Chapter 2

Ecosystem Stressors in Southern Nevada

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Introduction

Southern Nevada ecosystems and their associated resources are subject to a number of global and regional/local stressors that are affecting the sustainability of the region. Global stressors include elevated carbon dioxide (CO_2) concentrations and associated changes in temperature and precipitation patterns and amounts, solar radiation, and nutrient cycles (Smith and others 2009b). Global stressors are ubiquitous in nature and interact both directly and indirectly with regional or local stressors. Regional/local stressors in southern Nevada include: population growth and urbanization and associated increases in nitrogen deposition, energy development, water development, and recreation; increased effects of insects and disease; ongoing effects of livestock, wild horse and burro grazing; new and expanding invasive species; and altered fire regimes. 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 to restore, sustain, and enhance southern Nevada's ecosystems (Turner and others 2009).

Human population growth and changes in land use strongly affect the type and magnitude of local/regional stressors. From 1960 to 2010, Nevada's growth rate was the highest in the nation (www.census.gov/prod/cen2010/briefs/c2010br-01.pdf). Clark County has experienced particularly high growth, with a population increase of greater than 40 percent since the 2000 census. Factors like land ownership, historic and current land use, proximity to human and energy developments, and desirability for recreation all influence the level of human-caused stress.

The strong elevation/climate gradients and large differences in the environmental characteristics of southern Nevada ecosystems (fig. 1.2; Chapter 1) have a major influence on both patterns of land use and the dominant stressors for different ecosystem types. Shifts in land use related to population growth, urbanization, and energy development are largely focused in lower elevation ecosystems including sagebrush, blackbrush and shadscale, and Mojave Desert scrub. Water diversions influence riparian/aquatic ecosystems and springs, while groundwater pumping also has the potential to affect ecosystems that characterize lower valleys including Mojave Desert scrub. Recreational uses influence all ecosystems, and wild horse and burro use and livestock grazing affect all but alpine and subalpine ecosystems. Insects and disease, as well as invasive species are widespread stressors. Fire is limited to ecosystems with sufficient fuels to carry fire and is strongly influenced by invasive species in lower elevation Mojave Desert scrub, blackbrush and shadscale, and sagebrush ecosystems.

This chapter addresses aspects of several of the Goals and Sub-goals listed in the SNAP Science Research Strategy (table 1.3; Turner and others 2009). Altered fire regimes, invasive species, land use practices, and management actions are addressed in Goal 1—Sustain, Restore, and Enhance Southern Nevada's Ecosystems. The effects of these stressors on sensitive species and habitats are specifically addressed in Sub-goal 1.4—Sustain and Enhance Southern Nevada's Biotic Communities to Preserve Biodiversity and Maintain Viable Populations. Anthropogenic factors, such as recreation and urbanization, are referred to in 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.

Global Stressors

Climate Change and Elevated CO_2 Concentrations

Natural disturbance regimes of arid systems are characterized by resource pulses. Rainfall is infrequent and variable in amount, while fire and drought can temporarily increase available soil nitrogen (White and others 2006). Changes in the frequency and/or magnitude of these pulses associated with altered precipitation patterns may have profound effects on vegetation (Smith and others 2009a). For example, climate predictions include an increase in intense, short-duration rainfall events, which could temporarily increase plant productivity, facilitate plant invasions (Chapter 4), and episodically promote the spread of fire (Chapter 5). Similarly, enhanced levels of CO_2 may increase the rate and extent of invasive annual grass invasions, leading to unprecedented frequency in wildfires (Smith and others 2009b). Increasing levels of CO_2 are continuous and cumulative, representing a fundamentally different kind of stress from pulsed disturbance regimes (Smith and others 2009a; Stohlgren and others 2000).

Climate regimes are defined by patterns of both temperature and precipitation. Bioclimatic modeling has been used to estimate both the effects of climate change on the distribution of vegetation types, as well as to predict future distribution of individual species. Loarie and others (2009) predict shifts in plant community climate regimes based on temperature on the order of 1.26 km yr^{-1} (0.78 mi yr^{-1}) upward in elevation or latitude for desert systems. Work by Notaro and others (2012) project a region-wide decline in vegetation cover, a reduction in plant species richness in high-elevation evergreen forests, and a northward shift of the Sonoran Desert. Rehfeldt and others (2006) modeled current and projected climate profiles for 25 biotic communities of the western United States. Projections estimate that by the end of the century, 55 percent of western land area would not support present-day vegetation communities (as described by Brown and others 1998). Projections for individual species, however, do not necessarily follow those of the community as a whole. Consequently, community types (associations) that remain may not be comprised of the same species as are present today and may not have historical analogs (Williams and Jackson 2007). For example, arid shrublands may remain the same shrubland vegetation formation type but be comprised of different dominant species (vegetation alliances) or combinations of dominant and/or sub-dominant species (vegetation associations). Also, approximately half of the western United States, including most of southern Nevada, may have climate regimes not currently found there, likely resulting in completely novel community types (Rehfeldt and others 2006).

Atmospheric CO_2 increased approximately 32 percent during the last century (Wagner 2009), and is expected to double from today's levels by the end of the current century (Houghton and others 2001). This rise is predicted to affect ecosystems in two separate ways, through direct effects on plant physiology and indirect effects on the global climate (Smith and others 2009a). Increased concentrations of CO_2 have been shown to increase the rate of carbon assimilation by plants through photosynthesis, while decreasing water loss through transpiration (Smith and others 2009b and references therein). The net effect is one of increased water-use efficiency, potentially resulting in increased productivity of arid systems. However, potential gains in productivity will likely be mitigated by changes in climate. For example, plants are less responsive to elevated levels of CO_2 when soils are dry.

By far the most problematic effect of the rising atmospheric CO_2 concentration is its linkage to global warming and climate change. Over the last 150 years, average temperatures have risen globally in tandem with increasing CO_2 (Smith and others 2009a). Temperatures in the American Southwest are estimated to have risen 1.2-1.7 ^oC (2.2-3.1 ^oF) during the last century (Sprigg and others 2000), outpacing the global average. Data for Nevada show even greater warming, with temperatures having risen 2.0 ^oC (3.6 ^oF) since 1908 (Saunders and others 2008). Regional projections of climate change, based on general circulation models (GCMs), predict a further increase of 2-6 ^oC (3.6-10.8 ^oF) by the year 2100 (Saunders and others 2008; Wagner 2009). Moreover, nighttime temperatures have risen more than daytime maxima and will likely continue to do so (Wagner 2009). Nighttime temperatures limit the northern distribution of many warm-desert species (Beatley 1974; Pockman and Sperry 1997). Consequently, the potential range of these species is projected to expand northward (Smith and others 2009a). Temperature also influences snow pack accumulation, water storage, and the timing of spring runoff (Mote and others 2005).

Precipitation patterns also are influenced by rising levels of atmospheric CO_2 through changes in oceanic temperatures and global circulation patterns such as El Niño events. As global warming continues, longer and more intense droughts (Saunders and others 2008), and an increase in the frequency and intensity of extreme weather events (Archer and Predick 2008) are expected to occur throughout the West. Simulation model projections for the Mojave region vary, but many suggest reduced precipitation in general for the Southwest (Seager and others 2007; Wagner 2009). Other models predict an increase in El Niño events as well as increased summer precipitation (Smith and others 2009b). However, evapotranspiration will increase with increasing temperatures, likely resulting in overall drier conditions and an increase in the Palmer Drought Severity Index. In addition to expected changes in the amount and timing of precipitation, rising temperatures will likely decrease snowpack levels and increase the rate of snow-melt, resulting in lower mid-summer stream flows (McCabe and Wolock 2009). As of 2008, Lake Mead was only 50 percent full following consecutive years of below-average inflow (Saunders and others 2008). Continued 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

Nevada is currently the fastest growing state in the country. According to the 2010 U.S. Census, the population grew by 35 percent since 2000 and by 66 percent during the previous decade (1990-2000). In addition, Nevada is the only state that has maintained an average growth rate of 25 percent or greater over the last three decades, and is the fastest growing state for five straight decades (http://www.census.gov/prod/cen2010/briefs/c2010br-01.pdf). In southern Nevada, the population of Clark County in 2010 (1,951,269) was 42 percent higher than the 2000 census. The cities of Las Vegas, Henderson, and North Las Vegas have all posted impressive growth rates since 2000. Even the smaller, more rural communities of Mesquite, Pahrump, Overton, and Boulder City have had significant populations increases during this time frame (Chapter 10).

Rapid growth does not happen without significant impacts on the flora and fauna of native ecosystems. The vast majority of urban development has taken place in the Mojave Desert scrub ecosystem. Between 2001 and 2007, Clark County lost 56,512 acres of native ecosystems to urban development (Clark County 2008). Also, a significant amount of salt desert scrub located in Henderson/Green Valley and in northwest Las Vegas has been lost to urbanization (Burton Pendleton, personal observation of urbanization patterns since the 1960s in the Las Vegas Valley, Nevada).

The soil and vegetation disturbances taking place at the urban-desert interface and beyond constitute a major problem for public land managers. Issues created include dust generation, trash and materials dumping, off-road travel and resulting unauthorized roads, destruction of cultural resources, creation of dispersal corridors for invasive species, human-caused wildfires, and land degradation caused by uncontrolled recreation and ORV (off road vehicle) use. Vegetation communities at higher elevations are not as directly impacted by urbanization, but are impacted by recreational activities of the large urban population.

Nitrogen Deposition

Industrialization and urbanization have led to increased production of atmospheric nitrogen emanating from coal-fired power plants and vehicle exhaust along major highways and in metropolitan areas and deposited across broad regions downwind from their sources. Deposition levels near major cities like Las Vegas can be as high as 40 kg ha^{-1} yr^{-1} (35.2 lbs $acre^{-1}$ yr^{-1}; Smith and others 2009b). Levels away from metropolitan areas are on the order of 3-12 kg ha^{-1} yr^{-1} (2.6-10.6 $acre^{-1}$ yr^{-1}; Allen and others 2006). After water, productivity of desert systems is most limited by nitrogen. Increased levels of nitrogen may result in higher biomass production if accompanied by sufficient moisture. Invasive annual grasses are particularly responsive to increased levels of nitrogen. Allen and others (2006), working at Joshua Tree National Park, reported increased biomass of invasive grasses following even low levels of N-fertilization and theorized that continued N-deposition could cause a community shift from shrubland to one dominated by invasive grasses. Brooks (2003) also found increased biomass of invasive grasses following N-fertilization in a Mojave Desert ecosystem. Increased levels of soil N are also expected to alter nutrient cycling, but little empirical data are available to evaluate this potential effect.

Urbanization and human-caused disturbances also affect air quality in southern Nevada. Dust and other pollutants from energy development, housing development, and recreation result in increases in particulate matter. Of particular concern to humans and wildlife are particles smaller than 10 micrometers in diameter (PM-10). Particles of this size, when breathed into the lungs, can cause serious health effects (http://epa.gov/air/particlepollution/basic.html). In southern Nevada, most particulate emissions come from wildfires and windblown dust. A study by the Desert Research Institute found that windblown dust accounted for 89-90 percent of the PM-10 occurring in Clark County (http://www.clarkcountynv.gov). Control measures currently being implemented are expected to offset increases in vehicular and construction project dust emissions that accompany population growth.

Energy Development

There is an almost universal consensus among the international scientific community that greenhouse gas emissions must be reduced in order to slow the rate of global warming (Abbasi and Abbasi 2010; Dincer 2000). As fossil fuel costs and the impact of their use have become more readily apparent, there has been increased industry investment and government support for the development of renewable energy sources (Kunz and others 2007). Southern Nevada has been the focus of many recent renewable energy projects, partially due to the abundance of sun and wind needed as energy sources for the generation of electricity.

Solar Energy—The arid Southwest contains a large amount of Federal lands that receive significant amounts of solar radiation, and the majority of large-scale solar facilities in the United States are slated for development on these lands. All energy development requires water, and the amount varies with the type of energy facility (Sovacool and Sovacool 2009). There are two types of utility-scale solar energy developments: solar voltaic and concentrating solar. Solar voltaic facilities require minimal water use (3.8-7.6 liters or 1-2 gallons per MWh_e). In contrast, concentrating solar facilities concentrate solar energy to generate steam for power production and require 2,850 liters (750 gallons) of water per MWh_e (Pate and others 2007), an amount four times as much as a natural gas-fueled power plant and twice as much as a coal-fired or nuclear plant (Glennon 2009). Two new solar facilities slated for construction on BLM land in southern Nevada were approved in fall of 2010 (BLM 2011a). The Amargosa Farm Road Solar Project, a concentrating solar facility, will occupy 2,558 ha (6,320 acres) just east of Amargosa, Nevada, and will consume significantly more water resources than existing photovoltaic systems operating in southern Nevada. Construction of the Silver State North Project is almost complete and occupies 250 ha (618 acres) east of Primm, Nevada. Both are located in Mojave Desert scrub. An additional project, Silver State South, is undergoing environmental analysis with a decision anticipated in 2012. Both Silver State Projects use photovoltaic technology.

Boulder City has developed a 3,200-ha (8,000-acre) solar energy zone in Eldorado Valley, an area southwest of the town but within the city limits. The largest two operational utility scale solar facilities in southern Nevada are located in this zone (Acciona Solar's Solar One concentrated solar facility and Sempra Generation's Copper Mountain photovoltaic solar facility). Additional facilities are planned for this area (BLM 2011a). Grouping all of the solar facilities in one area creates a larger impact locally, but reduces energy sprawl, fragmentation of habitat, and impacts from transmission lines and service roads on a landscape level. The BLM is examining a similar approach and is coordinating public input in an effort to determine appropriate areas to locate solar energy zones (BLM 2011a). An updated list of operational and proposed alternative energy facilities in Nevada is located under alternative energy on the BLM website (www.blm.gov/nv). While new solar facilities produce far fewer CO_2 emissions than traditional power plants, their construction and operation are not without environmental impacts. These facilities also can use tremendous amounts of already limited groundwater. The Nation's limited experience with large-scale solar facilities means that there is little on-the-ground understanding of potential impacts (McDonald and others 2009; Tsoutsos and others 2005; Turner 1982). Attention during the planning, construction and operational phases could help to minimize the potential environmental impacts listed below (Tsoutsos and others 2005).

- Facilities must be kept free of vegetation for worker safety and to prevent the possibility of heat-induced wildfires. This results in large areas devoid of vegetation.
- Dust emissions from construction, resulting in un-vegetated areas, and roads will likely increase, even though chemical dust-control agents may reduce the total amount generated. Little is known regarding potential off-site movement of chemical dust-control agents or their effect on surrounding vegetation.

- The impact of solar energy development on wildlife has not been well studied. Effects on migration corridors and genetic linkages, as well as effects on resident species are largely unknown (USGS 2010).
- Maintenance roads may serve as corridors for dispersal of invasive plant species, increased unsupervised recreational uses, and augmented food supply for ravens.

Wind Energy—Wind energy is increasingly important as a means of alternative energy production. As with solar installations, new and much larger wind farms are planned or under development. For example, the Searchlight Wind facility is planned for 780 acres of BLM land east of Searchlight, Nevada, and if approved, would include 89 wind turbines and a substation (draft EIS not yet released).

The technology to develop energy from wind on a large scale is a more mature technology than that of large-scale solar development. However, our understanding of potential ecosystem impacts of proposed large-scale wind farms in southern Nevada is severely lacking (Drewitt and Langston 2006). Studies on the effects on wildlife are particularly lacking (Lovich and Ennen 2011). Habitat types most likely affected by wind energy production in southern Nevada are Mojave Desert scrub and adjacent sparsely vegetated rocky foothill habitats. As with fossil fuel production, impacts on wildlife from wind turbines will largely come from habitat fragmentation, wildlife avoidance behavior, and bird and bat mortality, rather than from direct effects from installation (McDonald and others 2009). Recent monitoring studies indicate large numbers of bat fatalities associated with wind energy facilities (Kunz and others 2007). Potential effects on birds, including raptors and eagles, are collision mortality, displacement due to disturbance, alteration or loss of migration flyways and local flight paths, and habitat change or loss (Drewitt and Langston 2006). To date, there have not been multi-region studies of bat and bird deaths related to wind power generation.

Water Development

Water is a very critical resource in the southwest, and in southern Nevada. The municipal and county water districts in southern Nevada united to form the Southern Nevada Water Authority (SNWA) in 1991, with the goal of managing existing water resources, developing new ones, and promoting conservation (SNWA 2009). 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 (Cohen 2011). Ongoing drought conditions have reduced the amount of flow into Lake Mead, reducing the amount of stored water to 52 percent of capacity by early 2009 (SNWA 2009). Since then, the water level of Lake Mead has continued to fall and was at 51.22 percent of a full pool on October 30, 2012 (http://lakemead.water-data.com). Climate change is expected to further deplete reservoirs due to decreased streamflow and increased evaporation rates. Based on current and projected demands, a long-term non-Colorado River water supply is needed.

The Water Resource Plan projects the need for additional groundwater resources to be brought on-line by 2020 (SNWA 2009). This has prompted the SNWA to seek further development of in-state groundwater resources, including applications to the BLM to construct a 525-km (326-mile) pipeline and drill additional groundwater wells to extract approximately 217 billion liters (57 billion gallons) of water per year from north-eastern central Nevada. The application and approval process for developing and transporting this water began in 2003. The aquifers in question are deep and extend across state lines. There are questions as to what effect groundwater pumping to provide additional water to southern Nevada will have on wells that service central Nevada and western Utah, as well as effects to surface vegetation and the wildlife that depend on this resource. Groundwater development studies are underway. The 90-day review of the draft is scheduled to be completed by spring 2013. Date for the final EIS publication has not yet been determined (BLM 2011b). In 1997, the SNWA developed the Las Vegas Valley Groundwater Management Program to protect and manage groundwater resources. Activities include development of a permanent recharge program, plugging unused wells in the valley, conservation education and increased groundwater quality monitoring. Conservation and management activities have led to a reduction in per capita water use. Between 1990 and 2008, use declined from 1,317 to 912 liters (348 to 241 gallons) per capita per day (Cohen 2011). The SNWA has adopted a goal of 753 liters (199 gallons) per capita per day by 2,035, a 17 percent decrease, yet total water usage is still projected to increase some 40 percent by that date due to population growth (SNWA 2009).

Colorado River basin water, utilized by much of the southwest, is not adequate to support increased regional populations, especially during a period of increased temperature and more frequent drought. This will put pressure on other water resources, including aquifers that support southern Nevada springs. There are three classes of aquifers in the SNAP area, mountain block, local, and regional. The three are not equally affected by ground water pumping, but all are affected by a number of above-ground stressors. The Clark County, Nevada, MSHCP Ecosystem Health Workshop, sponsored by the Desert Research Institute, was held January 29-31, 2008, in Las Vegas. Workshop participants developed a list of stressors based on previous research, past workshops, and the combined experience of the managers and researchers in attendance (Sada 2008). Most important stressors by aquifer type are given below.

- Mountain block aquifers: freezing, periodic drying from drought, low seasonal flow, avalanche, fire, and compaction and trampling by animal and human activity.
- Local aquifers: trampling and compaction by human activity and animals, water diversion, human recreational activity, and ground water removal.
- Regional aquifers: agricultural activities, pesticide contamination, water diversion, ground water pumping, grazing, and non-native aquatic species.

Work by a number of scientists in the last decade has been synthesized by Sada (2008) into a comprehensive system for prioritizing the management and restoration of Nevada springs. The Forest Service is currently developing a similar program (Solem and others 2012).

In 2010, the Spring Mountains National Recreation Area, Humboldt-Toiyabe National Forest, initiated a comprehensive Level II survey of the springs in the SMNRA. Forty-seven springs were surveyed in 2010 and 2011. This work identified over 25 types of disturbance, all of which stress the system. The most common disturbances, those found at a minimum of 30 percent of the springs sampled, consisted of:

- Soil compaction, including animal and human trails, trampling, and other ground disturbance;
- Erosion around springs and water channels;
- Large mammal disturbance from grazing (cattle are absent from the SMNRA), hoof disturbance (horses and elk), and other wild animal disturbance; and
- Water extraction effects on water availability.

There were a number of other disturbances that occurred at over 15 percent of the springs sampled, including fire, vehicle tracks, tree cutting, and flooding. The complete results are reported in Solem and others (2012).

The Mojave Inventory and Monitoring Network of the National Park Service is also beginning to monitor springs on Park Service land within the SNAP area. This work will also document stressors as more springs are sampled.

Recreation

The emergence of Las Vegas as a metropolitan area created significant needs for public lands to meet public uses. As the population in southern Nevada continues to grow, so too will the use of public lands, especially for recreation. Meeting recreational needs of both citizens and visitors to the area must be balanced with maintaining natural and cultural resources, conserving the unique biodiversity of southern Nevada's ecosystems, and maintaining the very qualities that are attractive for recreation. The majority of southern Nevada's population is concentrated in the major cities of Las Vegas, North Las Vegas, Henderson, Mesquite, Overton, Pahrump, and Boulder City. Public lands near these cities, such as the Spring Mountains and Lake Mead National Recreation Areas, and the urban/desert interface experience intense use.

According to the SNAP Recreation Team report, the most popular recreation activities are hiking, camping, viewing natural features and wildlife, and rock climbing (Holland and others 2010). Popular water activities are swimming, fishing, and boating (NPS 2009). Unregulated ATV (all-terrain vehicle) and ORV (off road vehicle) use are also favorite desert activities. A more complete review of southern Nevada's recreational opportunities is given in Chapter 10.

Population growth and accompanying increases in use of public lands for recreation puts added strain on Nevada's natural and cultural resources. The impacts of unrestricted use can be considerable, but determination of sustainable use levels is problematic, particularly under a changing climate. Insufficient funds for adequate management, staffing, and educational programs compound the problem. The most cost-efficient means of mitigating environmental damage are two-fold: the development and implementation of sound management plans and public education. For example, the BLM develops Recreation Area Management Plans (RAMPs) that identify goals and actions for recreation in designated areas. The Nevada Division of State Parks regularly updates its Comprehensive Outdoor Recreation Plan (DeLoney 2004). Public involvement helps to identify facility, infrastructure, and interpretive needs to accommodate the ever-increasing use levels. The difficulty is in providing reasonable access while still protecting cultural and natural resources. Problems accompanying recreational use include:

- Erosion from trail cutting;
- Human waste and trash from camping in undesignated areas;
- Declines in wildlife populations due to habitat fragmentation and avoidance behavior;
- Dispersal of invasive species;
- Land degradation due to off-road vehicle use and unrestricted camping; and
- Competition for scarce water resources.

Of major concern is rampant degradation from unrestricted camping and ORV use, particularly in Mojave Desert scrub. The BLM, NPS, FWS, and USFS all consider this issue of high importance (see Chapter 10). Programs are needed to educate those who consider the desert areas to be 'wasteland' of no particular value. Although ORV use is restricted to existing roads and trails in many areas, and existing roads, trails, and dry washes in some areas with specific regional restrictions), illegal ORV use occurs and damages vegetation and destroys biological soil crusts that hold the soil in place. Disturbing desert soils generates dust, reducing visibility and creating health problems.

Additionally, ORV use causes erosion, disperses invasive species, and fragments habitat for wildlife.

Public education and outreach programs are instrumental in teaching visitors about the importance and fragility of the desert environment. Most recreationists care about the environment and understand the need to balance recreation with resource conservation (DeLoney 2004). Given sufficient information, most will observe good visitor practices. For those that don't, additional monitoring and mitigation, as well as enforcement of regulations, are needed.

Insects and Disease

Insect and disease issues are not currently among the primary concerns of land managers in southern Nevada. The presence of pneumonia in Nevada populations of Desert bighorn sheep (*Ovis canadensis nelsoni*) was first reported in 1978 (McQuivey 1978). The disease appears to affect both native and domestic sheep, though not to the same extent. Stress from blowing dust and human proximity may aggravate the symptoms (Jessop 1981). Chronic wasting disease in deer and white nose syndrome in bats have the potential to occur in southern Nevada, but have not been detected within the state. Upper respiratory tract disease in the desert tortoise (*Gopherus agassizii*) is one of several factors contributing to the population decline of this threatened species. Issues associated with the decline and recovery of the desert tortoise are discussed in Chapter 6. Mistletoe and rust diseases affect conifer species in mountain areas, with white fir being the hardest hit (Guyon and Munson 1998). White-spored gall rust, found only in the Spring Mountains, affects the ponderosa pine growing there, complicating management of that species (Guyon and Munson 1998). Bark beetles cause the most insect damage, affecting bristlecone pine (*Pinus longaeva*), singleleaf piñon pine (*Pinus monophylla*), twoneedle pine (*Pinus edulis)*, ponderosa pine (*Pinus ponderosa*), and white fir (*Abies concolor*). In 2009, the Humboldt-Toiyabe National Forest conducted an aerial survey of bark beetle damage. Of the over 80,000 ha (200,000 acres) surveyed, tree mortality from mountain pine beetles occurred on 47 ha (117 acres), from western pine beetles on 5 ha (13) acres, and from piñon ips beetle on 1.6 ha (4 acres). Tree mortality from the fir engraver beetle decreased from 184 ha (461 acres) in 2007 to only 4.8 ha (12 acres) in 2009 (USFS 2009). The Humboldt-Toiyabe Aerial Insect Disease Detection Survey of 2011 (http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5349313.pdfcitation) also found a limited number of trees with indications of insect damage. Less than 210 ponderosa pines in 15 locations exhibited signs of bark beetle damage. Less than 30 true firs at two locations were damaged by fir engraver beetles. Given the large forested area of the SMNRA, these numbers did not indicate a significant insect problem in early 2011. However, during the fall of 2011, SMNRA and I&M staff noted a large number of newly infected trees within the Kyle and Lee fuel treatment areas. The extent of this beetle outbreak should be quantified during the 2012 Aerial Insect Disease Detection Survey.

In all cases, mortality increases when trees are under stress, particularly drought stress. Projected increases in temperature may allow more beetles to overwinter or complete two life cycles in one year (Lange and others 2006; Raffa and others 2008). High temperatures and prolonged drought conditions will create conditions under which outbreaks are more likely to occur. Bark beetle and rust in conifers are of greatest concern in the Spring Mountains as plant communities migrate up in elevation. Conifer communities of the future may contain species not currently found together, putting disease vectors or insect pests into new context. Plants and pathogens that have been previously separated by distance may come into contact (Flores 2008). The potential for large-scale die-offs of key species and the consequences for ecosystems can be illustrated by the recent widespread mortality of two needle piñon. In 2002-2003, 40-80 percent of piñons in a four-state region died following prolonged drought and unusually high temperatures (Breshears and others 2009). Mortality was apparently driven by protracted water stress, leading to carbon starvation and an associated increase in susceptibility to beetles (Breshears and others 2009). Regional mortality of key species has the potential to rapidly alter vegetation composition and associated ecosystem properties for decades.

Grazing

The Mojave Desert has not supported large numbers of native grazing animals since horses and other ungulates became extinct at the end of the Pleistocene, approximately 10,000 to 14,000 years before present (Grayson 1993; Thorne 1986). Horses first reappeared in North America as domesticated European stock with the second voyage of Christopher Columbus in 1493, and introductions continued in earnest throughout the Spanish colonial period through the 1700s (De Steiguer 2011). Cattle and sheep were also introduced during the same time period. At the beginning of the 1800s, bands of free roaming horses associated with the Spanish missions and rancheros in California had grown so large that efforts were initiated to reduce their numbers to protect forage for the emerging livestock industry. Western explorers, such as Lewis and Clark and Jedediah Smith, noted many bands of wild horses during the first decades of the 1800s, although their sightings were mostly from the northern Great Plains and Intermountain West. Thus, it appears that horses and livestock have likely been present in western North America for at least the past 200 years, although their historical abundance in the Mojave Desert is less well documented.

It is generally agreed that present day Mojave ecosystems did not evolve with significantly selective pressure from large-bodied herbivores (Beever and others 2003; Brown and McDonald 1995; Grayson 1987; Hall 1946), and desert vegetation is very slow to recover if overgrazed or disturbed (Abella and others 2007; Tueller 1989). Grazing, regardless of source, produces impacts on the ecosystems within the SNAP agencies' boundaries, and the greater the number of animals, the more extensive the impacts. Some disturbance impacts are common to all grazers, while others are unique to the particular grazer. These impacts are not uniform in their severity or in associated recovery times. The most significant impacts of both past and present grazing within the SNAP agencies' boundaries are disruption of soil crusts, alteration of carbon and nitrogen cycles, soil compaction, changes in vegetation cover and composition, reduction in soil seed banks, and disturbance of soil around springs (Beever and others 2003). Springs are particularly susceptible to disturbance effects. A more detailed discussion of these issues is contained in the following sections.

Livestock—Currently, livestock (cattle and sheep) grazing in the SNAP area is extremely limited and stocking rates on the few remaining allotments are well below allowable numbers. Few long-term impacts would be expected from the limited grazing occurring under current permits. No grazing is allowed in critical desert tortoise habitat (USFWS 2011). However, trespass grazing continues to be a problem in some areas (Fred Edwards, personal communication).

Despite the limited amount of grazing currently allowable, the area does carry a legacy of effects from past grazing practices when large numbers of cattle and sheep were introduced into southern Nevada. Determination of the effects of past grazing history in the Mojave can be difficult. Very few areas of truly ungrazed land exist; most areas have been extensively grazed in the past and records are either incomplete or nonexistent (Beever and Brussard 2000). Protected areas, such as military bases, can provide a reference frame for assessing the effects of historic grazing (Tueller 1989).

Historic photos and records also provide some context. Exclosures can be used to monitor recovery (e.g. Brooks 1995; Courtois and others 2004), but carry the legacy of past grazing, limiting their usefulness (Fleishchner 1994). Although most researchers agree that grazing negatively impacts desert ecosystems, there is some disagreement as to the level of these impacts (Brown and McDonald 1995 and references therein; Courtois and others 2004). This may be attributed, at least in part, to the reference community used by each author. For example, not all southwestern deserts are the same ecologically as the Mojave, and there are even subtle differences within sections of the Mojave. Also, impacts vary depending on grazing intensity (Brown and McDonald 1995).

Although the large-scale effects of grazing are typically of greatest concern, available information about livestock grazing in the Mojave Desert is in relation to localized effects (Brooks and others 2006). Grazing affects composition and production of the vegetative plant community through selective foraging. For example, at the Nevada Test Site, where grazing has been excluded for over 50 years, the blackbrush community has a healthy understory of desert needlegrass (*Stipa speciosa*) that is lacking in blackbrush sites that have been grazed (Tueller 1989). An early study by Webb and Stielstra (1979) described deteriorating range conditions due to sheep grazing, including a 60 percent reduction in understory herbaceous biomass and disruption of the soil surface. Brooks (1995) also reported increased forb biomass, shrub cover, and seed biomass following 12-14 years of livestock exclusion at the Desert Tortoise Research Natural Area. Densities of small mammals, lizards, and insects can also be affected (Fleischner 1994 and references therein; Brooks 1995).

Water sites are centers of grazing activity and are typically completely denuded of vegetation and have highly compacted and eroded soils. The effects beyond this high impact zone can extend hundreds of meters into the surrounding desert in roughly concentric gradients of impact referred to as a piosphere. In the west-central Mojave Desert, cover of invasive annual plants was shown to increase with proximity to watering sites, whereas cover and species richness of native annual and perennial plants decreased (Brooks and others 2006). Effects were most pronounced within 200 m of the watering sites, suggesting that control of invasive annual plants and restoration of native plants should be focused within the central part of the piosphere. A similar study was conducted to evaluate effects of piospheres on ant communities in the eastern Mojave Desert, but other than finding that total ant abundance was higher immediately at the high impact zone within the watering site, no gradient away from those sites was detected (Nash and others 2004).

A significant and long-lasting effect of grazing comes from soil compactions and disruption of the cryptobiotic soil crust, leading to erosion and disruption of nitrogen and carbon cycles. Biological soil crusts, present on desert soils, contribute to soil stability, nitrogen fixation, and water-holding capacity. These crusts are extremely susceptible to surface disturbance, including trampling by livestock. The recovery rate from disturbance, trampling, and compaction is long and can exceed 100 years (Belnap and Lange 2003).

Given changes in vegetative cover as described above, concurrent loss of seed banks (Brooks 1995), the advent of invasive weeds (Abella 2008), and accompanying fires (Brooks and Chambers 2011), these systems may have passed a threshold such that recovery to a pre-settlement condition is impossible, no matter how long grazing is excluded (Tueller 1989).

Wild Horses and Burros—There are five active wild horse and burro herd management areas (HMAs) in the BLM Southern Nevada District (BLM 2012). Muddy Mountain and Gold Butte HMAs have burros only, the Nevada Wild Horse Range has horses only, and the Johnnie and Red Rock HMAs have both horses and burros. The Muddy Mountain and Gold Butte HMAs, managed by the BLM, are adjacent to Lake Mead NRA, and the Wild Horse and Burro Protection Act does not apply to lands managed by the National Park Service (NPS). The NPS does not recognize HMAs and sets management prescriptions for minimal burro use on NPS lands. The NPS recognizes, however, that a certain amount of incidental use occurs from adjacent HMAs, and coordinates with the BLM on joint activities for burro management on NPS lands under the 1995 Lake Mead Burro Management Plan. The Nevada Wild Horse Range lies within the Nellis Air Force Test and Training Range, but is administered by the Las Vegas BLM Pahrump Field Office.

On BLM and USFS public lands, wild horses and burros are managed as self-sustaining populations of healthy animals with the goal of maintaining a balance with other multiple uses, including providing critical habitat for focal, threatened, and endangered species This is also called minimal management since resources are not added to the HMA in order to maintain a herd (Wild Horse and Burro Act of 1971). The issue in southern Nevada is not one of maintaining herds but rather herd overpopulation. Wild horses and burros have very high reproductive rates of 17-20 percent per year, and herds can double in size every 4 to 5 years. West-wide, as of February 2012, the BLM estimated wild horse and burro numbers at 37,300 (BLM 2012), nearly 11,000 more than the existing appropriate management level (AML). Funding for gathers (roundups) must be appropriated by Congress. Insufficient funding means that horse and burro numbers multiply beyond appropriate management levels. Also, public opinion generally runs against wild horse gathers, generating negative publicity (Resource Concepts, Inc. 2001). In a relatively new effort to control horse numbers, on March 3, 2011, the BLM announced the initiation of a 4-year study of the birth control vaccine PZP to test if the effects of the vaccine can be extended from 22 months to 3 to 4 years (BLM 2011c).

Although wild horses and burros are managed as a part of the cultural landscape, they can also have impacts that may threaten other resources. Their status as non-native species, and their potential to impact native natural resources, could lead to them being considered invasive species (Chapter 4). Wild horses and burros primarily consume herbaceous vegetation and some parts of woody vegetation in a wide variety of vegetation types in the Mojave Desert (Abella 2008), with use in southern Nevada concentrating at springs/seeps in the SMNRA. Their means of foraging differs from that of domestic livestock in a number of ways. Horses and burros are less selective in diet than domestic cattle, consuming a broad spectrum of plant species (Beever and others 2003). They are able to crop forage much closer to the ground than cattle due to the presence of upper front incisors (Beever and others 2003). Their use of lower quality forage may result in the consumption of 20-65 percent more forage than a cow of similar body mass (Hanley 1982; Menard and others 2002). Excessive use of grasses and forbs decreases the regeneration capability of these plants, resulting in decreased forage availability in successive years. Effects are concentrated at watering sites, decreasing vegetative cover by up to 90 percent and species richness by 70 percent (Beever and Brussard 2000; Beever and others 2008).

Wild horses and burros also differ in the amount of territory covered, often roaming over large areas (Abella 2008; Beever and Brussard 2000). Horses are known to roam farther from water than cattle, utilizing ridge tops and steeper slopes and making conspicuous trails (Beever and Brussard 2000). Beever and others (2003) found that several disturbance-related variables, including soil surface hardness and total plant cover, distinguished horse-occupied and non-occupied sites better than presence of palatable plant species. Ground disturbance caused by trampling, particularly in areas surrounding sensitive springs and seeps, creates conditions favorable to invasive species such as cheatgrass or red brome, or noxious weeds such as knapweed or perennial pepperweed. These weedy species out-compete native species and alter ecosystem function (BLM 2012; Cummings 2010; ENTRIX, Inc. 2008).

Non-native ungulates affect ecosystems in other ways as well, including nutrient cycling (Hobbs 1996) and diversity of small mammals and reptiles (Beever and Brussard 2004). The lack of time for ecosystems, particularly springs, to recover from the high pre-gather herd numbers is also of concern.

Wild horse and burro management is a difficult challenge and will likely be made more difficult in coming years. An examination of multiple climate change models for the southwest reveals almost universal agreement that the area managed by SNAP agencies will be warmer and dryer in the coming decades. Longer periods of drought are also predicted (Notaro and others 2012). In the context of these drying and warming trends, managers must address two relatively recent phenomenon that significantly impact the resources available for wild horse and burro herds: an increase in the biomass of exotic annual grasses and the accompanying changes in the size and frequency of wildfires.

Elk—Elk were introduced to the Spring Mountains beginning in the 1930s, with subsequent releases in the 1980s. Elk are found at higher elevations in piñon-juniper, mixed conifer, and bristlecone pine vegetation types. They prefer grasses and forbs, which are common on burned areas. Elk create trampled areas around springs and seeps, which are home to a number of rare species. Elk-created disturbance, therefore, has the potential to impact rare snails, moonworts, and other rare species (Solem and others 2011). Elk populations within the SMNRA were estimated at 246 in 1996, but subsequently declined to 130 in 2009. Reasons cited for the decline include increased recreational and off-road vehicle (ORV) use within the herd unit area, habitat degradation caused by excessive numbers of horses and burros, and extended periods of drought (Nevada Department of Wildlife 2011). An aerial survey conducted in 2010 reported sighting only 122 elk. The level of reproduction currently appears insufficient to sustain the population.

Invasive Species

Invasive Plants—Non-native invasive plants often produce large numbers of seeds that can spread rapidly across the landscape along road corridors, in contaminated animal feed, and by wind, animal, and human dispersal (Chapter 4). Invasive plants out-compete native species due to an ability to thrive on many different soil types and to utilize increased CO_2 and higher nitrogen levels that result from nitrogen deposition (Allen and others 2006; Ziska and others 2003). 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 (Chapter 5). Many invasive plants respond positively and quickly after fire, limiting the recovery of the native community (Abella 2009). In addition, invasive species can alter wildlife habitat and decrease native forage species (Brooks and Pyke 2001; Chapter 4). Restoration of communities dominated by invasives is difficult and costly. In the Mojave, management of invasive plants and fire must be integrated due to the linkages between the two issues (Brooks and Pyke 2001).

Wetland and Aquatic Invasives—The problem of wetland and aquatic invasive species is on the rise in southern Nevada (Chapter 4). Saltcedar (*Tamarix* spp.) and other riparian weeds alter streambanks and lower water tables, reducing the biodiversity of critical wetland communities (Sada 2008; Howell 2011). The release of nonnative fish into springs, quagga mussels (*Dreissena rostriformis*) into lakes, and nonnative bullfrogs (*Lithobates catesbeianus*) and crayfish (*Procambaras clarkia*) into lakes, rivers, and springs are impacting the native and endemic fish, amphibians, and snail species (Sada 2008). Removal of these problematic nonnatives is often not possible, and always extremely difficult and expensive (Chapter 4).

Altered Fire Regimes

Altered fire regimes are a significant cause of concern to managers in southern Nevada. In 2005, over 400,000 ha (1 million acres) of the Mojave Desert burned, much of it in southern Nevada (Brooks and Matchett 2006; McKinley and others, in press). The introduction of non-native invasive grasses has provided the fine fuel biomass needed to carry fire across large areas of Mojave Desert scrub, including blackbrush and Joshua tree communities. The size and frequency of these wildfires are a function of precipitation and the resulting annual invasive grass fuel load. Years of high winter and spring precipitation result in a flush of invasive annual grass biomass. The shrub communities of the Mojave Desert are generally not well adapted to large-scale fire (Chapter 5). Some species, such as blackbrush, do not form a persistent seedbank (Meyer and Pendleton 2005), requiring seeds to disperse from unburned patches of surviving individuals and hindering their recovery following fires. Only a small proportion of shrub species are physiologically able to resprout following fire, and their ability to resprout is further affected by fire temperature, soil moisture levels prior to fire, and post-fire drought (Brooks and Minnich 2006; Chapter 5). In contrast to native shrubs, invasive annual grasses can more easily survive fires as seeds, especially when they are lying on the surface of the mineral soil with little to no fuels immediately adjacent to them. The post-fire shrub community is less diverse with increased fine fuel loads that are prone to more frequent fire, and thus can reset the fire cycle outside of the timeframe under which these communities evolved.

Several factors complicate post-fire revegetation efforts. Aerial seeding has had limited success, in part due to the variability and timing of precipitation (Brooks and Klinger 2012; Chapters 5 and 7). Native seed is often not available as needed for large-scale restoration projects or may be cost-prohibitive. Post-fire reduction in the number of small mammals and other species that disperse seeds also inhibits natural reestablishment of pre-fire shrub communities (Beatley 1976). Thus, restoration of the post-fire landscape is problematic. Seeding success is species and situational specific (Abella and Newton 2009). Research on both the establishment needs of desert restoration species and techniques/equipment for planting and seeding is sorely needed. A comprehensive review of Mojave Desert restoration and rehabilitation is discussed in Chapter 7.

Suppression of naturally occurring fires at upper elevations also has created a problem for land managers. Some of the high elevation ecosystem types within the southern Nevada mountain ranges are fire-adapted (Provencher 2008; Chapters 5 and 7), and have been affected by fire exclusion. Fire suppression efforts have been particularly aggressive in the Spring Mountains because of the number of residences located within the canyons. Fire within steep canyons can pose a significant danger to residents as there is typically only one egress route down-slope. A hazardous fuels reduction project was proposed in 2007 to reduce fuels adjacent to the Spring Mountain communities and to facilitate the protection of important resource values. The fuels reduction project was conducted from 2008 through 2010. An implementation and monitoring audit conducted in the fall of 2010 looked at how closely the objectives were achieved. The recommendations will be useful in implementing the 10-Year Multiagency Fuel Treatment Plan, which was completed in 2010 (METI 2010). Under this plan, six areas of the SMNRA have been identified for future fuel treatment projects. The objectives for future projects include (1) coordinate treatment of right of ways and private facilities; (2) improve egress for residents, visitors, and staff and ingress for fire crews and equipment; (3) slow or prevent the spread of fires ignited along roadways; and (4) reduce the fuel loads in chaparral and mesquite so that fire can be reintroduced as a management tool (METI 2010). Understanding fire's history and behavior in the region under different conditions would help managers effectively and efficiently manage future wildland fires and provide insight regarding the role of fire within upper-elevation communities. See Chapter 5 for a more complete discussion of fire issues and Chapter 7 for restoration associated issues.

Knowledge Gaps and Management Implications

Southern Nevada is experiencing both a novel suite of stressors and a historically unprecedented rate of climate change. With the introduction of new stressors, rapid climate change, and increased frequency and size of disturbances, the interactions among all of these stressors will drive ecosystem change in potentially unknown directions. Managers are faced with situations for which we have no current answers.

- What can be done to control the new and existing invasive species?
- How should we manage fire size and frequency?
- Where should we try revegetation and what plant materials do we use given estimates of species migration due to climate change?
- How will human impacts on water use, recreation, and energy development affect regional ecosystem stability?
- How can we prevent the loss of endemic species that have specific habitat requirements such as desert springs and "Sky Islands" in the Spring and Sheep Mountains?
- Are species resilient enough, genetically variable enough, or are their specialized habitats protected enough for them to persist in place?
- Do they have life history features that will enable them to move with changing conditions?

These questions embody some of the big issues facing managers and provide a general overview of knowledge gaps. Gaps are discussed in more detail in subsequent chapters. Additional information needs that can be obtained through research and monitoring 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.

Development of education programs has the potential to mitigate many of the stressors caused by human activity. Education can point out rather simple and strait forward approaches that can minimize human impacts on the desert, while still permitting the recreational activities citizens enjoy. Educational outreach to teach citizens the economic and ecological value of energy efficiency and conservation is a step toward reducing the sprawl of energy developments in the western United States. Educational approaches in which the benefits of behavior changes are placed in an ecological context—for example, how the pieces, including humans, fit together to form the ecosystem—can instill a better sense of stewardship and a more developed conservation ethic.

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