

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

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### Introduction

Species conservation has traditionally been based on individual species within the context of their requisite habitat, which is generally defined as the communities and ecosystems deemed necessary for their persistence. Conservation decisions are hampered by the fact that environmental stressors that potentially threaten the persistence of species can operate at organizational levels larger than the habitat or home range of a focal species. Resource managers must therefore simultaneously consider local, regional, and/or global scale stressors for effective conservation and management of species of concern.

The wide ranging effects associated with global stressors such as climate change may exceed or exacerbate the effects of local or regional stressors. Although resource managers may only be able to directly affect local and regional stressors, they still need to understand the direct and interactive effects of global stressors and ultimately how they affect the lands they manage. Conservation of species in southern Nevada is further complicated by the fact that the region includes one of the largest and fastest growing urban centers in North America. To accomplish the goal of species conservation, resource managers must identify actionable management options that mitigate the effects of local and regional stressors in the context of the effects of global stressors that are beyond their control.

Species conservation is typically focused on a subset of species often referred to as species of conservation concern that have either demonstrated considerable decline or are naturally rare or have limited distributions. Stressors can directly and indirectly impact species in a variety of ways and through a diversity of mechanisms. Some stressors have been more intense in the past (e.g., livestock grazing) whereas others are only now emerging as new stressors (e.g., solar energy development, climate change). The primary stressors affecting southern Nevada ecosystems are listed in table 2.1 and reviewed in detail in Chapter 2. This chapter 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 (table 1.3; Turner and others 2009). We provide numerous examples of how stressors affect the range and/or habitat of select species of conservation concern. It is important to note that the species or groups of species discussed in this chapter by no means represent a comprehensive treatment of all species of conservation concern listed in table 1.2 (Chapter 1). Rather, several species were chosen as examples for each southern Nevada ecosystem type to illustrate how stressors and linkages among them can affect species of conservation concern, keeping in mind that many of the species considered here are found in more

than one ecosystem type. In addition, the stressors that may impact a species in one ecosystem may not be those that affect it in another ecosystem and different species in the same ecosystem may not be affected by the same suite of stressors. Finally, at the start of each ecosystem section we summarize key resource concerns, species used as examples, key stressors, and potential synergistic effects of those stressors relative to the species examples.

## **Alpine and Bristlecone Pine Ecosystems**

<b>Key resource concerns</b>	General lack of understanding of basic ecology of species, need for assisted migration
<b>Species examples</b>	Rare, covered (i.e., under regional resource management plans) and/or endemic plants
<b>Local and regional stressors</b>	Recreation, invasive species, nitrogen deposition, habitat modification, disease, altered fire regime
<b>Global stressors</b>	Climate change
<b>Synergistic effects</b>	Climatic induced susceptibility to nitrogen deposition, stochastic disturbance/recreation and invasive species, climate change altering local feedback systems (pollinators, herbivory, fire regimes)

The alpine ecosystem occurs at sites generally above 3,500 m in the Spring Mountains where alpine fell-fields and exposed dry rocky soils occur. Alpine meadows can also be found in swales where soil moisture accumulates in fine textured soils. We also include in this section the bristlecone pine ecosystem, which occurs on dry rocky slopes above the mixed conifer (2,600 m) and below the alpine ecosystems in the Spring and Sheep Mountain ranges. At its upper ecotone, bristlecone pine occurs as open woodlands transitioning into alpine fell-fields, whereas at its lower ecotones bristlecone pine is intermixed with other tree species as it transitions into the mixed conifer ecosystem. These alpine and bristlecone pine ecosystems occur as sky islands, where species occupy sites that occur in relative isolation amidst the vast lower elevation desert landscape. The geographic isolation among sites and the unique biophysical setting and environmental extremes of these ecosystems have led to the evolution of unique plant and animal assemblages and numerous endemic species, as is evident in the Spring Mountains (Clokey 1951). Several species of covered, rare, and/or endemics plant species occur within the alpine and bristlecone pine ecosystems of southern Nevada.

Alpine and bristlecone pine ecosystems are susceptible to various stressors and disturbances because of their relative isolation and extreme elevation. Species inhabiting these ecosystems have few options to negotiate associated stressors, especially those that operate at global and regional scales (e.g., climate change and atmospheric nitrogen deposition). Locally, recreation (e.g., snow skiing developments, rock climbing), invasive species (e.g., dandelion), associated stochastic disturbance events (e.g., avalanches), and

altered fire regimes can affect the species that occur here. The limited amount of available habitat in these ecosystems limits the degree to which species, especially plants, can respond to disturbance or stressors.

The effects of climate change and associated global stressors on alpine ecosystems in particular have been associated with increased species richness at mountain peaks as populations of lower elevation species move upslope (Pauli and others 1996). Subsequent increases in the numbers of potentially competing species may threaten resident alpine species. Climate change can lead to changes in snow duration, depth, and extent, which may differentially produce substantial changes in the carbon and nitrogen soil dynamics of alpine ecosystems (Williams and others 1998). Climate change can further affect the type, timing, and amount of precipitation, which is especially detrimental to species living in alpine and other ecosystems (Chapter 2). Warming climate conditions leading to longer growing seasons may also result in the upslope migration of mixed conifer species; the associated increase in understory fuels may alter fire regimes and threaten the persistence of bristlecone pines and other white pine species (Chapter 5).

Alpine and bristlecone pine ecosystems are also very susceptible to atmospheric nitrogen deposition, which is a broad scale regional disturbance that can alter naturally low rates of primary productivity and soil microbial activity (Chapter 2). Although nitrogen is a key nutrient for plants, high rates of nitrogen deposition from atmospheric pollutants have been linked to ecosystem stresses in plants including increased rates of herbivory, pathogen susceptibility, and reduced frost and drought tolerance (Bowman and Steltzer 1998). Nitrogen deposition has also been shown to promote dominance of invasive annual plants in the Mojave Desert (Brooks 2003), which could promote the establishment of altered fire regimes (Brooks and Pyke 2001). Nitrogen deposition is a consequence of urbanization and industrialization and, given the proximity of the alpine ecosystems to the greater Las Vegas area, its potential ecological effects are significant.

Because of difficulty in access and the relative isolation of the sky-island ecosystem, direct disturbance from human activity is rare. However, recreational use, including hiking, camping, and activities associated with rock climbing, can lead to soil disturbance and compaction and erosion, and these activities have increased during recent decades with human population increases in the greater Las Vegas region. In addition, recreational activities may facilitate the introduction of non-native plant species (DRI 2008) by both facilitating dispersal and causing disturbances that can facilitate weed establishment rates. Invasive annual grasses moving upslope could pose a particular threat to bristlecone pines from altered fire regimes (Chapter 5).

Alpine and bristlecone pine ecosystems are essentially high elevation deserts, with limited water availability and extremely short growing seasons. Collectively, the stressors that act on this ecosystem can have dire effects on species of conservation concern, potentially affecting key habitat requirements for naturally rare and/or endemic species. Few management options exist for regional managers to negotiate reductions to global climate change, or similar widespread regional stressors such as nitrogen deposition. However, actions focused on minimizing impacts from recreation and/or invasive species and altered fire regimes can be important for species of conservation concern that inhabit these ecosystems.

## Mixed Conifer Ecosystem

<b>Key resource concerns</b>	General lack of understanding of basic ecology of species, increased fire and invasive species risk
<b>Species examples</b>	Endemic butterflies
<b>Local and regional stressors</b>	Fire suppression, habitat modification/fragmentation, invasive species, vegetation management, recreation and unregulated grazers
<b>Global stressors</b>	Climate change
<b>Synergistic effects</b>	Fuels thinning operations and invasive species

The mixed conifer ecosystem occurs in the Spring and Sheep Mountains from 1,200 m to 3,200 m in southern Nevada. This ecosystem consists of three unique types: (1) white fir forests, (2) ponderosa pine forests, and (3) ponderosa pine/mountain shrub community (see Chapter 7). Unlike adjacent ecosystems at lower elevations, mixed conifer forests receive more precipitation, have longer growing seasons, and experience milder summertime temperatures, all of which provide the necessary conditions to support diverse groups of plants and animals.

The mixed conifer system is affected by a suite of local and regional stressors including fire and fuels management activities, recreation, and urban and water development. Historical fire suppression has promoted fuel accumulation, which can lead to high intensity fires that burn large areas and compromise habitat integrity (Battaglia and Shepperd 2007). These stressors have individually and synergistically compromised the stability and persistence of species of conservation concern in the region, and this is especially evident in the Spring Mountains. The effect of climate change on episodic and stochastic weather events coupled with long-term effects associated with years of fire suppression, and more recently invasive species and recreation, combine to impact the persistence of butterflies endemic to the Spring Mountains (USFWS 2011a).

Eight species of endemic butterflies occur in the Spring Mountains and are managed by the United States Forest Service (USFS) in cooperation with the United States Fish and Wildlife Service (USFWS) under a Conservation Agreement between the two agencies. Four of the eight species have been identified as conservation priorities including the Mt. Charleston blue butterfly (*Plebejus shasta charlestonensis*), Morand's checkerspot (*Euphydryas anicia morandi*), Spring Mountains acastus checkerspot (*Chlosyne acastus robusta*), and Spring Mountains dark blue butterfly (*Euphilotes ancilla purpura*). These four species were identified as a priority in the Conservation Agreement because of the limited number of locations where the species are currently known to occur. In 2006, these species were added to the Forest Service Regional (R4) Forester's Sensitive Species List, and they are currently among the species of conservation concern in southern Nevada (table 1.2; Chapter 1).

The Mt. Charleston blue butterfly, one of seven unique subspecies of the wider ranging Shasta blue butterfly (*Plebejus shasta*), was petitioned for listing as an endangered species in 2005. The habitat for the Mt. Charleston blue butterfly is characterized as flat ridgelines above 2,500 m occupied by its host plant species. Primary among these host plants is Torrey's milkvetch (*Astragalus calycosus* var. *calycosus*), a small, low-growing perennial and herbaceous legume that grows in open areas between 1,500 and 3,300 m in subalpine, bristlecone, and mixed-conifer communities in the Spring Mountains

(Weiss and others 1997). On March 8, 2011, the USFWS announced that listing the species is warranted, but precluded by higher priority actions; therefore they added it to the list of candidate species. If it rises higher on the priority list, the USFWS will develop a proposed rule to list this subspecies and make any determination on critical habitat during development of the proposed listing rule (USFWS 2011a).

Climate change is among the factors hypothesized to be responsible for the decline of the Mt. Charleston blue butterfly. Extreme climate events potentially linked to climate change can adversely affect butterflies with small restricted populations (Gilpin and Soulé 1986; Shaffer and others 2001). The Mt. Charleston blue is thought to be susceptible to random environmental and climatic events, specifically, extreme precipitation and drought events (Murphy and others 1990). The timing and number of emergent individuals that reproduce depend on a combination of environmental conditions; the result can mean the difference between a successful and an unsuccessful year for the species in question. Madsen and Figdor (2007) reported a nearly 30 percent increase in storm frequency associated with extreme precipitation in the past 6 decades in Nevada. Such extreme weather events directly impact the life cycle of the subspecies, and also indirectly impact the subspecies as mediated through host plant dynamics. The IPCC (2001) predicts that altered regional patterns of temperature and precipitation as a result of global climate change will continue. These altered climate patterns could increase the potential for extreme precipitation events and drought throughout the range of the Mt. Charleston blue, which may intensify the threats this species may be experiencing.

Various forms of habitat modification, including years of fire suppression, and introductions of non-native invasive species, are linked to the declines in species of conservation concern in the mixed conifer ecosystem (Weiss and others 1988). Historically, low-severity fires typically burned through Ponderosa pine stands within the range of the Mt. Charleston blue and may have allowed for a more open mixed conifer forest characterized by a more abundant and diverse understory. Fire suppression has led to altered community successional patterns, which has altered host plant dynamics, altered butterfly movement patterns and reduced solar insolation (Weiss and others 1997). Additionally, the closing of the forest canopy may have compromised the metapopulation processes including colonization and recolonization dynamics. Shrub and forb in-filling as well as increased dominance of invasive grasses may out-compete and potentially decrease the abundance and quality of host plant resources for this butterfly species.

The mixed conifer ecosystem may also be affected by various forms of recreational use, including hiking, rock climbing, and skiing. The Spring Mountains are home to the Las Vegas Ski and Snowboard Resort (LVSSR) that operates under a USFS special use permit. It is difficult to assess the degree to which the resort affects the endemic butterflies within the Spring Mountains. It is also possible that the active management for ski runs and potential expansion, including thinning of trees and shrubs and seeding of non-native species for erosion control, may indirectly impact the butterfly by preventing host plants from reestablishing in disturbed areas. Such disturbances are different from naturally created forest gaps and may not promote host plant establishment. In summary the effects of such disturbance features and events on host plant establishment are unknown and require further investigation.

In 2009, the USFS initiated the Spring Mountains National Recreation Area Hazardous Fuels Reduction Project to reduce accumulated forest fuel and lower fire risk by providing fuel breaks along human-use corridors, on the edges of private property, and at other human use areas such as campgrounds. Treatments varied widely depending on specific site conditions, but generally included use of heavy equipment and mastication treatments. These operations require investigation because they may directly impact butterfly population dynamics and habitat if individuals or host plant patches are killed or destroyed.

The mixed conifer ecosystem is the focus of a diverse and varied set of management programs including vegetation and fuels management, rare species conservation, non-native species management, endemic butterfly research, and more. Increased pressure from urbanization and recreation will continue to challenge resource managers with balancing permitted human activities with protecting ecosystem integrity.

## Piñon and Juniper Ecosystem

<b>Key resource concerns</b>	Range expansion and stand in-fill, larger and higher severity fires, non-native species, disease
<b>Species examples</b>	Piñon jay, gray vireo, gray flycatcher, desert bighorn sheep
<b>Local and regional stressors</b>	Fire, invasive species, nitrogen deposition, vegetation management and unregulated grazers
<b>Global stressors</b>	Climate change (e.g., extended drought, longer fire seasons and periods of severe fire weather), carbon dioxide enrichment
<b>Synergistic effects</b>	Conversion to annual grasses and complete loss of habitat, extended drought and insect outbreaks, grazing and brown headed cowbird parasitism, woodland expansion and increased bighorn sheep predation rates

The piñon-juniper woodlands occur between 1,500 and 2,500 m, below the mixed conifer ecosystem, and are often intermixed or adjacent to the sagebrush ecosystem. At the upper elevation ecotones the dominant species include single-leaf piñon (*Pinus monophylla*), Gambel oak (*Quercus gambelii*), mountain mahogany (*Cercocarpus* spp.) and sagebrush (*Artemisia* spp.), whereas at lower ecotones important species include Utah juniper (*Juniperus osteosperma*), Rocky Mountain juniper (*J. scopulorum*), western Juniper (*J. occidentalis*), rabbitbrush (*Chrysothamnus*) and sagebrush. While this ecosystem type makes up about 12 percent of the state, it is less well represented in southern Nevada.

The expansion of piñon-juniper woodlands has been widely documented across the southwestern United States (Miller and others 2008), and this is thought to be largely due to reduced frequency of fire (Bauer and Weisberg 2009). Reports indicate that over the past 150 years piñon-juniper woodlands have expanded into other ecosystem types (e.g., sagebrush) and have also experienced increased plant density (i.e., in-filling), which has resulted in reduced dominance or the complete loss of understory plant species (Bauer and Weisberg 2009; Miller and others 2008). Miller and others (2008) found that at sites in the Great Basin, the area occupied by piñon and or juniper has increased 125 to 625 percent since 1860. The woodland expansion is greater at mesic sites and in-filling rates are greater at lower elevations (Weisberg and others 2007). The landscape scale shifts are primarily thought to be due to climate change, altered fire regimes, and livestock grazing (Romme and others 2009a,b). These dynamics may promote insect pressure leading to mortality, fire risk, and non-native plant invasions. Conversion to piñon-juniper woodland from other critical ecosystem types (e.g., sagebrush) promotes

an increased risk of large-scale and higher severity fires, which impact wildlife within the piñon-juniper ecosystem. At lower elevations, fire may ultimately result in invasive annual grass dominance.

More recently, massive piñon pine die-offs have been documented across the West. Breshears and others (2005) found that from 40 to 80 percent of piñon (*Pinus edulis*) trees died between 2002 and 2003 at sites in Arizona, Colorado, New Mexico, and Utah, which may be related to climatic shifts and interactions with forest pathogens (Breshears and others 2009). Periodic droughts have promoted reductions in canopy cover, thereby resetting the successional clock in these systems (see Clifford 2011). Extended drought is a significant factor in insect outbreaks that can kill large stands of trees (Breshears and others 2005).

Within the piñon-juniper woodland, species including the piñon jay (*Gymnorhinus cyanocephalus*), gray vireo (*Vireo vicinior*), and gray flycatcher (*Empidonax wrightii*) are experiencing notable population reductions (Sauer and others 2008). Stand in-filling and piñon pine die-off have translated to decreased bird species' abundances in this ecosystem (Sauer and others 2008). The piñon jay caches piñon seeds, on which it relies throughout the year, in more open transitional stands near sagebrush and other more open habitat. However, shifts in community composition and die-off have resulted in lower piñon seed crops. The large expanses of closed-canopy stands without a satisfactory understory component are not suitable for piñon jays. According to ongoing telemetry studies being conducted by the Great Basin Bird Observatory, piñon jays prefer mixed age, early to mid-successional stands with a structurally diverse ecotone.

Gray vireos use mature or mixed-age piñon-juniper woodlands with scattered trees and open canopies, especially where juniper is more abundant (Goguen and others 2005). The gray vireo may be negatively impacted by stand in-fill due to altered fire regimes, reduction of shrub cover due to livestock grazing, increased abundance of invasive plants, and brown-headed cowbird (*Molothrus ater*) parasitism (Goguen and Mathews 2001). For example, Goguen and Mathews (1998) found that livestock grazing can indirectly affect the nesting success of some songbird species by increasing cow bird abundance, although data specific to southern Nevada is lacking. The gray flycatcher uses a diversity of habitats in Southern Nevada but has a preference for the piñon-juniper ecosystem in the Mojave portion of its distribution (Sterling 1999). Gray flycatchers use moderately open piñon-juniper/sagebrush transitional habitats and therefore have the potential to be negatively impacted by stand in-fill.

The desert bighorn sheep (*Ovis canadensis nelsoni*) occurs on sparsely vegetated steep slopes, canyons, and washes within multiple ecosystem types in southern Nevada, including piñon and juniper woodlands. Especially important habitat includes treeless or rocky areas that provide escape routes from predators. Desert bighorn sheep and other subspecies have experienced major population declines from the 1850s to the early 20<sup>th</sup> century (Buechner 1960). The desert bighorn is less studied than other subspecies, but reports suggest that numerous factors have contributed to population declines including disease, low reproductive output, habitat loss/fragmentation and degradation and predation (Buechner 1960; Gutiérrez-Espeleta and others 2000).

Disease is among the most important factors that has led to the decline of the desert bighorn sheep (USFWS 2000a), especially diseases contracted from domesticated cattle and sheep (Gildart 1999; Jessup 1985). Increased human effects, including habitat loss and degradation, have also impacted the desert bighorn sheep (DeForge 1981; Hick and Elder 1979). Such impacts include increased noise, lighting, and increased human and pet presence in sheep habitat. The increased presence of humans and pets promotes an increase in some predators including coyotes, especially along the wilderness/urban

interface (Ditchkoff and others 2006). Desert bighorn have also been shown to avoid areas where feral horses are present, potentially altering their foraging and watering preferences (Ostermann-Kelm and others 2008). Climate variability can also lead to poor diet quality for desert bighorn sheep, a pattern especially important at lower elevations such as occur in Mojave Desert scrub (Epps 2004).

Increased woodland expansion, especially increased cover near watering sites, may also be facilitating increased predation rates by mountain lions (*Puma concolor*) on desert bighorn sheep. This same phenomenon is thought to be occurring with the Sierra Nevada Bighorn (*Ovis canadensis sierra*) populations (R. Klinger, personal communication). Predation by other species, including coyotes (*Canis latrans*) and bobcats (*Lynx rufus*), may also reduce lamb recruitment, although the effects of these predators are not well known (Wehausen 2005).

Resource managers should consider using fire, vegetation management actions (thinning techniques), invasive species management, and restrictions on recreation activities when managing this ecosystem (see Crow and van Riper 2010). Dynamics brought upon by a changing climate, including drought and associated interactions with insects or other pathogens, will continue to challenge local resource managers.

## Sagebrush Ecosystem

<b>Key resource concerns</b>	General habitat loss and degradation, grass-fire cycle, woodland encroachment
<b>Species examples</b>	Sage thrasher, sage sparrow, burrowing owl
<b>Local and regional stressors</b>	Fire, invasive species, nitrogen enrichment, OHV use, energy development
<b>Global stressors</b>	Climate change (i.e., extended drought), carbon dioxide enrichment
<b>Synergistic effects</b>	Grazing, annual grass invasion and fire regime shifts; climate change and woodland encroachment

Sagebrush ecosystems are less well represented in southern Nevada compared to the rest of the state. In southern Nevada the sagebrush ecosystem can be found in the Spring, Sheep, and Virgin Mountains at elevations between 1,500 to 2,800 m (RECON 2000). The loosely applied term sagebrush ecosystem is used to describe ecological systems where members of the genus *Artemisia* are the dominant species. In southern Nevada this includes big sagebrush (*A. tridentata*), low sagebrush (*A. arbuscula*), Bigelow sagebrush (*A. bigelovii*), silver sagebrush (*A. cana*), and black sagebrush (*A. nova*). The specific species association depends on elevation, topography, soil type, and degree of aridity.

Sagebrush ecosystems represent a contentious place marker among ranchers and conservationists across the Intermountain West. It has been argued that decades of improper land management have led to deterioration of this ecosystem type. It is thought that overgrazing, among other causes, has contributed to the reduction of associated species thereby promoting the invasion and dominance of invasive annual grasses, including cheatgrass (*Bromus tectorum*) and red brome (*B. madritensis*) (DiTomaso 2000). With

the expanding dominance of invasive annual grasses, fine fuels have become ubiquitous, and the potential for fire to ignite and rapidly spread is increased. Once burned, the area can become dominated by invasive grasses that effectively out-compete native species. This then allows for a reduction in the fire return interval from about 50 to 200 years to only several years. This is a well-established dynamic called the grass-fire cycle, which has rapidly transformed countless hectares of landscape to invasive annual grass dominance (Brooks and others 2004; D'Antonio and Vitousek 1992). Sagebrush is not well adapted to fire and is only able to regenerate from seed post fire, which may take years to decades. With the onset of the grass-fire cycle, natural regeneration of the native dominated communities is nearly impossible and active restoration efforts are not widely successful. Mojave scrub and blackbrush communities, other ecosystems described in this chapter, are also degraded by this grass-fire cycle dynamic.

To further complicate matters, climate change from carbon dioxide enrichment has been shown to increase productivity and biomass accumulation as well as alter the carbon to nitrogen ratio and digestibility of *Bromus* spp., potentially enhancing the competitive abilities of these non-native invaders (Smith and others 1987) and increasing the fuel loads (Ziska and others 2005). Sagebrush communities are also under threat from piñon-juniper expansion. Moreover, energy development, urban development and off-highway vehicle (OHV) recreation also place pressure on this ecosystem, which may be further exacerbated by future changes in climate (change in precipitation timing and type, melt off, and temperature shifts).

The ecological impacts associated with sagebrush habitat deterioration, or loss to annual grassland type conversion, have been widely documented in the Intermountain West. The deterioration alters soil morphology (Norton 2004), soil biota (Belnap and others 2005), native plant biodiversity (Humphrey and Schupp 2001), as well as diversity of invertebrates (Ostoja and others 2009), small mammals (Ostoja and Schupp 2009), reptiles (Newbold 2005), and birds (Knick and others 2003; Knick and Rotenberry 2002; Paige and Ritter 1999). However, the evaluation of specific mechanisms for shifts of wildlife species or communities have received less attention (but see Rieder and others 2010).

At the same time, the upper elevation sagebrush ecotones are experiencing increased juniper dominance, which may also compromise the integrity of the ecosystem for specific wildlife populations or guilds (see piñon-juniper section above). In fact, much of what is mapped by the USFS as the sagebrush ecosystem in the Spring Mountains National Recreation Area has a substantial component of juniper trees (Steven Ostoja, personal observation of plant community composition in the Spring Mountains, June, 2009).

In southern Nevada, bird species of conservation concern in sagebrush habitat include the sage thrasher (*Oreoscoptes montanus*), sage sparrow (*Amphispiza belli*), burrowing owl (*Athene cunicularia*), and others (see [www.gbbo.org](http://www.gbbo.org)). Each of these species is negatively affected by habitat degradation and loss caused by urban, agricultural, energy, or other development. Sage thrashers use sagebrush habitat in southern Nevada during winter and migration periods; they prefer large expanses of sagebrush or shrub habitat, avoiding areas with junipers even when at low densities (Noson and others 2006). The burrowing owl is declining throughout much of its former range and is recognized as a National Bird of Conservation Concern by the U.S. Fish and Wildlife Service (Klute and others 2003). The owl is a yearlong resident throughout most of Clark County, but is only a summer and spring resident in adjacent southern Nevada counties. Increased

development and associated effects (e.g., roads) promotes human disturbance to breeding colonies of owls (Poulin and others 1993). Moreover, because they are a ground nesting owl, domestic and feral dogs also have the potential to do great harm to their populations. The sage sparrow relies on large expanses of southern Nevada sagebrush and shrubland habitat during winter and migration periods. The sage sparrow is reported to be sensitive to cheatgrass invasion because of the reduction of shrub cover and loss of sparsely vegetated inter-shrub area that it requires for foraging. Research investigating the effects of grazing on sagebrush birds has shown mixed results (Page and others 1978; Saab and others 1995).

Invasive brome grasses, woodland expansion, and human activities will likely continue to threaten the sagebrush ecosystem in southern Nevada. Without question, these dynamics are closely linked to global stressors like climate change and pose a significant management challenge to land managers. The degree to which increased brome grass invasion is due to local disturbance versus increasing concentrations of carbon dioxide, nitrogen deposition, and climate mediated events is unclear. Climate models with projections of species range expansion may aid managers when considering management actions for species of conservation concern in this ecosystem type. At the same time, because so little of the sagebrush ecosystem naturally occurs in the region, conservation of what remains is important in the development of land management plans.

## **Blackbrush and Shadscale Ecosystems**

<b>Key resource concerns</b>	General habitat loss and degradation, grass-fire cycle
<b>Species examples</b>	Blackbrush
<b>Local and regional stressors</b>	Fire, invasive species, nitrogen enrichment, OHV use, energy development
<b>Global stressors</b>	Climate change (precipitation patterns), carbon dioxide enrichment
<b>Synergistic effects</b>	Unknown

Blackbrush ecosystems are woody evergreen shrublands dominated by blackbrush (*Coleogyne ramosissima*) and are primarily found on thermic and shallow limestone-derived soils between 1,200 and 1,800 m in elevation (Pendleton and others 1995). Some blackbrush stands also occur on more mesic, deeper, and sandier soils, although that is not the norm in the Mojave Desert (Brooks and Matchett 2003; Matthew Brooks, personal observation of blackbrush community substrates throughout the Mojave Desert during the 1990s and 2000s). Shadscale (*Atriplex confertifolia*) can be dominant within the same elevation range on heavy, rocky soils (Brooks and others 2007). Associated species include Mormon tea (*Ephedra* spp.), wolfberry (*Lycium* spp.), hopsage (*Grayia spinosa*), and various species of grasses (Brooks and others 2007). The distribution of the ecosystem type is influenced by moisture, temperature, and soil types within the elevation range. Recent genetic analyses suggest that blackbrush is divided into two unique metapopulations, one centered in the Mojave Desert and the second on the Colorado Plateau (Richardson and Meyer 2012). Although we include both the blackbrush and

the shadscale ecosystems in this section due to their similar ecological ranges, we focus on the dynamics and species composition associated with blackbrush due to the limited information available on shadscale.

Blackbrush/shadescale ecosystems are used as winter forage by deer and bighorn sheep (Bowns and West 1976) and habitat for numerous species of birds and small mammals (Brown and Smith 2000). In addition, there are 11 covered species that occur in the blackbrush ecosystem of Clark County, eight of which are reptiles and three of which are vascular plants. Here, we limit our discussion to blackbrush because it has been reduced to remnant patches or is in a highly degraded state throughout southern Nevada. The blackbrush ecosystem is one of the most flammable ecosystems in the Mojave Desert. Fires burn plants to ground level and destroy soil seedbanks (Brooks and Draper 2006; Brooks and others 2007). Because natural recruitment is low for all plants in this ecosystem, it may take centuries for natural recovery to occur following fire (Minnich 2003; Webb and others 1987). Disturbances, including grazing and recreation, allow the establishment of invasive species including *Bromus* spp. (see sagebrush section in this chapter). Once *Bromus* spp. is established, the grass-fire cycle is initiated and conversion of the area to non-native annual grasses is likely.

Fire, invasive species, grazing, development and recreation are among the greatest stressors to this ecosystem type. Grazing appears to have lasting effects on blackbrush shrub cover, soil crusts, and associated perennial plant cover (Jeffries and Klopatek 1987). Blackbrush ecosystems in healthy ecological condition were likely more extensive prior to European contact (see Brooks and others 2007). Large areas of blackbrush were burned into the mid-1900s to increase livestock forage production and are currently dominated by early seral species. Only sporadic re-colonization by blackbrush has occurred, and that has been focused on the more mesic end of this species' ecological range (M. Brooks, unpublished data). Recreational use, including foot, bike, horseback riding, and OHV use, can cause soil compaction and limit plant recruitment, which may facilitate habitat fragmentation. Habitat fragmentation may be especially problematic near rural and urban development.

Other potential stressors that threaten blackbrush and the integrity of the ecosystem include the application of pesticides, climate change, increased carbon dioxide in the atmosphere, and fire ants (*Solenopsis* spp.). It is possible that the use of pesticides near rural areas may harm burrowing insects (e.g., ants) and small vertebrates (e.g., lizards and small mammals), thereby affecting patterns of plant recruitment and growth. Additionally, climate change may affect soil moisture and associated warming temperatures may affect associated species of conservation concern in this ecosystem. Rising carbon dioxide concentrations in the air have been linked to increased productivity of non-native annual grasses (Ziska and others 2005). Native ant species burrowing activities are important to this ecosystem, and, may be negatively affected by non-native fire ants. Fire ants may also reduce survivorship of native mammals and ground-nesting birds (Lessard and others 2009; Smith and others 2004).

As suggested for the sagebrush ecosystem, focusing on protecting the remaining remnant patches of the blackbrush/shadscale ecosystem would be of greatest benefit. Because natural regeneration is so limited, especially for blackbrush, it is feared that this ecosystem could disappear without intense restoration management efforts (Jones 2011). Restoration efforts to reestablish blackbrush in the Mojave Desert have had limited success due to seed and seedling predation and low germination rates under hot and dry conditions.

## Mojave Desert Scrub Ecosystem

<b>Key resource concerns</b>	General habitat loss, fragmentation and degradation
<b>Species examples</b>	Bajadas: desert tortoise; Sand dunes: three-corner milkvetch and white marginated penstemon; Gypsum soils: sticky ringstem, Las Vegas bearpoppy, and Las Vegas buckwheat
<b>Local and regional stressors</b>	Fire, invasive species, nitrogen enrichment, OHV use, energy development, habitat loss/fragmentation, feral dog/cat predation, grazing, mineral extraction and dumping
<b>Global stressors</b>	Climate change (precipitation patterns), carbon dioxide enrichment
<b>Synergistic effects</b>	Land development, recreation, and invasive species

The Mojave Desert scrub ecosystem is characterized by widely and regularly spaced shrubs up to 3 m tall, and occurs on well-drained soils on slopes, fans, and valley bottoms below 1,200 m (Shoenherr 1992). Several subtypes are considered within this ecosystem type, including bajadas (also called alluvial fans), sand dunes, and gypsum soil.

### *Bajadas*

Bajadas are the most common landform in southern Nevada and are dominated by creosote bush (*Larrea tridentata*) and white bursage (*Ambrosia dumosa*), with other sub-dominant species including desert thorn (*Lycium andersonii*), bladder sage (*Salazaria mexicana*), indigo bush (*Psoralea fremontii*), blackbrush, brittlebush (*Encelia farinosa*), and burro bush (*Hymenoclea salsola*). This is the primary ecosystem type surrounding the major cities of southern Nevada and through which most of the major highways pass (fig. 1.2; Chapter 1), placing it within the wildland urban interface. Increased urbanization promotes human activities that have placed this ecosystem type and the iconic species it supports, including the desert tortoise (*Gopherus agassizii*) and the burrowing owl, at increased risk.

Federally listed as threatened under the Endangered Species Act, the Mojave population of the desert tortoise can be found in regions throughout the Mojave and Colorado Deserts north and west of the Colorado River in Utah, Arizona, southern Nevada, and California. The desert tortoise frequents creosote bush dominated Mojave Desert scrub vegetation, and other low elevation vegetation types, including saltbrush (*Atriplex* spp.), and to a lesser extent blackbrush ecosystems (Bury and others 1994). As of 2007, the estimated desert tortoise population density in the northeast Mojave Desert was 1.7 individuals/km<sup>2</sup>, the lowest of all six recovery units (USFWS 2011b).

Recreational human activities such as target shooting and off road driving are known to directly kill or injure desert tortoises (Ladehoff and others 1990). For example, about 10 percent of shell remains from a tortoise study plot near Littlefield, Arizona, were found to have bullet holes ([www.federalregister.gov](http://www.federalregister.gov)). These occurrences are obviously more common at locations near urban areas where human activity is more frequent. People also collect tortoises for pets, food, and various commercial trades, which further compromises tortoise populations (Grover and DeFalco 1995).

Livestock grazing has been implicated in the decline of desert tortoise populations (Berry 1986). Avery and Neibergs (1997) noted that for most vegetation metrics considered, grazed sites were similar to ungrazed sites, although they did find that bulk density and penetration resistance of soils were greater at grazed sites. Cattle may compete with desert tortoises for forage, especially after winters of above average rainfall when abundant ephemeral resources are available (P. Medic, personal communication). Direct effects of cattle can include rubbing and nudging of tortoises; indirect effects include trampling of actively used burrows and destruction of shading vegetation around actively used burrows (Ladehoff and others 1990).

OHV use and livestock grazing have been implicated in concomitant reductions in native vegetation and increases in invasive species (Brooks and Pyke 2001; Lovich and Bainbridge 1999). Tortoise resource availability and quality may be locally compromised where invasive species densities have increased. Where vegetation cover has been reduced, tortoise habitat quality also is reduced, because fewer sites to shelter from the sun are available to them (USFWS 2008, 2011b).

Tortoises are also subject to diseases that affect populations. Upper respiratory tract disease (URTD) and a shell disease occur in the species. URTD occurs more commonly in wild populations near cities where captive animals may have infected those populations (USFWS 2008, 2011b). Habitat degradation, poor nutrition and drought are likely involved in increasing the susceptibility of individual animals to URTD (Jacobson and others 1991). The USFWS suggests that reducing the human-related spread of URTD and improving habitat conditions may be effective management tools for controlling URTD in wild populations (USFWS 2008, 2011b).

The common raven (*Corvus corax*) is a predator of the tortoise. The raven is associated with human subsidized food resources throughout the Mojave Desert (Kristan and Boarman 2007). Consequently, common ravens have been implicated as contributors to the decline of the desert tortoise (Kristan and others 2004) through direct predation on hatchlings and juveniles (USFWS 2011b). Predation pressure on tortoises can be especially important in drought years (Esque and others 2010).

Climate change may affect the desert tortoise through changes associated with animal metabolism and water relations that could shift population demography (see Henen and others 1998). Other effects of climate change may come indirectly, with changes in vegetation patterns or increased dominance of invasive species. These, too, may further compromise tortoise habitat. The USFWS (2011b) desert tortoise recovery plan estimates that \$159 million, plus additional costs that cannot be estimated, is needed in order for the species to become self-sustaining into the future.

## **Sand Dunes**

Sand dunes form with the combination of a sand source and windy conditions. In the Mojave Desert scrub ecosystem, sand dunes are common to playas, remnant lakes, and xeric bottomland basins. Sand dunes are home to highly specialized species that are adapted to living in harsh environmental conditions with limiting resources and water. The model animal of sand dunes may be the desert kangaroo rat (*Dipodomys deserti*), whose fossorial nocturnal nature and fine-tuned biology allows it to escape predators, survive without free water, and recover stored food caches when resources dwindle. Also present in dune systems are several plant species of conservation concern that are receiving some attention (are 'covered') under the Clark County Multiple Species Habitat Conservation Plan (MSHCP): three-corner milkvetch (*Astragalus geyeri* var. *triquetrus*) and white margined beardtongue (*Penstemon albomarginatus*). Three-corner milkvetch is a small ephemeral annual forb that occurs on open, deep sandy soil or dunes that are

generally stabilized by vegetation or gravel veneer (Morefield 2001). Reports indicate that difficulty in managing the species comes from general lack of knowledge regarding the species ecology and population dynamics (RECON 2000). White-margined beardtongue is a small herbaceous perennial forb with a long taproot requiring fine, deep, alluvial sand within the Mojave Desert scrub ecosystem. This species prefers sand dunes at the base of hills and mountains in wind-blown sand dune areas but is also found in deep loose sand in washes (Button 1991; Scogin 1989).

Significant threats to the aforementioned species are posed by human activities, including the use of OHVs and multiple use trails that impact habitat and directly kill individual plants (RECON 2000). Energy development and associated urban expansion also threaten species directly and indirectly through habitat loss (Anderson 2001). Many trails and roads created for energy development directly affect individuals and populations. Once the trails or roads are on the landscape, they become available to the general public, support access to the desert landscape and allow increased, repeated use by various recreation groups. Established white-margined beardtongue individuals may survive isolated or infrequent OHV disturbance because the plant can re-sprout from the tap root if the above ground portions are damaged (Scogin 1989). However, sustained and repeated disturbance is much more likely to kill individual plants, and can have a significant impact on populations of both species. Domestic livestock grazing and activities associated with feral animals have the potential to result in significant habitat destruction as well (RECON 2000). Activities associated with water management, including diversion and ground water pumping, can make natural water unavailable and also potentially threaten the species.

### *Gypsum Soils*

This ecosystem supports various gypsum soil community types. Gypsum is a soft sulfate mineral, and gypsum soils occur on more than 100 million ha on Earth (Verheye and Boyadgiev 1997). Gypsum soils are restricted to arid and semi-arid climates where low precipitation prevents gypsum from leaching (Parsons 1976). The physical and chemical properties common to gypsum soils are stressful to most plants. At the same time, these soils support a conspicuous and diverse set of endemic and rare plants in arid and semi-arid regions, and southern Nevada is no exception. The Las Vegas bearpoppy (*Arctomecon californica*) is endemic to gypsum soils in the eastern Mojave Desert and a MSHCP covered species. It has a patchy distribution across low “badland” hills, and is sometimes found on ridges and benches. Larger populations occur in Las Vegas Valley and on gypsum soils associated with the Colorado River drainage (RECON 2000). Another MSHCP covered species is sticky ringstem (*Anulocaulis leisosolenus*), which also occurs on gypsum derived soils, primarily in the Frenchman Mountain area east of Las Vegas and further east to the Muddy Mountains and Gold Butte (RECON 2000). Sticky ringstem often co-occurs with the Las Vegas bearpoppy (RECON 2000). The Las Vegas buckwheat (*Eriogonum corymbosum* var. *nilesii*) is also restricted to gypsum-rich soils in Clark and Lincoln counties.

Once widespread and abundant, the Las Vegas bearpoppy has experienced population extirpations throughout southern Nevada (RECON 2000). The Las Vegas bearpoppy’s decline is attributed to land development, general habitat degradation, highway construction and backcountry road development, and OHV use (ADGF 2000). Habitat loss and fragmentation due to urbanization are also cited as contributing to population losses and declines (RECON 2000). These direct effects on the populations have also translated to associated higher order effects, and reports indicate that pollinators have declined due to habitat fragmentation (NNHP 2001). Sticky ringstem habitat has been modified and degraded due to urbanization, development including mining, recreational activities,

and trampling by ungulates (RECON 2000). Increased recreational use could result in mortality of individual plants as well as loss or disturbance to cryptogamic crusts (RECON 2000). Many of the historical populations of the Las Vegas buckwheat were lost to development as the greater Las Vegas area expanded. Extant populations are experiencing threats from habitat loss, invasive species, and climate change (USFWS 2010) and it is currently a candidate for Federal protection.

Mojave scrub is the most extensive habitat type in the region, and because of its prevalence at the wildland-urban interface it will be subject to increased local, regional, and global threats. Management efforts that concentrate on maintaining natural shrub densities, soil crusts, and healthy native vegetation where widespread intensive disturbance has been minimal would be most beneficial.

## **Desert (Mojave Lowland) Riparian Ecosystem**

<b>Key resource concerns</b>	Tamarisk invasion, biological control beetle
<b>Species examples</b>	Yellowbilledcuckoo, southwestern willow flycatcher
<b>Local and regional stressors</b>	Invasive species, fire, grazing, water diversion and extraction
<b>Global stressors</b>	Climate change (precipitation patterns and runoff)
<b>Synergistic effects</b>	Beetle induced vegetation/habitat changes and selective herbivory by unregulated grazers

In southern Nevada, this ecosystem occurs at elevations below 1,200 m and includes the Virgin, Muddy, and Colorado Rivers and Las Vegas Wash as well as adjacent systems (RECON 2000). Desert riparian and associated aquatic ecosystems are influenced by precipitation, topography, and geology (Poff and others 1997). Additionally, the intensity, timing, and frequency of flood events have an important role in shaping and maintaining this ecosystem type. Historically, Mojave riparian ecosystems were dominated by Fremont cottonwood (*Populus fremontii*), Goodding’s willow (*Salix gooddingii*), and various species of shrub willows (*Salix* spp.). In higher elevations velvet ash (*Fraxinus velutina*) was an important species. Other riparian plants include honey mesquite (*Prosopis glandulosa*) and a variety of native herbaceous species. Mojave riparian ecosystems contribute disproportionately to local and regional species richness despite the relatively small area they occupy compared to other ecosystems in the region (Naiman and others 1993).

All rivers in the Mojave Desert in Nevada have been altered through surface water diversions, channelization, and dams, thereby resulting in compromised biological and hydrogeomorphic conditions and a loss of system structure and function. The biophysical characteristics (periodic scour, flooding, and sediment deposition) necessary to support riparian plant species and patterns of heterogeneity no longer exist for river systems in southern Nevada (Busch and Smith 1995). Consequently, much of the riparian vegetation is now dominated by invasive species, especially tamarisk, which is also called saltcedar (*Tamarix* spp.) (Shafroth and others 2005).

This ecosystem type is one of the most degraded and imperiled systems in the region. Stressors to this ecosystem include global effects of climate change; regional and local effects of fire, recreation, water manipulation projects; and the aforementioned effects of invasive species (e.g., Tamarisk, and aquatic – see Chapter 3). Climate change effects, especially resulting in changes in flow regimes linked to precipitation (timing

and quantity), and increased evapotranspiration may further impact this ecosystem. It is expected that climate change will result in a warmer, drier climate, and reduced surface water across the range of species of conservation concern (i.e., yellow-billed cuckoo (*Coccyzus americanus*) and southwestern willow flycatcher (*Empidonax traillii* subsp. *extimus*)). However, various regional and local stressors individually and synergistically may prove to have a greater influence on species of conservation concern.

Tamarisk is highly competitive with native species and in most cases is the dominant species where it occurs. The effect of Tamarisk dominance on wildlife habitat has been considered most commonly for birds (van Riper and others 2008), and generally indicates that moderate levels of Tamarisk provide better habitat than sites that are Tamarisk monocultures. Although reports have stated that Tamarisk is the preferred habitat for flycatchers (Davis and others 2011) it should be cautioned that previously published reports on this subject (van Riper and others 2008) do not reach the same conclusion.

Efforts to control Tamarisk have been widely implemented and include the use of chemicals, mechanical methods, and fire. Most recently, land managers have released a biological control agent, the northern Tamarisk beetle (*Diorhabda carinulata*), which is native to Eurasia. In 2006, the northern Tamarisk beetle was released near St. George, Utah, and has subsequently expanded along reaches of the Virgin River. During the summer of 2011 the beetles became established within Tamarisk stands farther downstream along the Virgin River, and it may reach Lake Mead National Recreation Area (NRA) by 2012 or 2013. Based on patterns of defoliation along the Colorado River near Moab, Utah, the beetles will require multiple generations to cause substantial impact or even death to localized patches of Tamarisk stands at Lake Mead NRA. However, the effect of the beetle on wildlife is unknown (Bateman and others 2010). Efforts are in place to evaluate the long-term effects of the northern Tamarisk beetle on wildlife and associated habitat quality (Bateman and others 2010; also see Bateman and Ostojka 2012).

Although, the effects of introduced biological control species on wildlife groups have received little consideration (but see Pearson and Callaway 2005, 2006, 2008), two potential outcomes seem plausible. First, the beetle may provide increased resources for insectivorous and omnivorous species, thereby conferring advantage for wildlife able to capitalize on these increased prey numbers (Pearson and Callaway 2005, 2006, 2008). However, beetle-caused defoliation and eventual death of Tamarisk trees may negatively affect birds by reducing breeding and nesting habitat. For example, defoliation may change the conditions surrounding a nest, which may lead to reductions in nest success due to loss of cover and increased predation associated with the microclimate of the nest. How the flycatcher and the cuckoo respond to this dynamic is unknown, but is of keen interest to ecologists and managers working in the area (see Bateman and others 2010).

Even with widespread type conversions, this ecosystem continues to support a diversity of organisms including fish, invertebrates, reptiles, amphibians, birds, and mammals (Bateman and Ostojka 2012). This ecosystem is also home to numerous species of conservation concern including the Federally endangered southwestern willow flycatcher and yellow-billed cuckoo. These are two species that are also covered in the Clark County MSHCP (Clark County 2000).

The southwestern willow flycatcher is a small insect eating neotropical bird that uses riparian habitat for feeding, sheltering and cover while breeding, migrating, and dispersing (Paxton and others 2007). It was Federally listed in 1995 due to its small population size, historical and recent population declines, and habitat threats. The yellow-billed cuckoo is a medium sized bird that breeds in large blocks of riparian habitat (Johnson and others 2008). Nevada has listed the species as critically imperiled due to extreme rarity, imminent threats, and/or biological factors (Morefield 2011).

In Clark County, Nevada the yellow-billed cuckoo's decline has been linked to the reduction and degradation of riparian habitat, river channelization, livestock grazing, and use of pesticides, non-native species (Tamarisk), recreation, and brown-headed cowbird parasitism (Clark County 2000). Nevada has listed the species as a State Rank S1 Nevada State Protected, which means that the species is protected in Nevada and is considered critically imperiled due to extreme rarity, imminent threats, and/or biological factors.

Other local stressors that influence the habitat conditions for the flycatcher and cuckoo include grazing and recreation. Unregulated grazing along riparian systems can compromise ecological integrity where animals occur in sufficient numbers. Livestock that freely roam along arid riparian ecosystems can introduce a great deal of disturbance including reductions in stream bank stability and erosion. Loss of stream bank quality can lead to increased bank deterioration and reductions in habitat for wildlife. In addition, livestock can shift the competitive balance among co-occurring plant species via selective herbivory. Grazing animals can selectively remove desirable plants such as germinating cottonwood (*Populus* sp.) and willows, thereby decreasing native plant regeneration, and thereby indirectly facilitating co-occurring less palatable weedy plants. The effort to remove Tamarisk will be undermined if unregulated grazers selectively remove regenerating native vegetation, thereby facilitating increases in secondary weed populations. These types of synergistic effects are certainly difficult to predict but merit consideration and attention.

Best management practices for conservation of this ecosystem include 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, mixed species and with a varied age canopy, shrub thickets, flowering shrubs, and forbs with ample floodplain and wetland sites intermixed. Protection of old growth trees and sites that have minimal invasive species dominance could also be given priority. Conservation would be enhanced if grazing and OHV use could be kept at levels whereby sites are not permanently impacted and bare soil is not exposed in large patches. Restoration of sites where Tamarisk has been controlled or burned could also be a priority, especially where these sites are adjacent to nearby native patches and where the effect of grazing or OHV use is absent to minimal. Evaluation of biocontrol effects on vegetation trajectories and wildlife habitat would be useful to support future land management decisions.

## Spring Ecosystems

<b>Key resource concerns</b>	Habitat loss/deterioration, unregulated grazers
<b>Species examples</b>	Relict leopard frog
<b>Local and regional stressors</b>	Diversion/ground water pumping, land/water development, unregulated grazers, non-native aquatic species, recreation, disease (Chytrid fungus)
<b>Global stressors</b>	Climate change (precipitation patterns)
<b>Synergistic effects</b>	Water/urban/agricultural development & habitat isolation; small population size/isolation and disease susceptibility

Aquatic springs are biophysically diverse ecosystems due to differences in water chemistry, slope, substrate type, persistence, morphology, and size. Springs are most influenced by the type of aquifer, flow rate, landscape position, and local biology. There are two main types of springs, perennial and intermittent. Perennial springs are typically found at sites where deep aquifer ground water reaches the surface. Intermittent springs are typically fed by shallow ground water from localized precipitation. Most springs in Clark County are intermittent and less than 200 are persistent (Sada 2000). They vary in size, are biophysically diverse, and can be found from 250 m to 3300 m elevation in all landscape settings. The basic environmental and biological characteristics of several hundred larger springs within Clark County have been inventoried (Sada 2000; Sada and Nachlinger 1996, 1998).

Springs are inhabited by many spring-obligate species including invertebrates and vertebrates, some of which may be found only in one spring with highly limited distributions (see LaRivers 1949, 1950, 1962). This ecosystem type also provides habitat for 14 MHSCP-covered species including the relict leopard frog (*Rana onca*), which is a candidate for Federal listing under the protection of the Endangered Species Act. The relict leopard frog is a small sized spotted frog with an adult body length of 1 ¾ to 3 ¼ inches (Jennings 1988, 1993). Typical habitat includes permanent small streams, springs, and spring-fed wetlands (Jennings 1988). The species prefers relatively open shorelines where dense vegetation does not dominate. Once thought to be extinct, the relict leopard frog is known to occur at fewer than 10 unique sites (Jaeger and others 2001). The loss of relict leopard frog populations occurred concurrently with the loss or alteration of aquatic habitat due to spring drainage and water development for agricultural and urban applications (Jennings and Hayes 1994). Other notable high-profile species endemic to this ecosystem type not considered here include various species of desert fishes, for example dace (*Rhinichthys* spp.) and pupfishes (*Cyprinodontidae* spp.).

Spring ecosystems are highly sensitive to environmental disturbances. Because water resources are especially prized in arid ecosystems, natural spring systems are used for livestock, recreation, agriculture, and various domestic purposes (Sada and Vinyard 2002). Springs also are indirectly impacted by regional groundwater withdrawal pumping and water diversions. Most springs have been invaded by non-native aquatic and terrestrial species that can affect ecosystem properties (Chapter 3). Invasive species include invertebrates, bullfrogs (*Rana catesbeiana*), crayfish, turtles (e.g., red-eared slider (*Trachemys scripta* ssp. *elegans*)), introduced aquarium species (e.g., mosquito fish (*Gambusia* sp.)), cichlids and other predatory fishes, as well as plants (e.g., Tamarisk species, fan palms). Introduced cichlids are voracious predators and may consume eggs and tadpoles (Romin 1997). Introduced bullfrogs, another fierce predator, are known to eliminate native leopard frogs in the western United States through competition and predation (Hayes and Jennings 1986).

Non-native and unregulated ungulates have been shown to negatively affect spring and associated aquatic habitat by trampling vegetation and soils, and concomitantly causing water quality impacts. Cattle using water sources can draw down smaller water bodies, leaving amphibian egg masses exposed. This leads to desiccation of the eggs, which can increase fungal infections (USFWS 2000b). Cattle can also directly kill egg masses and maturing and adult animals (USFWS 2000b). Loss of streamside vegetation due to cattle grazing can reduce habitat for insects and small mammals (USFWS 2001), which are important dietary components for aquatic species (Cordone and Kelley 1961), including the relict leopard frog. Feral burros also have been implicated in the reduction of frog population numbers due to overgrazing of shoreline vegetation, trampling, and urination and defecation in the water (CBD 2002; Jaeger and Barnes 2001). It should be noted, however, that frogs benefit from open water habitat, which may be increased

by cattle or other ungulate grazing. Three recent population extinctions occurred when emergent vegetation encroached into pools following the removal of livestock (RLFWDG 2001). At still another two sites, after livestock grazing stopped frog populations were reported to stabilize (CBD 2002; Jaeger and Barnes 2010). Management actions require a detailed understanding of the interactions of the variety of influences on habitat condition. Monitoring is also important, so that managers know if the actions taken are leading to the desired conservation outcome. It is important to note that burros and horses rely on predictable water sources when present within any ecosystem type and sustained trampling and grazing at the water sources can have a variety of negative effects.

Chytridiomycosis is an infectious disease of amphibians caused by the fungus *Batrachochytrium dendrobatidis* ("Bd" or chytrid fungus; Berger and others 1998). The extraordinary virulence of chytrid fungus has caused the decline or extinction of hundreds of amphibian species around the world during the last several decades (Skerratt and others 2007) and hundreds more are considered at risk as chytrid fungus spreads into new areas. Chytrid fungus damages the mouthparts of tadpoles, then damages keratin in the skin of metamorphosed frogs, eventually killing them. Spores of chytrid fungus are ubiquitous in soil, but the aquatic spores infecting frogs is relatively new to science (Berger and others 1998). In 1998, chytrid fungus was found in numerous Arizona amphibians (RLFWDG 2001). Reports suggest that chytrid fungus is most virulent at temperatures  $\leq 23$  °C and its pathogenicity and virulence decline significantly at  $\geq 27$  °C (Piotrowski and others 2004). It appears that thermal springs provide important habitat where frogs can persist despite the presence of chytrid fungus. Luckily, the relict leopard frog only occurs naturally in thermal springs that all have source temperatures  $>30$  °C (Jaeger and Haley 2011).

While attention was given to a single species in this section, other notable species exist in this and associated riparian ecosystems. These include various species of pupfishes and daces as well as invertebrates and plants. The habitats that support these species are highly imperiled due to direct effects of historical and ongoing manipulation or destruction, and their conservation will be an ongoing challenge to resource managers. While not discussed in this section, the effects of climate change are likely to intensify the local and regional stressors. Management of the springs ecosystem is particularly difficult because of its critical dependence on already limited water availability.

## Knowledge Gaps and Research Guidance

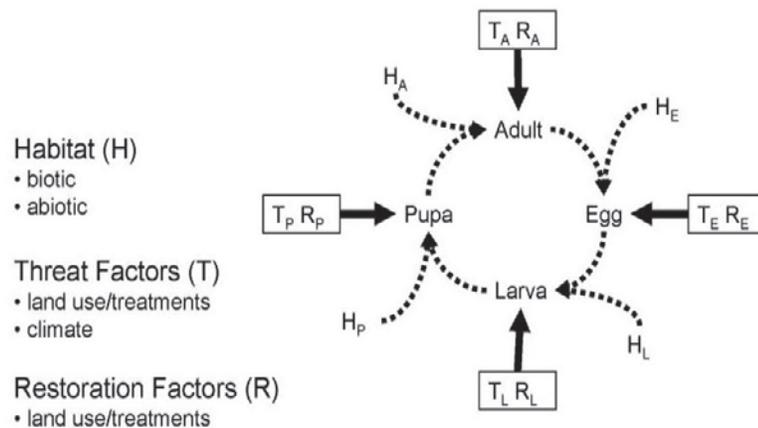
The overview of research on species of conservation concern provided in this chapter is not a complete review of all species and research topics, but it is a good representation of the nature of single species research in southern Nevada. One of the hallmarks of this body of research is that very little is known about the relative threats posed to, or the mitigation actions needed to protect virtually all species of concern 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 on 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 could most benefit conservation programs. In the section below, we provide a case study that illustrates how a research program was organized in a hierarchical and thoughtful way, in order to provide maximum cost-efficiency and ultimate utility in the management of species of conservation concern.

## Research Strategy Case Study: Endemic Butterflies of the Spring Mountains

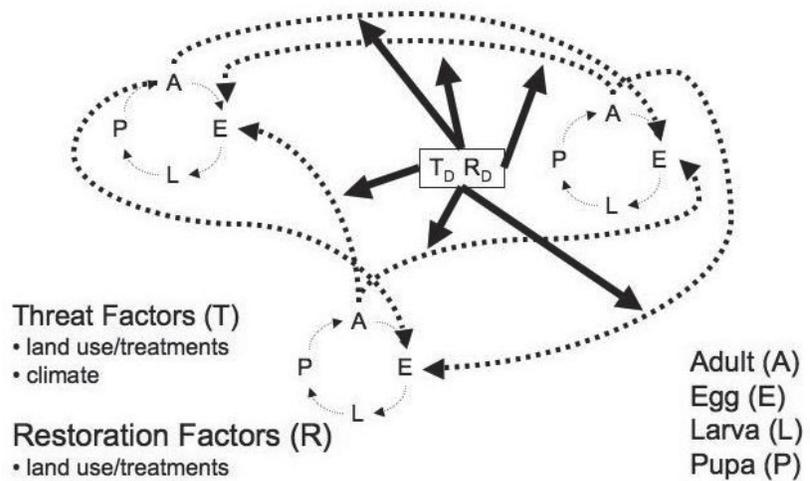
The Spring Mountains are home to numerous endemic species, including eight butterfly taxa, as discussed previously. Four of these species have very limited distributions and there is concern that their populations may be declining. One of these species, the Mt. Charleston blue butterfly, is currently a Candidate species for listing by the USFWS. Very little is known about the autecology and habitat requirements of these eight butterfly species. Conservation of these species can be based on a comprehensive research framework such as the one proposed below. Although this framework is specific to the endemic butterflies of the Spring Mountains, it provides a good example of what is required to fully inform land managers about species of conservation concern.

Initially, it is critical to understand the life cycles and the key habitat, threats, and restoration factors associated with each life history stage for each butterfly species. Detailed information is needed regarding overwintering stages, larval development, pupation, and adult behavior including oviposition, roosting, basking, and mating. For all of these stages, habitat preferences and related phenologies (the specific seasonal timing of life history events) must be understood, as well as potential threats and mitigating restoration factors (fig. 6.1). This kind of natural history information has been critical in other studies of the population persistence of butterflies (e.g., New and others 1995; Weiss and others 1988).

The next step is to describe the species' population structure and dynamics, including identification of the highest priority populations that are critical to the persistence of each butterfly. Butterflies occur in relatively discrete patches or populations across the landscape (fig. 6.2). The degree to which patches of occupied habitat are or are not connected by dispersal is of primary importance for the management of rare species (Hanski and Thomas 1994). From a conservation perspective, it is also important to know if all patches have equal probabilities of going extinct or being recolonized following extinction (as is assumed in a classic metapopulation). In reality, all patches do not have equal probabilities of persistence through time; instead, some locations act as demographic sources (providing migrants that move to other locations) while others act as sinks (receiving immigrants that act to maintain local populations that would otherwise not persist) (Boughton 1999).

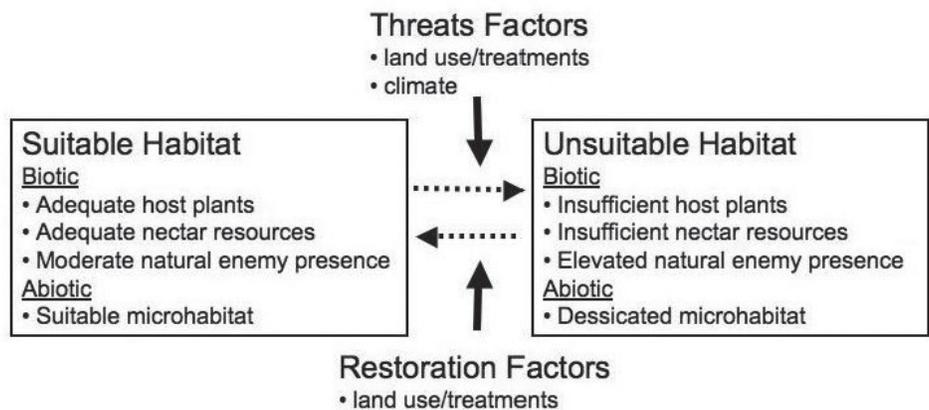


**Figure 6.1**—Conceptual model illustrating how habitat factors (H), threats (T), and/or restoration activities (R) could impact a butterfly or invertebrate species, and their relationships with critical habitat factors at the adult (A), egg (E), larval (L), and pupa (P) life history stages at the within-patch scale.



**Figure 6.2**—A conceptual model showing how threats and restoration can affect among (habitat) patch dispersal. Patches are represented by life cycle diagrams for adults (A), eggs (E), larva (L) and pupa (P), and dispersal among patches is shown as dotted lines being potentially impacted by both threats ( $T_D$ ) and restoration ( $R_D$ ).

The third step is to describe the structural and floristic composition of the habitat for each species, including habitat used during each season as well as for dispersal. Attempts to characterize habitat for butterflies and other species can often be hampered by pre-existing biases regarding “suitable conditions” for a particular species. For butterflies, presence of larval host plants and nectar resources is often assumed to be sufficient to define requisite habitat, but that assumption can be erroneous. There is a pressing need to understand the net habitat requirements (across life history stages) for focal butterfly species, and in particular how to distinguish between suitable and unsuitable habitat (fig 6.3). Specifically, there is a need to characterize suitable habitat (both within and among patches) associated with population persistence. In some cases natural enemies may be an important habitat consideration, because mortality from natural enemies can



**Figure 6.3**—A habitat dynamics model illustrating the transition of habitat from suitable to unsuitable (or vice versa) depending on the influence of threats and/or restoration factors (the list of habitat characteristics here is illustrative, not exhaustive).

be a significant factor that is frequently ignored in butterfly conservation plans (Bergman 1999). Precise knowledge of habitat requirements is needed to inform a range of management decisions including where and how to initiate restoration efforts, where to allocate resources when it comes to mitigating certain threats, and where to attempt reintroductions of butterflies should that become necessary. Knowledge of habitat requirements can also direct management efforts by identifying species most at risk through habitat destruction or degradation. This is especially important in the Spring Mountains where vegetation management activities (i.e. fuels reduction/thinning operations) could have an impact/threat on the habitat condition of these species and could easily be modified.

As only a final step, habitat restoration and mitigation actions should be evaluated. Ecological restoration is accomplished by the redirection of natural populations, communities, wildlife habitat, or other ecosystem processes toward trajectories deemed more desirable (Jordan and others 1987). These trajectories can be defined in many ways, but are often focused on promoting specific habitat features known to be critical to a species, which is the focus of conservation planning (e.g., the Spring Mountains endemic butterflies). The development of relevant restoration treatments to achieve desired outcomes requires an understanding of the essential habitat features of the focal species, and the ecological processes necessary to increase the abundance and/or quality of these habitat features. Accordingly, it is not prudent to initiate and/or implement restoration activities until such information is available. In fact, many restoration attempts have failed, and resources have been wasted, because of insufficient knowledge regarding species' autecology (Montalvo and others 1997; Pullin 1996). In brief, it is critical to know what is damaged and what one should be repairing before repair attempts are initiated. However in the short-term it may be prudent to eliminate stressor impacts to reduce the potential threat so the species is able to persist even when the desired information to make a completely informed decision is unavailable.

## Management Implications

Historically, actions such as limiting grazing or closing OHV trails have been some of the primary tools used by land managers in southern Nevada to reduce anthropogenic impacts to species of conservation concern. However, managers are increasingly faced with broader and more complex issues that cannot be effectively addressed by regionally or locally based management actions. For example, few if any options exist for local resource managers to directly combat effects associated with climate change or nitrogen deposition, even though they are responsible for ensuring the protection of the species directly or indirectly affected by such stressors. Research that can help disentangle local or regional effects from global effects would be especially useful for conservation planning and management of species of conservation concern. Additionally this would help focus management toward factors where there are actionable options.

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