapter 7, Maintaining and Restoring, Sustainable Ecosystems in Southern Nevada*, in "The Southern Nevada Agency Partnership Science and Research Synthesis—Science to Support Land Management in Southern Nevada" (RMRS-GTR-303).

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Chapter 8

Human Interactions With the Environment Through Time in Southern Nevada

Carol B. Raish

Executive Summary

Southern Nevada is rich in irreplaceable cultural resources that include archeological remains, historic sites, cultural landscapes, and other areas of significance to Native Americans and other cultural groups. This chapter provides information related to Goal 2 in the SNAP Science Research Strategy, which is to "Provide for responsible use of Southern Nevada's lands in a manner that preserves heritage resources and promotes an understanding of human interaction with the landscape." Specifically, it addresses Sub-goal 2.1, which is to "Develop an understanding of human interactions with the environment through time" (see table 1.1). The summary presents a review of human occupation in the region as derived from studies of southern Nevada's cultural resources. The depth with which these questions can be discussed is dependent upon the nature and extent of archeological survey coverage of the region and the nature of the resources themselves (fig. 8.1). The area shows wide ranging use of resources and environmental zones over time. The focus of this overview is on the time periods primarily informed by archeological sources, which is roughly from 11,950 BP (10,000 BC) to 100 BP (AD 1850). This period encompasses the end of the Pleistocene/beginning of the Holocene until occupation by Euro-Americans.

Focal Area

The focal area is mainly southern Nevada's Clark County but lands in Lincoln and Nye Counties are also included, as well as a small portion of Mohave County, Arizona. The geographic focus includes areas surrounding Lake Mead, the Muddy and Virgin Rivers, and the Las Vegas Valley. It extends west to Sloan Canyon National Conservation Area, the Spring Mountains National Recreation Area, and Ash Meadows National Wildlife Refuge. Physiographic features important for human occupation in and surrounding the location include the Muddy and Virgin Mountains, Moapa and Virgin Valleys, the Valley of Fire, the Muddy and Virgin Rivers, Las Vegas Valley, and the Spring Mountains (figs. 8.2 and 8.3).

Culture History

Tables 8.1 and 8.2 outline the chronology of the region. The earliest period of human occupation in the area is the Paleo-Archaic, known primarily from diagnostic projectile points. Paleoenvironmental research in southern Nevada and the Great Basin indicates that climatic changes from a moister, temperate regime to current climatic conditions began around 13,950 BP (roughly 12,000 BC) with deglaciation of the mountains within the area.

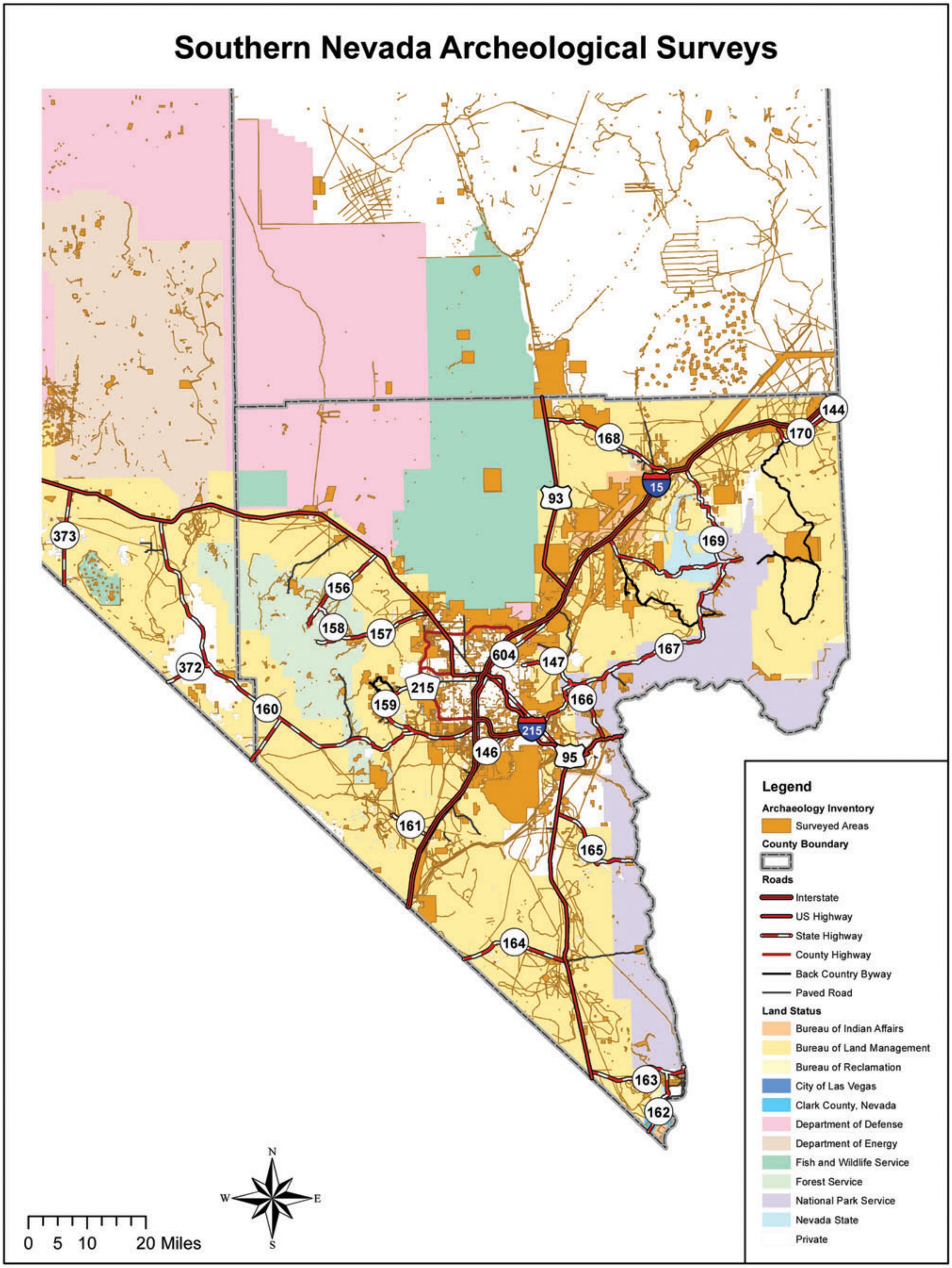

Figure 8.1—Map of southern Nevada archeological survey coverage.

For Informational Use Only

Figure 8.2—Map of the Moapa and Virgin Valleys.

For Informational Use Only

Figure 8.3—Map of the Las Vegas Valley.

Table 8.1—Chronological sequence for the Moapa and Virgin River Valleys (adapted from Ahlstrom and Roberts 2012[1]; Ezzo 1995[2]; Harper and others 2006[3]; Lyneis 2012[4]). Question marks indicate uncertain date range.

Period	Subperiod	Date range	Source
Paleo-Archaic		11,950-7450 BP (10,000-5500 BC)	3
	Paleo-Indian	11,450-10,950 BP (9500-9000 BC)	2, 3
	Early Archaic	11,150-7450 BP (9200-5500 BC	3
Archaic	Middle Archaic	7450-4950 BP (5500-3000 BC)	3
	Late Archaic	4950-2350 (?) BP (3000-400 (?) BC)	3
	Late Archaic/Early Agricultural	2350 (?)-1450 BP (400 (?) BC-AD 500)	3
Virgin Branch		1600-750/650 BP (AD 350-1200/1300)	1, 3, 4
	Moapa phase	1600-1400 BP (AD 350-550)	3
	Muddy River phase	1400-1200 BP (AD 550-750)	3
	Lost City phase	1200-800 BP (AD 750-1150)	3
	Mesa House phase	800-750/650 BP (AD 1150-1200/1300)	1, 3, 4
Late Prehistoric and Protohistoric		750/650-150 BP (AD 1200/1300-1800)	3, 4
Historical		150-0 BP (AD 1800-1950)	3

Table 8.2—Chronological sequence for the Las Vegas Valley (adapted from Roberts and Ahlstrom 2007).

Period	Subperiod	Date range
Paleo-Archaic		11,450-7450 BP (9500-5500 BC)
	Paleo-Indian	11,450-10,950 BP (9500-9000 BC)
	Early Archaic	11,150-7450 BP (9200-5500 BC)
Archaic	Middle	7,450-4950 BP (5500-3000 BC)
	Late	4950-1450 BP (3000 BC-AD 500)
	Terminal Late	1949-1450 BP (AD 1-500)
Ceramic	Early	1450-950 BP (AD 500-1000)
	Middle	950-450 BP (AD 1000-1500)
	Late	450-100 BP (AD 1500-1850)
Historical	Early	450-100 BP (AD 1500-1850)
	Late	100-50 BP (AD 1850-1900)

A continuing trend toward aridity and drying of pluvial lakes is indicative of southern Nevada's climate in the Holocene, with an increase in succulent plants in lower environments and a movement of woodlands to higher elevations. Clovis points attached to the thrusting spear or atlatl (spear-thrower) are representative of the Paleo-Indian occupation found across the Americas and are generally considered to represent the activities of nomadic groups hunting and scavenging Pleistocene megafauna, represented by mammoth, camel, horse, and bison. Paleo-Indian sites include camps, kill and butchering locations, and isolated projectile points.

The Archaic periods represent adaptation to Holocene animal and plant resources similar to those of the present. Site locations indicate that groups continued a mobile strategy seasonally exploiting ecological zones from a wide range of elevations and landforms. During these times, plant procurement and processing tools, storage cists, and snares and traps for small game came into use. In earlier portions of the period, sites seem to be located near water sources such as drainages and remnant pluvial lakes. Unusually arid conditions are thought to drive the settlement pattern. Later portions of the period are described as having a climatic shift toward greater precipitation and an increasing diversity of plant resources available to southern Nevada groups, with sites occurring in riverine areas, lowland zones, and mountains. Upland sites were also more frequently used in later portions of the period. Both of these trends suggest the growing importance of plant foods. Sites include caves, rockshelters, campsites, roasting pits, hearths, and scatters of flaked and ground stone.

The following periods represent the beginnings of agriculture in the region and its growing importance as a subsistence strategy, although exploitation of wild resources coupled with seasonal movement continued to play an important role in food procurement. These time periods represent the beginning of the Virgin Branch Ancestral Puebloan occupation of the area. The Virgin Branch is most strongly represented in the Moapa and Virgin River Valleys, expanding its occupational range into the Las Vegas Valley during the later portions of the period when population peaked in the area. Key features include the appearance of the bow and arrow, ceramics, two-handed manos, and various types of metates (grinding implements). Habitations consisted of pit structures with above-ground, surface structures appearing in the later portions of the period. Site location in relation to the best agricultural land in the valley indicates the growing importance of agriculture during these times.

By approximately 750/650 BP (AD 1200/1300), the Virgin Branch cultural tradition was no longer present in southern Nevada. With the decline of agriculture as a major subsistence practice in the area, archeological remains reflect a return to a more nomadic foraging way of life that was supplemented by smaller-scale agriculture. This adaptation is associated with the Southern Paiute, who were residents of the region at European contact and who occupy southern Nevada today.

European Contact

The first reported direct European contacts were with the Spanish in the late 1700s with the expeditions of Garcés and of Domínguez and Escalante. After the explorers, trappers, and traders extended their operations into the area, an active slave trade began that lasted from the late 1700s to the mid-1850s. Captives, often Southern Paiute, were transported along the Old Spanish Trail between California and New Mexico. This slave trade seriously impacted the people of the Moapa and Las Vegas Valleys forcing them away from favorable agricultural lands, depopulating some Southern Paiute bands, and increasing their hostility and fear of travelers and other outsiders. Slave raiding continued in the region until the mid-1850s when steps taken by the Mormons and the territorial legislature ended the trade.

During the 1850s, the Old Spanish Trail became the Mormon Road, which brought settlers and other travelers to the area. Increased Euro-American settlement displaced the Southern Paiute from long-used agricultural, foraging, and hunting lands, which became depleted by livestock grazing and larger farming operations. Interactions with Mormon settlers increased so that by the 1870s the majority of Southern Paiute had direct contact with Euro-Americans, with some settling near Mormon communities.

Expansion of Euro-American settlement led to increasing hostilities. In 1873, an executive order was issued setting aside 3,900 square miles (10,101 square kilometers) to form the Moapa River Reservation. The reservation was expanded in 1874 then sharply reduced to 1.5 square miles (2.4 square kilometers) in 1875 to accommodate complaints from white settlers within the reservation lands. In 1982, the reservation was increased to its present size of 112 square miles (180 square kilometers) after a petition to congress from the Moapa Band of the Paiute.

In 1951, the Southern Paiute filed a claim with the Indian Claims Commission that was resolved in 1965 with a monetary settlement. Portions of the money from the settlement were invested in improvements to the reservation's business enterprises. In 2011, there were 287 enrolled Tribal members with approximately 180 members living on the reservation. The total population was estimated at 425 residents (http://www.xeri.com/Moapa/moapa.htm). The Southern Paiute have persevered over the years in the face of many obstacles and hardships associated with Euro-American occupation and settlement of the area and are actively working to preserve their heritage in publications detailing their history and culture.

Knowledge Gaps and Management Implications

Knowledge gaps concerning southern Nevada's past, as derived from the archeological record, result from several sources. Chief among them are the extent of archeological survey coverage (the most common means of identifying cultural resources) and the nature of archeological survey itself. Approximately 783,756 acres (317,174.8 hectares) or 7 percent of the area under consideration have been surveyed for archeological resources (fig.8.1). Thus, a large portion of the area has received no coverage.

Because of the sparse nature of archeological survey coverage, basic inventories of cultural resources are needed. In particular, inventories that are not associated with planned development projects are desirable to expand surveyed lands and address gaps in coverage. Complete survey of the public lands in the study area is not a realistic goal owing to the cost involved. SNAP offices manage over 7 million acres—which is a huge area—to meet the "complete survey" expectation that would require over 500 man-years to survey with 30-meter transects at 2-miles per hour. In addition, cultural resource recording standards, as well as the sites themselves, will continue to change over time. A more realistic goal for regional-scale inventory would be to expand and improve the sample of lands that have been examined and sites that have been located and recorded. Because cultural resources represent finite, non-renewable resources that must be protected for the future, an important goal of inventory is to provide baseline information for measuring changes in the condition of sites through time.

In addition to the basic need for greater survey coverage, several studies have identified both specific and more general information gaps and have provided recommendations for addressing them. A major recommendation from the working group on the Information and State-of-the-Science Summary developed for the Ecosystem Health Assessment of Southern Nevada Project was to prepare a new Historic Context for the region that would structure and promote research important to the agencies. Such a context has been prepared, is currently in draft form, and is used in this review.

Other general recommendations from the working group include compiling region-wide data sets featuring both survey and excavation data. This data base would include layers suitable for GIS with information on plant communities, springs, surface geology, soils, and other pertinent resource information reflective of the close association between archeological sites and their environmental surroundings. The group also recommended producing "finder's guides" to identify locations of existing collections of materials and records to assist researchers in locating available information on the regions' cultural resources. More detailed discussions of needed research are found in the draft Prehistoric Context for Southern Nevada.

Managers in the area must take the limitations of archeological surveys into consideration when planning ground-disturbing projects to ensure that all sites are protected and free from damage. Managers in the area must take the limitations of archeological surveys into consideration when planning ground-disturbing projects to ensure that all sites are protected and free from damage as required, or that potential damage is mitigated by data recovery as mandated under Federal regulations.

Interpretive scenarios must also take into account the ongoing possibility that discovery of previously unknown resources will alter time lines and chronological schemes. The previously discussed recommendations made in the Draft Prehistoric Context for Southern Nevada address these issues and make recommendations to assist managers in dealing with the difficulties inherent in interpreting the archeological record. For a more in-depth discussion of the topics reviewed in this summary, see *Chapter 8, Human Interactions With The Environment Through Time* in "The Southern Nevada Agency Partnership Science and Research Synthesis—Science to support land management in Southern Nevada" (RMRS-GTR-303).

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Chapter 9

Preserving Heritage Resources Through Responsible Use of Southern Nevada's Lands

Carol B. Raish

Executive Summary

Southern Nevada's cultural resources (heritage resources) include archeological remains, sacred sites, historic sites, and cultural landscapes of significance to Native Americans and many other cultural groups. Locating, maintaining, and protecting these special places are part of the mandate of Nevada's Federal and state agencies. This summary addresses Sub-goal 2.2 in the SNAP Science Research Strategy, which is "To preserve these resources through responsible use of southern Nevada's lands" (see table 1.1). Cultural resources at risk, risk factors, and needed measures to protect them are discussed, focusing on non-destructive identification, preservation, and protection measures.

Cultural Resources at Risk

Nevada is one of the fastest growing states in the country. In southern Nevada, the population of Clark County (1,951,269) grew by 42 percent from 2000 to 2010. In-migration from other states has contributed strongly to this growth, with newcomers often having little knowledge of the role and importance of the state's history. These population growth trends have considerable influence on how the state preserves its past. Urban growth and development can lead to resource destruction as homes and businesses are built on previously undeveloped lands. Growing pressure on resources from increased recreation and the use of all-terrain vehicles (ATVs) has resulted in rising vandalism and illegal looting (collecting artifacts and/or excavating on an archeological site without a permit) on previously remote and inaccessible sites. Agency reports identify the following threats to heritage sites:

- Increasing visitation,
- Increasing use of public lands for permitted projects,
- Insufficient staffing and funding for cultural resource programs and law enforcement,
- Looting and vandalism, and
- Urban sprawl and development.

Cultural Resource Protection Measures and Organizations

Federal agencies in southern Nevada use and recommend a number of measures to assist in protecting heritage resources: public education and outreach programs, cultural resource site monitoring, and law enforcement for cultural resources.

Public Education and Outreach

Public education and outreach efforts range from preparing sites and structures to receive visitors with trails, signage, and other protection measures such as fencing, to active public involvement programs. Rapidly increasing recreation access requires public education concerning the importance and fragility of archeological and historic sites. Some of the most successful programs involve public participation, but they reach a more limited audience. Brochures and information kiosks also can be effective teaching tools and reach a wider audience. They are especially effective when they are attractive, current, and appropriately placed near the resource in question.

Several agencies have long-running, successful public involvement programs. An example of these is Adventures in the Past, which includes Project Archaeology, a national Bureau of Land Management (BLM) education program designed for teachers of upper elementary and mid-school students. The program trains teachers and provides curriculum materials for teaching students to value and care for their archeological and historic heritage. A Nevada-specific program, *Preserve Nevada*, is a non-profit organization dedicated to preservation of the state's cultural, historic, and archeological heritage. *Preserve Nevada* works with the Public History program at the University of Nevada, Las Vegas, and provides the opportunity for graduate students to gain experience and training by working on the organization's projects.

Other examples of creative outreach and education programs come from Lake Mead National Recreation Area, which has an active education and interpretive program featuring educational programs, field trips, and volunteer experiences. Education programs include not only cultural resource activities but also activities from other science programs for students and teachers. There is a Hispanic outreach program and a Hispanic community partnership program, which includes other Federal agencies that are part of SNAP, such as the BLM, U.S. Forest Service (USFS), Fish and Wildlife Service (FWS), and National Park Service (NPS). Specific examples of historic and cultural programs for students include "Hiking Through History," which focuses on the Hoover Dam and the U.S. Government Railroad, and "Puzzle Pieces of the Past," which focuses on archeological sites and artifacts.

Cultural Resource Site Monitoring

Monitoring the condition of heritage resources is an important part of agency responsibilities to their lands. Unfortunately, there are rarely sufficient law enforcement officers and staff to undertake comprehensive site monitoring on a realistic scale and time frame. Thus, in 2004, the Southern Nevada Agency Partnership (SNAP) Interagency Cultural Site Stewardship Team created the SNAP Cultural Site Stewardship Program (CSSP). The program is managed under a cooperative agreement with the University of Nevada-Las Vegas, Public Lands Institute (UNLV-PLI). The UNLV-PLI Program Manager provides a variety of services including recruitment of volunteer site stewards, standardized training, reporting of monitoring results to the appropriate Federal agency, and public outreach. The program is composed of volunteers who serve as site stewards to monitor at-risk sites for natural or man-made damage, which is reported to the responsible land manager. The volunteer site stewards monitor their assigned sites at least four times per year. To date, over 540 volunteer site stewards have been trained. Stewards have reported over 645 significant impacts that have resulted in criminal investigations, and have informed management actions including closing of unapproved roads, development of a Road Designation Plan, and removal of graffiti from rock art sites. The program has been very successful and has received several awards.

Law Enforcement for Cultural Resources

Federal agency law enforcement plays an important role in protecting archeological and historic remains from looting and vandalism. However, Federal heritage resource professionals believe that there are far too few agency law enforcement officers. Despite this shortage, there have been various successful prosecutions in recent years that have increased awareness of the problem of looting on archeological sites. BLM enforcement personnel have had some highly publicized and successful enforcement actions taken against organized thieves stealing archeological artifacts from the public lands. The USFS has successfully prosecuted an ARPA (Archaeological Resources Protection Act) case resulting in replacement of a petroglyph to its original location. The NPS had a successful prosecution of a man who was sentenced to time in Federal prison and ordered to pay restitution for defacing petroglyphs with paintballs in the Grapevine Canyon area of Lake Mead National Recreation Area. "This sentence comes as a result of the hard work of park rangers, special agents of the National Park Service Investigative Services Bureau, and the U.S. Attorney's Office. We are pleased with the result," said Bill Dickinson, superintendent of Lake Mead National Recreation Area. Despite such successes, there are still too few enforcement officers to protect the cultural resources on the extensive public lands of the state. "For every criminal caught in an ARPA violation, it is believed that many more violations go un-discovered, much less un-prosecuted."

Non-Destructive Techniques for Identification of Archeological and Historic Remains

Because information on both surface and subsurface cultural resources is needed for management decisions, non-destructive techniques to uncover subsurface features can play an important role as part of the heritage resource toolkit. Geophysical surveying systems, such as ground penetrating radar, magnetometry, and soil resistivity surveying, non-invasively and non-destructively map subsurface features. These techniques are useful where excavation is undesirable, too costly, or otherwise not possible. They can assist managers in determining which areas to avoid during construction or other land-disturbing activities and which areas may require additional testing or excavation. However, these non-invasive methods require special equipment and training and may be costly. In addition, their land coverage rate is low owing to the nature of the methods and the time needed to implement them. Thus, they are mainly practical at small scales and are not cost-effective in replacing standard archeological survey techniques.

Knowledge Gaps and Management Implications

Southern Nevada's heritage resources are at risk from a variety of factors including urban development and sprawl, and increased recreation use and access to previously remote, undisturbed areas. The Federal agencies that manage these vast acreages and irreplaceable resources remain understaffed and underfunded resulting in substantial management challenges. Nonetheless, they have implemented public education and outreach projects, volunteer site monitoring efforts, and law enforcement programs in attempts to protect the areas at risk. Continued research is needed to assess the effectiveness of these programs and develop additional means of cultural resource protection that can be implemented with limited funding.

When implementing projects, managers must address issues associated with protection and preservation of known sites as well as identifying and protecting any newly discovered sites. There are significant knowledge gaps relating to southern Nevada's past, as derived from the archeological record. Only 783,756 acres (317,174.8 hectares), or 7 percent of the lands under consideration, have been surveyed for archeological resources (see fig.8.1); thus, a large portion of the area has received no survey coverage. Because of the sparse nature of archeological survey coverage, basic inventories of cultural resources are needed. In particular, inventories that are not associated with planned development projects are desirable to expand the acres of surveyed lands and address gaps in coverage. Complete coverage of the public lands in the study area is not a realistic goal owing to the cost involved, because SNAP offices manage 7 million acres (2,832,799 hectares), a huge area to meet the "complete survey" expectation. That would be over 500 man-years to survey with 30-meter (32.8 yard) transects at 2 miles (3.22 kilometers) per hour. In addition, cultural resource recording standards, as well as the sites themselves, will continue to change over time. A more realistic goal for regional-scale inventory would be to expand and improve the sample of lands that have been examined and of sites that have been located and recorded. Because cultural resources represent finite, non-renewable resources that must be protected for the future, an important goal of inventory is to provide baseline information for measuring changes in the condition of sites through time. For a complete discussion of topics in this executive summary, see *Chapter 9, Preserving Heritage Resources Through Responsible Use of Southern Nevada's Lands* in "The Southern Nevada Agency Partnership Science and Research Synthesis—Science to support land management in Southern Nevada" (RMRS-GTR-303).

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Chapter 10

Recreation Use on Federal Lands in Southern Nevada

Alice M. McSweeney

Executive Summary

Providing for appropriate, diverse, and high quality recreation use of southern Nevada's lands and ensuring responsible visitor use is an ongoing challenge for Federal agencies that manage much of this land (fig. 1.1). This chapter examines recreation on these Federal lands and addresses Sub-goal 2.4 in the SNAP Science Research Strategy (table 1.1). The demands for various types of recreational opportunities are discussed and the ways in which Federal agencies can provide quality recreational experiences without compromising resources are explored. Also discussed are current visitor use patterns and services provided by the designated recreation areas in southern Nevada.

Two significant factors influence recreationists and the natural resource base that supports outdoor recreation in Nevada. One is the fact that the State of Nevada ranks first in Federal land management (over 87 percent of Nevada's land is administered by the Federal government); and the second is the highly urbanized population of the state (94 percent resided in urban areas in 2000). The rapidly growing population of southern Nevada results in an increase in recreational demands on the area's public lands, and an associated shift in demographics brings changes in recreation tastes and preferences.

Outdoor Recreation Issues

The Nevada Division of State Parks (NDSP) developed the 2003 Statewide Comprehensive Outdoor Recreation Plan (SCORP), which provides review and study of recreation use within the entire state. The intention of the plan is to increase and improve the quality of outdoor recreation opportunities to meet the needs of the citizens of Nevada as well as the state's many visitors. The dominant concern of respondents to the study was to keep Federal lands open for a wide variety of outdoor recreation activities while protecting the state's natural resources.

Snap Interagency Recreation and Wilderness Planning

There are four Federal land management agencies in southern Nevada with eight congressionally designated resource areas. The Bureau of land Management (BLM) oversees Red Rock Canyon and Sloan Canyon National Conservation Areas (NCAs). The National Park Service (NPS) administers Lake Mead National Recreation Area (NRA). The United States Forest Service (USFS) manages Spring Mountains National Recreation Area (NRA). The United States Fish & Wildlife Service (USFWS) has the Desert National Wildlife Refuge Complex, which is comprised of four distinct National Wildlife Refuges (NWRs): Ash Meadows NWR, Desert NWR, Moapa Valley NWR, and Pahranagat NWR.

In 2002, the Federal managers of SNAP directed the four agencies (BLM, NPS, USFW, and USFS) to conduct interagency recreation management and to form the Interagency Recreation Team. The team's vision is to provide interagency collaboration in the planning and management of recreational opportunities, facilities, and services while honoring the natural setting and complementing the quality of life in Southern Nevada. The SNAP Recreation Team initiated recreation visitor sampling on all SNAP lands using a single monitoring program based on the USDA FS National Visitor Use Monitoring (NVUM) program. Collectively, these NVUM reports provide comprehensive statistics on recreation use, visit characteristics, visitor spending, and the satisfaction of recreationists with recreation opportunities and resource conditions.

There were differences in the popularity of recreation choices across agencies, as management objectives, topography, and recreation resources differ from agency to agency. For example, on BLM lands there was a greater percentage that listed driving for pleasure and rock climbing as primary activities; water-based recreation was most prevalent on NPS lands; viewing wildlife was listed as the primary activity on USFWS lands; while camping was listed as the primary activity on USFS land. The overall rating of the four SNAP agencies indicated that the vast majority of visitors surveyed were at least "somewhat satisfied" with their visit.

Regional Trail Planning and Outreach

Partnerships between agencies (Federal, state, regional, and local), non-profits, businesses, individual citizens, and community partners played a critical role in the establishment and management of trails in southern Nevada. The proposed 113-mile Vegas Valley Rim Trail would serve to bind many land management areas, recreational destinations, municipalities, and agencies together.

The cities of Las Vegas and Henderson have completed open space plans designed to provide a ring of open space and wildlands that will encircle the Greater Las Vegas area and protect scenic, ecosystem, and cultural resources. Most of the corridor rests on BLM-managed lands, suggesting the need for continual coordination between the local community and Federal agency.

Knowledge Gaps and Management Implications

Southern Nevada's rapidly increasing population has resulted in an increase in recreation demands on public lands, while an associated shift in demographics has altered recreation tastes and preferences. There are changes in visitor types to a more urban population who expect more expensive recreation enhancements.

These changes in the population impact the profile of recreation in the area and highlight the need for understanding the needs of a multi-cultural urban population. Additional information and management strategies are needed to meet future demands and trends. Funding of recreation areas and facilities with support staffing must be sufficient to keep pace with these increasing demands.

Southern Nevada's growing population influences recreation activity on Federal lands and impacts the area's natural resources. While these areas are beneficial to human population as healthy retreats from urban life, they are essential as habitat for many native species of flora and fauna. Therefore, it is imperative to consider the effects of increasing recreation demands on natural resources. Cooperation and collaboration between the four Federal land management agencies and with southern Nevada's adjacent communities is necessary to achieve the goals of promoting natural and cultural resource stewardship while providing appropriate and sustainable recreation opportunities. For a complete discussion of topics in this executive summary, see *Chapter 10, Recreation*

Use on Federal Lands in Southern Nevada in "The Southern Nevada Agency Partnership Science and Research Synthesis—Science to Support Land Management in Southern Nevada" (RMRS-GTR-303).

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Chapter 11

Science-Based Management of Public Lands in Southern Nevada

Matthew L. Brooks and Jeanne C. Chambers

Executive Summary

Landmark legislation provides guiding principles for land management planning in southern Nevada and the rest of the United States. Such legislation includes, but is not limited to, the Forest Service Organic Administration Act of 1897 (16 U.S.C. 473-478, 479-482 and 551), National Park Service Organic Act of 1916 (U.S.C. Title 16, Secs. 1-4), Wilderness Act 1964 (P.L.88-577), National Environmental Policy Act of 1969 (P.L 91-190), Endangered Species Act of 1973 (P.L. 91-205), National Forest Management Act of 1976 (P.L. 94-588), and Federal Land Policy and Management Act of 1976 (P.L. 94-579). The acts establishing congressionally designated areas within southern Nevada, such as Lake Mead National Recreation Area, Spring Mountains National Recreation Area, and Desert National Wildlife Refuge, also contain guidelines for the management of these lands. These documents variously require preservation of natural and cultural resources and wilderness character, protection of species, and prevention of undesirable environmental effects from land management actions. These requirements must be met while allowing for multiple "uses" of certain public lands (e.g. recreation, ranching, resource extraction, renewable energy development, etc.) to the degree that they do not threaten protection, prevention, and restoration goals. Many considerations therefore come into play in the development and implementation of land management plans and actions. The planning process requires a balancing act that sometimes pits one need or priority against another. When priorities align, management actions can have multiple benefits. In some cases specific priorities can trump other needs and priorities and receive disproportionate consideration. Overall, the management of public lands is a very complicated and sometimes contentious process.

Science provides an objective way to help weigh quantifiable information and draw conclusions about the effects of past and potential future land management policies, decisions, and actions. When effectively integrated into adaptive management, science-based information can reduce uncertainties, increase knowledge, and improve decision making. However, the specific science information needed for effective management is often lacking or difficult to access or interpret. Science is typically reported in scientific journals as discrete units describing individual studies with other scientists as the primary audience. Translations of these studies and syntheses of multiple studies into formats that can be readily used in land management planning efforts are often lacking.

Identifying and articulating the highest priority science and research needs is one of the primary purposes of the Southern Nevada Agency Partnership (SNAP; http://www.SNAP.gov) Science and Research Team (Turner and others 2009; Chapter 1). The SNAP Science and Research Strategy (Strategy) calls for a synthesis report to be written every 5 years summarizing the state of knowledge, information gaps, and management implications of scientific information as it relates to the SNAP Strategy goals (Turner and others 2009). This General Technical Report serves as the first SNAP Science and

Research Synthesis Report (Synthesis Report) commissioned by the Science and Research Team. The Synthesis Report is mostly based on information from the peer-reviewed scientific literature, and is itself peer reviewed and constitutes a new contribution to the scientific literature. This final chapter addresses Sub-goal 2.3, which is to "Manage current and future authorized southern Nevada land uses in a manner that balances public need and ecosystem sustainability," and Sub-goal 2.5, which is to "Promote an effective conservation education and interpretation program to improve the quality of resources and enhance public use and enjoyment of southern Nevada public lands." It summarizes information from the previous chapters on what scientific information is known currently and what remains largely unknown, and it discusses how science can be used to make future management decisions that balances public needs and ecosystem sustainability.

Current Scientific Understanding and Information Needs

Ecosystem stressors associated with human activities, wild horse and burro and livestock grazing, and altered fire regimes have been the traditional focus of land managers in southern Nevada. Concerns about invasive species emerged during the 1990s, and perhaps even greater concerns regarding climate change, energy development, and water development arose during the 2000s. The current challenge is to understand how to manage these many, and often interacting, stressors to maintain ecosystem sustainability. This task is more daunting today than it was only a few decades ago because of the rapidly expanding human population, the increase in the number of stressors of significant concern, and the need to address both public access and resource issues on Nevada's public lands.

The effect of climate change on ecosystem sustainability is perhaps the greatest unknown stressor with respect to current management planning in southern Nevada. The science is clear that anthropogenic caused climate change is occurring on a global scale and that longer and more intense droughts and increased temperatures are becoming increasingly more likely in the deserts of southwestern North America (Chapter 2). However, the precise nature of these changes are not yet known and the scaled-down predictions necessary for determining the most effective management actions have yet to be developed. Also, it is not clear how these conditions will interact with other ecosystem stressors that land managers can potentially control.

The current state of science can help tease out some of the most significant stressors threating ecosystem sustainability in southern Nevada (see Chapter 2). However, there is much more that remains unknown regarding these stressors and potential ecosystem responses. The sections that follow summarize these primary knowns and unknowns, and suggest research priorities for the major management topics in southern Nevada.

Water and Water Use

The hydrology of southern Nevada is characterized by regionally limited recharge areas within mountain ranges, and interbasin flow from adjacent regions. Discharge occurs through seeps and springs, evapotranspiration, subsurface flow out of the region, and pumping (Chapter 3). The Colorado River (Lake Mead) and its tributaries (the Muddy and Virgin Rivers), along with Las Vegas Wash, form the major fluvial systems in the area. Although recharge from precipitation can vary widely among years, large subsurface aquifers historically buffered inter-annual fluctuations in ground water levels across much of southern Nevada. This means that the discharge from springs and seeps was maintained for long periods of time, supporting locally endemic species and their habitat (Chapter 6). Accelerated rates of ground water pumping during recent decades now affect discharge patterns threatening spring and seep ecosystems, and projected increases in pumping may pose even greater ecosystem threats in the future.

In order to effectively manage water resources in southern Nevada, it is important to understand future patterns of ground water recharge. Predictions of a warmer climate, potentially higher evapotranspiration rates, and more variable precipitation could dramatically alter ground water dynamics. An understanding of these potential future scenarios is critical to ensure that current planning decisions related to ground water pumping and water use do not adversely impact ground water resources or otherwise cause significant and potentially irreversible environmental degradation. (See Chapter 3 for a detailed discussion of information needs related to water and water use in southern Nevada.)

Invasive Species

The concern associated with invasive species on wildlands in southern Nevada gained prominence following President Clinton's Executive Order 13112 in 1999 and the development of a national strategy for management of this ecosystem stressor. At that time the science to support this mandate was not very extensive, as invasion biology had only emerged as a major branch of ecology during the 1980s. During the past few decades there has been a tremendous amount of new information generated regarding biological invasions worldwide.

In southern Nevada it is now clear that the main invasive plants of concern in upland areas are annual species, especially red brome (*Bromus rubens*) and Mediterranean splitgrass (*Schismus* spp.), which are associated with altered fire regimes. Riparian areas are most threatened by perennial plants, especially Tamarisk (*Tamarix* spp.), which can compete with native plants, degrade wildlife habitat, and potentially alter hydrologic and fire regimes. Aquatic plants are not yet recognized as major threats to the degree as their invasive analogs in terrestrial ecosystems. However, there are a few poised to invade southern Nevada that could become aquatic ecosystem transformers, including Eurasian water-milfoil (*Myriophyllum spicatum*) and giant salvinia (*Salvinia molesta*).

Various non-native terrestrial animals are also of significant management concern in southern Nevada, ranging from ants, dogs, and cats, to free-roaming cows and equids (Chapter 4). The effects of species like ants and dogs and cats are related primarily to competition with or predation on native species, but habitat alteration by cows and equids is also a major concern. Non-native aquatic animals range from the quagga mussel (*Dreissena rostriformis*), American bullfrog (*Rana catesbeiana*), red swamp crayfish (*Procambarus clarkia*), to various fish species. Threats from these species include altered food web dynamics and predation on native species.

Perhaps one of the most significant unknowns relates to the ability to accurately predict future patterns of spread for existing invasives, establishment and spread of new invasives, and the relative and cumulative threats posed by all invasive species in southern Nevada. This information, and an understanding of the feasibility for controlling the different species, is critical for prioritizing management actions among the plethora of non-native and potentially invasive species in this region. (See Chapter 4 for a detailed discussion of information needs related to invasive species management in southern Nevada.)

Fire History, Effects, and Management

It is generally understood that fire has been infrequent in most of southern Nevada since the last ice age, which ended approximately 10,000 years ago (Chapter 5). What is less recognized is that some landscapes have continuously experienced at least moderate fire frequencies during this time period. These include sagebrush, piñon-juniper, and mixed conifer ecosystems, and in these areas fire may be an important ecosystem process. However, the vast majority of the current southern Nevada landscape is dominated by blackbrush and lower elevation vegetation types that did not support frequent fire historically and where large and/or frequent fires are ecosystem stressors. Key fire management messages that can be derived from current science are that: (1) potential effects of fire should be evaluated in the context of ecosystem type, fire behavior characteristics, and site-specific characteristics (e.g., resistance to invasive species); (2) fire suppression is ultimately the most effective way to manage fire at middle and lower elevation where fire was historically infrequent, but wildland fire use or fire surrogates may be appropriate under certain circumstances at higher elevations; and (3) the post-fire rehabilitation/restoration tools that are currently being used at middle to lower elevations appear to be ineffective or poorly evaluated (Chapter 5).

Information is needed on both long-term ramifications of fire in middle and upper elevation vegetation types (i.e., blackbrush and above), and post-fire management of lower elevation vegetation types dominated by creosotebush (*Larrea tridentata*) and saltbush (*Atriplex* spp.). In all future fire studies, the potential influence of climate change should be considered to place the results in the context of climate projections for the next decades through the end of the current century. (See Chapter 5 for a detailed discussion of information needs related to fire history, effects, and management in southern Nevada.)

Species of Conservation Concern

Aside from the desert tortoise (*Gopherus agassizii*), which has been studied more than any other species in southern Nevada, relatively little is known about the life history characteristics and specific habitat requirements of most species in this region (Chapter 6), including the species covered under the Clark County Multiple Species Habitat Conservation Plan. Research has often focused on mitigation strategies to protect sensitive species without a full understanding of the life history and ecophysiological constraints on the species and the stressors that are causing their declining status.

With so many unknowns associated with the many species of concern in southern Nevada, it is a challenge to prioritize which species should be the focus of scientific research and which questions should be addressed. The default is often to focus on species that agencies have specific legal requirements to protect (e.g., Federally listed). Development of effective conservation plans requires an understanding of the life history characteristics, habitat requirements, and specific stressors affecting the listed species. These plans may initially lack the desired level of detail. However, critical information needs can be identified in the planning process and new research projects coupled with habitat and population monitoring can be used to develop an effective adaptive management program. (See Chapter 6 for a detailed discussion of information needs related to species of conservation of concern in southern Nevada.)

Maintaining and Restoring Sustainable Ecosystems

The overarching objective for land managers in southern Nevada is to maintain and restore sustainable ecosystems that are resilient to disturbance and resistant to invasion (Chapter 7). The ecosystems types within southern Nevada differ significantly in both their environmental characteristics and dominant stressors and, consequently, in their resilience to disturbance and resistance to invasive species. In order for restoration and management strategies to be effective, they must account for these differences. A useful decision support framework based on ecosystem resilience and resistance distinguishes among: (1) protection from current and future stressors; (2) preventive management actions designed to increase resilience and resistance of areas with declining ecological conditions; and (3) restoration activities following disturbance or other ecosystem degradation (table 7.1). This framework allows for customized guidelines for each of the major ecosystems types in southern Nevada (table 7.2). An integrated and consistent assessment of southern Nevada ecosystems and their relative resilience and resistance can be used to prioritize management and restoration activities using this framework. Monitoring programs designed to track ecosystem changes in response to both stressors and management actions can be used to increase understanding of ecosystem resilience and resistance, realign restoration and management approaches, and implement adaptive management.

Cross-cutting information needs for restoration and management of southern Nevada's diverse ecosystems include a better understanding of the factors that determine resilience and resistance and of the interacting effects of the region's stressors. They also include knowledge of the environmental conditions required for establishment and persistence of native plant species and methods for their restoration. (See Chapter 7 for a detailed discussion of information needs related to maintaining and restoring sustainable ecosystems in southern Nevada.)

Human Interactions with the Environment through Time and Preserving Heritage Resources

Southern Nevada has been continuously inhabited by humans at least since the end of the last ice age (Chapter 8). This period marks the shift from a more mesic and temperate climate to the more arid desert climate that exists today. During most of the post ice age Holocene (i.e., the last 12,000 years), human occupation was characterized by small nomadic bands that migrated seasonally following resources needed for subsistence. During the last few thousand years, larger settlements emerged that were associated with a move towards more agricultural societies in the riverine bottomlands. The first Europeans travelled to southern Nevada in the late 1700s, and by the middle 1850s settlers were steadily migrating into the region along the Old Spanish Trail (later the Mormon Road) and displacing Native Americans from their agricultural, foraging, and hunting lands. Settlers also brought with them horses and livestock that were having significant effects on the landscape as early as the 1800s, and these stock animals have been continuously present through to the present (Chapter 2).

Population levels moved upward with the construction of Hoover Dam in the 1930s, but really increased substantially during the past few decades resulting in urban sprawl, increased development within public lands, and increased visitation to remote areas of southern Nevada (Chapter 9). This has resulted in the loss of cultural sites through development, looting, and vandalism. Public education, law enforcement, and monitoring of cultural sites are widely recognized as ways to minimize damage to these sites. However, agency resources are generally insufficient to address all of these needs.

The major remaining information gap is the limited extent of archeological survey coverage; only 7 percent of Southern Nevada has been surveyed, primarily within the Las Vegas Valley and associated with development projects (Chapter 8). A complete survey for the region is not realistic, but additional targeted surveys that expand and improve the sample of lands examined would go a long way towards improving the baseline information in the region. More comprehensive links between archeological sites and their environmental settings would increase understanding of potential interactions between humans and ecosystem conditions. Also, continued research is needed to evaluate the effectiveness of public education and outreach, volunteer site monitoring, and law enforcement programs in achieving the objectives of reducing damage to and loss of cultural sites. (See chapters 8 and 9 for a detailed discussion of information needs related to human interactions with the environment through time and preserving heritage resources in southern Nevada.)

Recreation Use on Federal Lands

The vast majority of lands are open to human use in southern Nevada. The burgeoning human population is increasing the use of these lands for recreational purposes, creating a very difficult challenge for Federal land managers (Chapter 10). Also, the human population is becoming more urban and multi-cultural, resulting in potential changes in recreational patterns that will require flexibility in current management approaches. To plan for these changes, land managers need information about how these changing demographics may affect the types and patterns of recreational use of public lands. (See Chapter 10 for a detailed discussion of information needs related to recreation use on federal lands in southern Nevada.)

The Role of Science in Land Management

Management that balances public need and ecosystem sustainability is informed by the science information in this Synthesis Report. The goal of ecosystem sustainability has its origins in legislation mentioned at the beginning of this chapter, and subsequent national policies that call for natural resources, and by inference to the ecosystem processes that sustain them, to be preserved unimpaired for future generations. However, land managers must balance the goal of ecosystem sustainability with other goals derived from other laws and national policies associated with recreation, resource extraction, and other land uses that collectively constitute the land management context of southern Nevada. Although science often plays a major role in the initial legislation and policy development and can form the foundation of initial planning goals and objectives, subsequent science produced through targeted research studies and monitoring for status and trend of resources has the greatest influence on deciding when a management response is warranted or when established management objectives may need to be modified (fig. 11.1).

Objectives should be written with specific science-based, objective, and measurable standards in mind. For example, allowing livestock grazing up to a limit of x percent vegetation biomass consumption based on a sliding scale that takes into account recent climatic conditions and other potential interacting stressors. Objective standards greatly simplify the process of monitoring and decision making because they are relatively unambiguous (fig. 11.1). The problem is that science is often insufficient to justify specific standards, and therefore standards are based on general scientific theory and are relatively subjective (for example, allowing grazing practices that do not negatively affect the health, productivity, and diversity of plant communities, which is subjective and hard to monitor). Subjective standards require more complicated monitoring and generally make decision making more difficult and controversial.

Once management plans are implemented, monitoring plans that are specifically coupled with management objectives can help land managers monitor the status and trend of their ecosystem resources and determine if management responses or modifications of management objectives are warranted (fig. 11.1). With the advent of the information age and ability to archive and share data remotely, there has been a move towards more standardized monitoring methods to facilitate large scale analyses across multiple land management agency units. However, these standard methods are often not ideally suited for evaluating management objectives that are designed for smaller

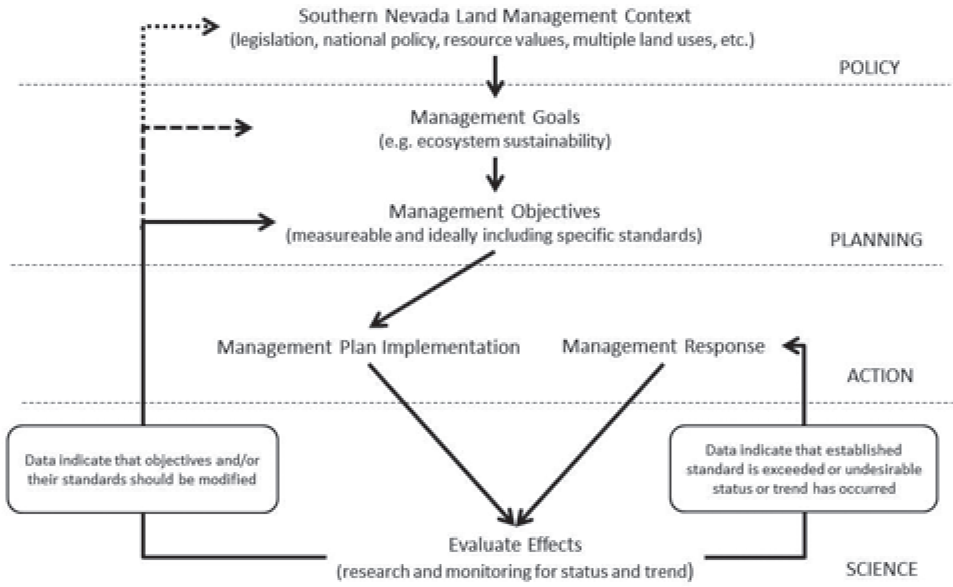

Figure 11.1–The role of science in the management of Federal lands in southern Nevada.

landscapes and their local land management contexts. Land managers must understand these potential limitations and choose their monitoring and data management methods carefully to ensure that they will give them the scientific information necessary to effectively evaluate their management objectives and management actions.

The Role of Science in Education

This Synthesis Report serves as an outreach document to inform stakeholders and the general public about the major ecosystem stressors, and natural, cultural, and recreational resources in southern Nevada. It also provides valuable information on management alternatives.

An educated populace makes it easier for land managers to communicate science-based management with the public and should ultimately streamline the approval processes for land management plans. As mentioned above, science information is often written by scientists for scientists and science products are often not ideal for communication with the general public. There is, therefore, a need for science-based objective summaries of key land management topics that clearly distinguish between what is scientifically known and what is more generally derived from professional opinion and cultural influences. The mode of information delivery should also be varied to capture a wide range of audiences (e.g. print, radio, television, websites, and social media).

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