Chapter 9: Effects of Climate Change on Terrestrial Animals

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Introduction

Climate Change and Terrestrial Species

The Intermountain Adaptation Partnership (IAP) region encompasses a high diversity of grassland, shrubland, and forest habitats across a broad range of elevational gradients, supporting high biodiversity in the interior western United States. Terrestrial species comprise a wide range of life forms, each expressing varying levels of habitat specialization and life history traits. Species exist within complex communities that have formed over time through a long process of adaptation and coevolution. Over the last century, this balance has been disrupted first by human-induced changes to fire regimes and land conversion, and more recently by climate change.

Currently, the IAP region is facing unprecedented rates of change in climatic conditions that may outpace the natural adaptive capacities of some native species (box 9.1). Climate change is expected to alter the structure and composition of plant and animal communities and destabilize some of the properties and functions of existing ecosystems (box 9.1). The nature of climate change, which includes increased variability and more extreme conditions, will favor species adapted to frequent disturbance and potentially increase the abundance of invasive species. Limited water availability will be exacerbated as higher temperatures increase evaporation rates and human consumption (Chapter 3 and box 9.2). Despite a growing body of science, the magnitude and likelihood of some climate effects remain uncertain. Abrupt changes in conditions are likely to vary across landscapes, and species will vary in their sensitivity to climate. Climate also influences dynamic processes such as wildfire and insect outbreaks, as well as interactions between disturbances.

Climate effects for terrestrial species can be considered in four categories:

- **Habitat loss and fragmentation** are already increasing in animal populations, and the location and condition of suitable habitats will be further altered by changes in temperature and precipitation (Ibanez et al. 2008; McCarty 2001; Sekercioglu et al. 2008).
- **Physiological sensitivities** are typically considered innate characteristics of a species that influence how well it may cope with changing temperature and precipitation conditions.
- **Alterations in the timing of species life cycles** that result from changes in seasonal temperature and precipitation regimes have direct impacts on migration, hibernation, and reproductive success.
- **Indirect effects** on species occur through disruption of predator-prey, competitor, and mutualistic interactions within and across communities.

In the short term, climate-related changes will affect food, cover, and nest site availability. Decreased plant productivity during droughts will reduce food supplies and seed dispersal by small mammals and birds within forest habitats (McKinney et al. 2009; Tomback and Achuff 2010). Habitat changes are expected to reduce roost and nest sites as plant mortality increases because of the interactive effects of drought, wildfire, and insects. Abiotic features of habitat, such as snowpack, are also likely to change, causing negative impacts for snow-dependent species (McKelvey et al. 2011; Murray et al. 2008). Over longer time periods, shifts in habitat are likely to disrupt many communities as the distribution and abundance of species change in response.

Species may respond to habitat changes by moving into more favorable ranges or otherwise adapting, or by going extinct. Shifting habitats can be inaccessible to species with low dispersal ability, and migratory species will be exposed to disparate changes across a large geographic area (Jiguet et al. 2007; Visser 2008). In the absence of adaptation, losing favorable habitat can reduce fitness and abundance, with effects on biodiversity (Settele et al. 2014). Even where species are capable of shifting habitats, there is no certainty that new habitats will effectively fill the roles in current established forests. In the northeastern United States, some bird species in spruce-fir forests have shifted to lower elevations in response to climate change, but these “new” habitats are marginal, so populations may encounter low reproductive success (DeLuca 2012; DeLuca and King 2017).

Physiological requirements and limitations related to temperature and moisture determine critical components of energetics, survival, and reproduction in animal species (Bernardo and Spotila 2006; Helmuth et al. 2005; Sinervo et al. 2010). A species can tolerate the range of new ambient conditions, be more restricted in activity, or be subject to more extreme climate-related events such as fires or storms

Box 9.1—Summary of Effects of Climate Change on Terrestrial Animal Species

Conservation of important natural resource values, including biodiversity, will be increasingly difficult as community compositions begin to shift in response to climatic changes. The ability of terrestrial species to respond successfully to climate change depends on their sensitivity to expected climatic conditions, innate capacity to deal with change, ongoing threats and issues that reduce resilience, and capacity for management to reduce negative impacts.

Climate impacts for terrestrial species can be considered in four categories:

- **Habitat loss and fragmentation**, which are already major driving forces in declining animal populations. The location and condition of suitable habitats will be further altered by changes in temperature and precipitation (Ibanez et al. 2008; McCarty 2001; Sekercioglu et al. 2008).
- **Physiological sensitivities** or areas of resilience. These are typically innate characteristics of a species that influence how well it may cope with changing temperature and precipitation.
- **Alterations in the timing of species life cycles** resulting from changes in seasonal temperature and precipitation regimes. Changes in life-cycle timing have direct impacts on migration, hibernation, and reproductive success.
- **Indirect effects on species** through disruption of predator-prey, competitor, and mutualistic interactions within and across communities. These effects will be profound and the most difficult to predict.

Effects of Habitat Change

- The literature describes a dynamic future resulting from multiple processes both physical (hydrology, soils) and biological over short and long time scales. Warming trends and shifts in seasonal precipitation patterns and temperatures will exert considerable control over soil moisture, plant regeneration, disturbance regimes, and the presence of disease and pest and invasive species.
- Altered tree species distribution and abundance have important implications for availability of cover and food resources for animal species. In the immediate future, reduced cone production and loss of mature, cone-producing trees as a result of drought, wildfire, and insect outbreaks will limit food resources, especially in high-elevation forests. Over longer time periods, shifts in tree species composition will affect nest site availability and predator-prey dynamics in animal communities.
- Climate change will facilitate range shifts within many habitats and in particular, an uphill migration of many tree species. For some animal species, these shifts may represent an expansion of suitable habitat, but for others, shifts will represent significant declines in habitat distribution.
- Abiotic changes in snowpack amount and duration will be an important determinant of species response in most forested habitats. For snow-dependent species such as wolverine and lynx, these changes mean a reduction in winter habitat. For ungulates, lower snowfall increases areas available for winter forage. Reduced snowpack may also limit physiological protection provided by winter and spring snowpack.
- Climates suited to shrublands and grasslands are projected to expand over the next century, although uncertainty exists about which communities will persist in the future. Considerable change in plant species composition and structure are likely because of the combined effects of drought, fire, invasive annuals, and changes in the timing of precipitation events.

Species Assessments

Flammulated owls, wolverines, and greater sage-grouse were the most vulnerable species assessed in this analysis. Utah prairie dogs and American three-toed woodpeckers were the least vulnerable with total scores indicating a relatively neutral response to expected changes. Habitat and physiology scores varied the most among the species assessed, and altered phenology was a common issue for most species. Habitat loss was often an issue for species restricted to high elevation or habitats associated with surface water.

Conclusions

Potential shifts and loss of habitat and habitat features as a result of climate change have both short-term and long-term implications for wildlife species. It is difficult to say with certainty which climate influences will have the greatest effects on habitats and terrestrial species. However, our extensive review of the scientific literature and use of state-of-science vulnerability assessment tools have identified the habitats and wildlife that are most likely to be affected either positively or negatively in a warmer climate.

Box 9.2—Summary of Expected Future Climatic and Hydrological Conditions

- Increased mean annual temperature and warming in all seasons (Diffenbaugh and Giorgi 2012; Romero-Lankao et al. 2014)
- Increased occurrence of extremely hot seasons and warmer summers (Diffenbaugh and Giorgi 2012; Romero-Lankao et al. 2014)
- Decreased snowfall and snowpack, and winter precipitation falling as rain instead of snow (Diffenbaugh and Giorgi 2012)
- Variable precipitation patterns during the year, increased frequency of extreme storms and shift in precipitation events and amounts (Doesken et al. 2003; Worrall et al. 2013)
- Decreased precipitation for some areas, particularly winter precipitation for the American Southwest (Seager and Vecchi 2010; Seager et al. 2007)
- Increased number of hot days, increased drought frequency, and greater frequency of warm, dry summers (Allen et al. 2010; Drake et al. 2005; Gutzler and Robbins 2011; Romero-Lankao et al. 2014; Sheffield and Wood 2008)

(Walsberg 2000). Aestivation, torpor, inactive life stages, and low metabolic rates can improve the adaptive capacity of a species to cope with fluctuating resources (Bronson 2009; Humphries et al. 2002). In addition, more variable and extreme weather can have positive effects on availability of ephemeral water bodies, maintenance of some spawning habitats, and prevention of encroachment of woody plants.

Species whose phenology or timing of activities (e.g., reproduction, migration) is triggered by temperature or moisture cues may be at a disadvantage in a changing climate. When life events become unsynchronized with critical resources or favorable conditions, survival and reproduction decline (Both et al. 2006). Species at the greatest risk of timing mismatch are those that migrate over long distances, obligate hibernators, and species that rely on ephemeral resources. Warmer temperatures are leading to earlier snowmelt, plant green-up, and flowering (Romero-Lankao et al. 2014; Settele et al. 2014), with substantial consequences for terrestrial species. In the IAP region, spring advancement has led to breaks in hibernation (Ozgul et al. 2010), earlier flowering (Hülber et al. 2010; Lambert et al. 2010), earlier arrival dates for migratory birds (Thorup et al. 2007), and decoupling of community phenological behavior (Both et al. 2010; Parmesan 2006; Thackeray et al. 2010).

Earlier spring growth and a longer growing season (Settele et al. 2014) could lead to increased habitat and forage availability and longer breeding seasons for some species. However, ungulates and small mammals are known to be particularly sensitive to the timing and duration of plant phenology (Senft et al. 1987), and it is unclear how current trends will affect them. Earlier snowmelt can also decrease floral resources, thus affecting insect population dynamics and pollinators (Boggs and Inouye 2012; Gilgert and Vaughan 2011). Species with the capacity to engage in irruptive migration or explosive breeding will be least affected by increased resource variability (Visser et al. 2004). Longer, more flexible, and more productive reproductive periods are also beneficial traits for coping with variable and unpredictable conditions, although species with short reproductive periods may be favored during drought (Chessman 2013; Jiguet et al. 2007).

Individual species response to climate change may have ramifications for entire communities by affecting predator-prey relationships, disease, pollination, parasitism, or mutualism. Gradual warming and variable precipitation could reduce resources in favor of diet and habitat generalists; local extinctions and range shifts have been documented in small mammals (Morelli et al. 2012; Moritz et al. 2008; Rowe 2009; Rowe et al. 2011). Generalist species can switch to different prey or host species and thus are not as sensitive to changes as species with more restricted diets (Chessman 2013). These changes in biotic interactions can further alter vulnerability if tied to survival or reproduction (Freed et al. 2005; Gilman et al. 2010; Memmott et al. 2007). In the IAP region, climate-related changes in snowpack and pine cone production will probably affect predator-prey and competitive interactions between snowshoe hares and Canada lynx (Murray et al. 2008), and between boreal owls and martens (Boutin et al. 1995), as well as between keystone species such as red squirrels (fig. 9.1) and Clark's nutcrackers. Ultimately, species composition among habitats may change under new selective pressures. Unless otherwise specified, common and scientific names for all species mentioned in this chapter are given in Appendix 9.

Finally, it is important to note that some climate-related habitat changes will benefit terrestrial species. Elevated carbon dioxide levels and warmer temperatures can enhance the growth of some plants and lengthen the growing season, providing more forage or longer breeding periods (Morgan et al. 2001). Reduced snowpack in quaking aspen and higher elevation habitats could provide increased winter range for ungulate species. Tree damage and mortality caused by drought and insect outbreaks can increase insect food sources and lead to more down woody debris, which provides cover for many species (Hahn et al. 2014). Disturbances

Figure 9.1—Red squirrel. This keystone species depends on pine cones as a food source and provides food for other species by caching cones (photo: U.S. Fish and Wildlife Service)

from climate change or nonclimate stressors that create standing snags and large woody debris can benefit cavity-dwelling animals in the short term. However, these benefits may be short lived because a shift to early-seral forests will ultimately reduce important habitat components for these species (Weed et al. 2013).

Climate Change Assessment for Habitat

In this assessment, we identify critical needs and opportunities for terrestrial species under expected climate change. First, we review the literature to identify the major effects of climate change for wildlife within specific habitats in the IAP region. Second, we use an index-based vulnerability assessment system to quantify vulnerability for 20 species.

Potential shifts and loss of habitat and habitat features as a result of climate change have both immediate and long-term implications for wildlife species. The following discussion considers the many ways in which forests, woodlands, and nonforest habitat are likely to be influenced by climatic changes, and summarizes our knowledge of the consequences of those changes for wildlife within specific vegetation types. It is difficult to say with certainty which climate influences will have the greatest effects on ecosystems and associated terrestrial species. Through reviewing the scientific literature, however, we can begin to identify the ecosystems and wildlife that are most likely to be affected either positively or negatively under warmer conditions.

The literature depicts a dynamic future resulting from multiple biophysical processes over short and long timescales. Warming trends and shifts in temperature and seasonal precipitation patterns will exert considerable control over soil moisture, plant regeneration, disturbance regimes, and the presence of diseases and invasive species. We cannot at this time predict what these effects, which also interact, will mean for future habitat and wildlife nonforest community composition, although these conditions will probably be different from those that have occurred in the past.

Forest Vegetation

We have considered climate-related effects for six forest types as defined by the U.S. Department of Agriculture Forest Service (USFS) Intermountain Region (Chapter 6). The range of potential effects to any one of these types varies, as does the potential effect (positive or negative) for the constituent species within the habitats. To understand potential species response to climate, we must consider both direct effects related to environmental conditions (e.g., heat waves, snowpack) and indirect effects arising from the alteration of forest composition and distribution. Because tree species have varying capacities to adapt to climate change and wildfire, significant changes in the structure, composition, and distribution of forests are likely.

Subalpine Pine Habitat

Subalpine whitebark pine communities provide food, cover, and nesting sites for a diversity of terrestrial species (table 9.1). Pine seeds are a major food source for many birds and mammals, including Clark's nutcrackers, Steller's jays, common ravens, mountain chickadees, red-breasted nuthatches, pine grosbeaks, Cassin's finches, chipmunks, golden-mantled ground squirrels, red squirrels, black bears, and grizzly bears (Tomback and Kendall 2001). Dusky grouse are highly dependent on subalpine pine communities, where they roost in dense crowns of whitebark pine, feed on needles and buds, and obtain shelter from wind and predators (Andrews and Righter 1992).

Altered distribution and abundance of tree species will affect many animal species (box 9.3). Climate change is likely to alter the effects of invasive species, such as cheatgrass, accelerate the migration of twoneedle pinyon and junipers into bristlecone pine areas (Van de Ven 2007), and shift the relative dominance of whitebark pine and bristlecone pine (Briffa et al. 2008; Gibson et al. 2008; Salzer et al. 2009) (Chapter 6). Fire exclusion that accelerates succession and the establishment of other conifer species, such as Douglas-fir, Engelmann spruce, and subalpine fir (Tomback and Achuff 2010), results in loss of food, structural heterogeneity, shelter, cover, and ultimately the biodiversity of subalpine habitats (Smith 1990). Climate-related changes to forest composition will alter competition for nest sites, cavities, and food (Bunnell 2013), as well as other species interactions.

Table 9.1—Terrestrial vertebrates that depend on subalpine whitebark pine habitat for at least part of their life cycle (Lonner and Pac 1990; Tomback 1978; Tomback and Kendall 2001).

Terrestrial vertebrate group	Associated species
Raptors	Cooper's hawk, golden eagle, great horned owl, northern goshawk, prairie falcon, red-tailed hawk
Long- and short-distance migratory birds	Allen's hummingbird, common nighthawk, downy woodpecker, hairy woodpecker, mountain bluebird, western tanager, white-throated swift
Mammals	American marten, bighorn sheep, bushy-tailed woodrat, Canada lynx, common porcupine, coyote, elk, mountain lion, mule deer, snowshoe hare, yellow-bellied marmot, wolverine

Loss of trees through these mechanisms will also result in less shade and cover, fewer snowdrifts, and earlier snowmelt (Means 2011). A change in snow cover dynamics may reduce populations of snowshoe hare, a key prey for Canada lynx (Murray et al. 2008; Squires et al. 2010). Climate-related changes to subalpine pine and spruce-fir forests will probably reduce food and nest resources for the boreal owl through several mechanisms (Bunnell 2013) (box 9.3).

Mutualisms may also be disrupted where warm, dry conditions may cause species range shifts in mammals and birds that are important seed dispersal agents (Tomback and Kendall 2001). For example, regeneration of whitebark pines after wildfire is largely from seed caches left by Clark's nutcrackers (Lanner 1996; Lanner and Vander Wall 1980). Whitebark pine depends nearly exclusively on nutcrackers for dispersal, although nutcrackers will feed on and cache seeds from other pines (limber pine, bristlecone pine) that co-occur with whitebark pine. Plasticity in foraging behavior of the nutcracker may enable it to survive range shifts in suitable habitat, but potentially to the detriment of whitebark pine, which could undergo reduced regeneration, dispersal to other areas, and reduced genetic variability

Box 9.3—Potential Effects of Climate-Related Changes on Subalpine Pine and Subalpine Spruce-Fir Habitats for Terrestrial Species

- Declines of forest types at high elevation will result in fewer microhabitats for plants and animals, including blue grouse (Andrews and Righter 1992), and may depress populations of Neotropical migrants such as western tanagers, flycatchers, warblers, and finches (Pyle et al. 1994).
- Altered food supplies and seed dispersal abilities of small mammals and birds will occur with increasing tree damage and mortality and reduced cone production (McKinney et al. 2009; Tomback and Achuff 2010).
- Increased wildfire and insect outbreaks could diminish late-successional dense canopy forests preferred by northern goshawks and American martens (Graham et al. 1999; Kennedy 2003).
- Coarse woody debris left from disturbance may benefit American martens (Buskirk and Ruggiero 1994), although decreased habitat and population connectivity are likely for this species (Wasserman et al. 2011).
- Increased tree mortality and downed wood from wildfire and insect outbreaks may increase nesting sites for species such as American three-toed woodpeckers (Wiggins 2004) and red-breasted nuthatches that use tree snags (Bunnell 2013). Drought-related outbreaks of insects such as wood-boring beetles will also benefit American three-toed woodpeckers (Hansen et al. 2010).
- Boreal owl nest success and survival are tied to prey abundance, so warmer and drier conditions that decrease small mammal populations will negatively affect owl populations (Hayward 1989; Hayward and Verner 1994).
- Snow crusting from repeated freeze-thaw cycles hinders winter hunting of boreal owls, which dive through snow to capture prey (Hayward and Verner 1994).
- Reduced spring snow cover will reduce availability and increase fragmentation of habitat for wolverines, which need snow cover and cool summer temperatures for denning (Copeland et al. 2010; Peacock 2011). Without persistent spring snow cover, wolverine populations may not be able to survive and reproduce successfully (Brodie and Post 2009; McKelvey and Copeland 2011; Peacock 2011).
- Reduced snowpack will reduce suitable nesting habitats and cover for snowshoe hares (Murray et al. 2008).
- Decreased snowpack will reduce habitat quality for Canada lynx and snowshoe hares (Squires et al. 2010, 2013).

(Tomback and Kendall 2001; Tomback and Linhart 1990). Furthermore, reduction in pine seed production means more competition for this resource among birds, squirrels, and other mammals, and a greater chance of species consuming the seeds instead of caching or storing them. Whitebark pine provides an important seed food source for grizzly bears and red squirrels (themselves a prey source for grizzlies), and populations may suffer with increased tree mortality (Mattson and Reinhart 1996). With a reduction in seed availability in the subalpine zone in late summer and fall, grizzly bears will wander farther in search of food, very likely increasing their encounters with people (Mattson et al. 1992; Tomback and Kendall 2001).

Subalpine Spruce-Fir Habitat

Spruce-fir forests provide cover and nesting sites for a diversity of species (table 9.2). Numerous studies point to the importance of structurally diverse stands for supporting biodiverse communities. Standing snags and down woody debris are important habitat features that provide cavities for birds and small mammals (Bunnell 2013; Scott et al. 1978), especially for boreal owls, American three-toed woodpeckers (Klenner and Huggard 1997; Leonard 2001), and red-breasted nuthatches (Bunnell et al. 2002). American three-toed woodpeckers prefer mature, old-growth forests with insect-infested snags and dying trees (Klenner and Huggard 1997; Leonard 2001). Red-breasted nuthatches nest in trees broken off by heart rot and wind (Bunnell et al. 2002). American martens, fishers, and black bears use tree cavities formed by fungi and decay or fire (Bunnell 2013). Dense stands also provide ample shade during summer for ungulates, small mammals, birds, and bears (Blanchard 1980). Dusky grouse overwinter in subalpine spruce-fir and rely on the dense cover to escape predators (Schroeder 1984). Both Canada lynx and snowshoe hares prefer older spruce-fir forests with dense understory canopies for cover, foraging, and denning, especially habitats with ample winter snow cover (Squires et al. 2010, 2013).

These forests provide important browse and forage in addition to nesting and cover sites. Engelmann spruce is browsed when other food resources are scarce (Alexander 1987). Spruce grouse and dusky grouse feed on buds and needles of spruce and fir (Schroeder 1984; Steele et al. 1981), and spruce seeds are consumed by small mammals and birds (Alexander 1987; Youngblood and Mauk 1985). Red squirrels are known to store spruce and fir seeds in middens (Lanner 1983; Uchytil 1991). Subalpine fir is a minor browse for mule deer, elk, bighorn sheep, and snowshoe hares, but a major food source in winter and spring for mountain goats (Saunders 1955) and in winter for moose (Peek 1974). In Yellowstone National Park, grizzly bears are known to strip away bark and eat the cambium of subalpine fir (Blanchard 1980); huckleberries associated with subalpine fir are a critical food for grizzly bears (Contreras and Evans 1986).

Spruce-fir forest distributions and the presence of important habitat features such as snags and downed wood are likely to change given the likelihood for an increase in fire frequency with drought and faster snowmelt. Some vegetation projections show movement of spruce and fir into alpine areas (Decker and Fink 2014). Climate and nonclimate stressors may increase white fir and Douglas-fir regeneration over ponderosa pine at low-elevation sites and increase Engelmann spruce and subalpine fir at high-elevation sites (Battaglia and Shepperd 2007; Fulé et al. 2002; Jenkins et al. 1998). Spruce and fir growth is reduced when snowpack is low (Hu et al. 2010), but a warmer, longer growing season may improve seedling survival, provided there is shade (Moir and Huckaby 1994).

Species-habitat interactions in spruce-fir forests are affected through changes in food and shelter for terrestrial species (box 9.3). Tree damage and mortality can affect food supplies and the seed dispersal abilities of small mammals and birds. Changes in tree mortality may cause declines in suitable nesting habitats for some species such as northern goshawk (Graham et al. 1999; Kennedy 2003), but an increase in nesting sites for others such as the American three-toed woodpecker and red-breasted nuthatch that use tree snags and down woody debris (Bunnell 2013; Wiggins 2004). Climate-related changes in primary cavity nesters will also influence availability and competition for cavity nest sites (Hayward and Hayward 1993).

Spruce-fir forest provides critical microclimates for wolverines and boreal owls, both of which have low temperature thresholds and rely on cooler habitats during the summer (Copeland et al. 2010). Warming will negatively affect both species through this limiting factor, especially at the southern edge of their range (Copeland et al. 2010; Hayward 1997; Hayward and Verner 1994; McKelvey et al. 2011; Peacock 2011). Loss of trees will reduce shade and cover, reduce the number of snowdrifts, and lead to earlier snowmelt with direct effects on species that rely on snow cover (box 9.3).

Table 9.2—Specific resources provided by spruce-fir forest for terrestrial species.

Browse, cover	Nesting, cover, foraging	References
Mule deer, elk, moose, bighorn sheep, mountain goat, woodland caribou (northern Idaho), black bear, grizzly bear, snowshoe hare, northern flying squirrel, red squirrel, porcupine, American marten, fisher, Canada lynx, mice, voles, chipmunks, shrews	Northern goshawk, boreal owl, great horned owl, northern flicker, woodpeckers, flycatchers, kinglets, nuthatches, dark-eyed junco, thrushes, chickadees, crossbills, pine siskin, sapsuckers, brown creeper, dusky grouse, sooty grouse, spruce grouse	Scott et al. 1982; Steele et al. 1981; Uchytil 1991

Creation of open space resulting from tree mortality within spruce-fir forests may encourage other species to move in and may thus disrupt predator-prey relationships and competitive interactions. For example, red-tailed hawks, great horned owls, and long-eared owls can take over northern goshawk nesting sites (Graham et al. 1999). Loss of mature spruce-fir forests and change in snow cover dynamics may reduce populations of snowshoe hare, a key prey species for Canada lynx (Murray et al. 2008; Squires et al. 2010). Red squirrel midden activity declines following drought and wildfire (Mattson and Reinhart 1996), thereby reducing food resources for grizzly bears.

Climate-related changes to spruce-fir habitat will probably reduce food and nest resources for boreal owls through several mechanisms (Bunnell 2013). Boreal owls and American martens prefer mesic over drier spruce-fir forests because of their preferred prey, red-backed voles (Buskirk and Ruggiero 1994; Hayward 1989), which forage on fungal species found in mesic habitats (Rhea et al. 2013). Boreal owl populations are directly related to prey abundance, and warmer and drier conditions that reduce vole numbers may negatively impact nest success and bird survival (Hayward 1989; Hayward and Verner 1994). American marten predation on owls and nests also increases when vole abundance is low (Hayward and Hayward 1993).

Lodgepole Pine Habitat

Lodgepole pine habitat provides cover for mule deer, elk, moose, ruffed grouse, and small mammals and birds (Anderson 2003; Boccard 1980). The value of cover changes throughout the year and by successional stage. Mature, closed-canopy forests provide little forage but excellent cover, whereas open, immature stands support understory growth of grasses, forbs, and shrubs (Ramsey and West 2009). In Utah, lodgepole pine forests are critical summer habitat for mule deer, elk, and Rocky Mountain bighorn sheep, and crucial winter habitat for moose (Baldwin and Banner 2009). Northern goshawks nest in lodgepole pine canopies; lodgepole pine forest communities with mature, large trees are considered high-quality habitat for breeding (Graham et al. 1999). Down woody debris provides cover and drumming sites for ruffed grouse (Boag and Sumanik 1969; Hungerford 1951). Dense lodgepole stands in Washington State with abundant snowshoe hares were the preferred habitat for Canada lynx (Koehler 1990).

Palatability of lodgepole pine is poor, and trees are often browsed only when other food is scarce (Alexander 1986; Kufeld et al. 1973; Ritchie 1978). Snowshoe hares, pocket gophers, voles, squirrels, porcupines, and black bears feed on cambium because the bark is thin and easy to remove (Alexander 1986; Boccard 1980; Sullivan 1985). Foraging on seedlings and saplings by mammals can reduce growth and regeneration and cause significant damage and mortality in lodgepole pine (Barnes 1974; Ferguson 1999; Koch 1996; Sullivan 1985; Sullivan et al. 1993). Mountain pine beetle larvae are a good source of food for woodpeckers (Bull 1983). Pine seeds are an important food for red crossbills, red squirrels, dusky grouse, spruce grouse, and other mammals and birds (Anderson 2003; Benkman 1999; Benkman et al. 2003). Red squirrels are a significant seed predator (Benkman 1999; Lotan and Critchfield 1990).

Vulnerability to climate-related disturbances is likely to be greatest for lodgepole pine at the southern edge of its distribution (western Nevada, northeastern Utah). Typically, lodgepole pine will dominate subalpine spruce-fir after a stand-replacing fire, and will eventually be succeeded by aspen or Engelmann spruce, or both, if a viable seed source is available (Stahelin 1943). Pine beetle outbreaks are likely to increase in a warmer climate, and beetle-related mortality is likely to increase under more arid conditions. Declines in lodgepole pine could reduce food supplies and seed dispersal abilities of small mammals and birds.

Mortality of lodgepole from beetle attacks will reduce critical thermal cover and important winter forage for moose (Ritchie 1978; Wolfe et al. 2010a). Reduced lodgepole pine forage can induce vitamin E or selenium deficiency, leading to lameness, excessive salivation, and death from heart degeneration (Blowey and Weaver 2003; Flueck et al. 2012; Wolfe et al. 2010b). Loss of trees will also affect northern goshawk habitat over time. Goshawk will continue to nest in forests with up to 80-percent beetle-killed trees as long as trees are standing, but as trees start to fall, habitat value for goshawk declines (Graham et al. 1999). Loss of trees and fragmentation of mature forests, especially near riparian areas, will affect American marten habitat (Buskirk and Powell 1994; Zielinski 2014).

Down woody debris from insect outbreaks creates cover for many species (Hahn et al. 2014) including golden-mantled squirrel and northern flying squirrel (Saab et al. 2014). Beetle-killed forests benefit cavity-nesting birds (American three-toed, downy, pileated, and hairy woodpeckers, mountain chickadee, red-breasted nuthatch, house wren) and those nesting in understory shrubs (chipping sparrow, yellow warbler, Swainson’s thrush, flycatchers). Mountain pine beetle outbreaks provide food (beetles and beetle larvae) for bark-drilling woodpeckers, such as American three-toed woodpeckers and black-backed woodpeckers (Saab et al. 2014). Serotiny and dropping of unopened cones triggered by warm, dry conditions after a mountain pine beetle infestation may benefit ground-foraging mammals and red squirrels (Teste et al. 2011). This may explain short-term increases in mammal diversity after beetle disturbances, including elk, mule deer, snowshoe hares, squirrels, voles, and chipmunks (Stone 1995).

Moose that inhabit these forest types may suffer range constraints and contractions from warmer, drier conditions, especially at the southern distribution of their range (e.g., Utah) (Rennecker and Hudson 1986; Wolfe et al. 2010a). In addition, warm spring temperatures coupled with low to absent snow cover may increase winter tick abundance and infestation on moose, leading to mortality (Delgiudice et al. 1997; Wolfe et al. 2010a).

Mixed Conifer Habitat

Mixed conifer communities provide a diverse set of habitats and support a large number of species (table 9.3). Mixed conifer sites with deep snow are important habitat for snowshoe hares and voles, which, in turn, are winter food for American marten (Zielinski et al. 1983). Mature, large-diameter trees of ponderosa pine in dry mixed conifer forest are suitable nesting sites for northern goshawks (Crocker-Bedford and Chaney 1988) and flammulated owls (Hayward and Verner 1994). Pine seeds are important food for Clark's nutcrackers, Cassin's finches, and pine siskins (Hutto et al. 2015). Open, shrubby understory patches created by low-intensity fires provide nesting sites for hummingbirds, lazuli buntings, and MacGillivray's warblers (Hutto 2014).

Shifts in the distribution and abundance of mixed conifer forest will lead to more early-successional stands and will not favor species that prefer mature, diverse forests with large-diameter trees (table 9.4). More high-intensity fires could also eliminate habitat patchiness and suitability for hummingbirds, lazuli buntings, and MacGillivray's warblers (Hutto 2014). Loss of mixed conifer forest or replacement by a less diverse plant community following a stand-replacing fire may reduce diversity of insects (Gilgert and Vaughan 2011), including endemic butterflies (e.g., Mt. Charleston blue butterfly, Morand's checkerspot, Spring Mountains acastus checkerspot, dark blue) (Ostoja et al. 2013). In particular, Mt. Charleston blue butterflies are susceptible to extreme precipitation and drought (Murphy et al. 1990). In addition, climate change effects on host plants (e.g., Torrey's milkvetch) could negatively affect these butterflies (Gilpin and Soulé 1986; Shaffer et al. 2001).

Several species may benefit from increased mortality of trees caused by fire and insect outbreaks (table 9.4). Dead trees provide good nesting and foraging (beetle larvae, ants) for many bird species. Coarse woody debris will also benefit American martens, which occasionally use cool-moist mixed conifer forest (Buskirk and Ruggiero 1994). Seeds released after fire are important food for Clark's nutcrackers, Cassin's finches, and pine siskins (Hutto et al. 2015). Black-backed woodpeckers are a burned-forest specialist known to favor recent high-intensity burns, where it feeds on wood-boring beetle larvae (Bent 1939; Fayt et al. 2005; Hutto 2008).

Extended effects on species interactions are also likely. Snowpack conditions are likely to affect snowshoe hares and voles, which rely on deep snow for foraging and caching; in turn, changes in populations of these species will affect winter food resources for predators such as Canada lynx and American martens (Zielinski et al. 1983). Reduced snowpack could expose martens to life-threatening temperatures in winter.

Aspen Habitat

Quaking aspen forests provide summer shade, hiding places, and thermal cover for many mammals and birds (DeByle 1985b; Shepperd 1986). Deer use forests as fawning grounds (Kovalchik 1987), snowshoe hares use them for hiding and resting in summer (DeByle 1985a,b), and ruffed grouse use accumulated snow in winter for burrowing cover (Perala 1977). Aspen and associated shrubs, forbs, and grasses are also important breeding and foraging resources. Elk, mule deer, white-tailed deer, moose, and livestock

Table 9.3—Some bird and butterfly species that rely on mixed conifer habitat (Hutto et al. 2015; Ostoja et al. 2013; Rhea et al. 2013).

Birds	Endemic butterflies
Black swift, Clark's nutcracker, calliope hummingbird, flammulated owl, Mexican spotted owl, northern goshawk, American three-toed woodpecker, black-backed woodpecker, hairy woodpecker, northern flicker, Lewis's woodpecker, lazuli bunting, Williamson's sapsucker, olive-sided flycatcher, northern hawk owl, great gray owl, mountain bluebird, western bluebird, dark-eyed junco, Townsend's solitaire, MacGillivray's warbler	Mt. Charleston blue butterfly, Morand's checkerspot, Spring Mountains acastus checkerspot, dark blue

Table 9.4—Potential winners and losers under climate change for bird species that inhabit mixed conifer forests (Hutto et al. 2015). Winners include species that will benefit from increased beetle-induced tree mortality; losers include species that rely on mature forests with large-diameter trees.

Winners	Losers
Black-backed woodpecker, hairy woodpecker, northern flicker, Lewis's woodpecker, Williamson's sapsucker, olive-sided flycatcher, northern hawk owl, great gray owl, bluebirds, flammulated owl, dark-eyed junco, Townsend's solitaire, red crossbill, house wren	Flammulated owl, northern goshawk, Mexican spotted owl

(sheep and cattle) browse on aspen year-round (DeByle 1985a,b; Ritchie 1978). Grizzly bears and black bears eat understory forbs and berries (DeByle 1985b). Rabbits, snowshoe hares, and American pikas feed on aspen buds, twigs, and bark (Stubbendieck et al. 1997). Aspen is an important food source and dam-building material for American beavers and many other rodents, including porcupines, which feed on aspen bark, leaves, buds, and twigs (DeByle 1985a,b). Common gray foxes, red foxes, mountain lions, and bobcats also use aspen forests (Banner et al. 2009).

Aspen communities support a wealth of feeding and nesting resources for songbirds, owls, and raptors, and many insects that are food for woodpeckers and sapsuckers (DeByle 1985b). The high biotic diversity of aspen forests is associated with structurally diverse stands. Mature aspen stands are used by dusky grouse, yellow-rumped warblers, warbling vireos, dark-eyed juncos, house wrens, and hermit thrushes in Utah. Young stands are used by chipping sparrows, song sparrows, and lazuli buntings. Community edges provide resources for mountain bluebirds, tree swallows, pine siskins, red-naped sapsuckers, and blue grosbeaks (DeByle 1981, 1985a,b). Ruffed grouse rely on communities with at least three size classes for foraging, courting, breeding, and nesting (Brinkman and Roe 1975; Gullion and Svovoda 1972).

Increased wildfire activity is likely to increase aspen regeneration, although a transition from aspen to conifers is possible where conditions become much warmer and drier (Morelli and Carr 2011). In the Dixie National Forest, many of the aspen forests have late-successional classes and vegetation on a conversion pathway to conifer establishment and growth. Replacement of aspen by conifers results in a loss of cover, hiding spaces, and roosting spots for wildlife. Some evidence points to more deer being killed by mountain lions in conifer and pinyon-juniper habitats than in nearby aspen and mountain mahogany habitats (Altendorf et al. 2001; Laundre and Hernandez 2003). Transitions have also been associated with decreased songbird abundance, especially for American robins and Lincoln's sparrows, and increased nest predation of species that prefer deciduous forests for nesting (LaManna et al. 2015). There may also be an increase in conifer-dependent nest predators, such as red squirrels (Goheen and Swihart 2005).

Site conditions will play an important role in whether aspen stands respond to changes in climate (Morelli and Carr 2011). On sites that are dry and have shallow soils, aspen are more susceptible to damage by disease, insects, herbivores, and drought (Rehfeldt et al. 2009). Drought-induced aspen decline and mortality could also reduce snowpack and snow depth (Kovalchik 1987), with consequences for many terrestrial species. Earlier snowmelt can decrease floral resources, thus affecting insect population dynamics (Boggs and Inouye 2012). Increased temperature may reduce the time interval between egg hatch of forest tent caterpillars and bud break in aspen (Schwartzberg et al. 2014).

Response of aspen-associated animal species to climate change will largely depend on their ability to adapt or move and the persistence of mature aspen forests. Generalists and opportunists may adjust to changes, but more specialized animals (e.g., ruffed grouse, beaver, cavity nesters, some herbivores) may be at a disadvantage. Northern goshawk is a habitat generalist at large scales, using a variety of forest types but with a preference for mature forests with large trees, closed canopies, and open understories during the breeding season (Barrett 1998; Kennedy 2003). Therefore, any disturbance that affects these habitat characteristics on a large scale (e.g., wildfire, insect outbreaks), and particularly within aspen (Graham et al. 1999), will negatively affect nestling success (Kennedy 2003) and juvenile survival (Wiens et al. 2006). Purple martins and ruffed grouse may face a decline in the availability and quality of nesting and foraging habitat if aspen forests shift or disappear. Reduced water in aspen ecosystems also threatens purple martins, although this species may be able to move to new sites even in urban areas, as long as it can find suitable cavities and foraging sites over open water (Rhea et al. 2013). Ruffed grouse may be less adaptable to changes in aspen because grouse rely on mixed forest age classes throughout the year. Young stands are important for brood-rearing habitat, 10- to 25-year-old stands are important for overwintering and breeding, and older stands are used for foraging (Brinkman and Roe 1975; Gullion and Svovoda 1972).

Birds and rodents nest in the canopy, on the ground, in understory vegetation, and in cavities, so aspen mortality would reduce suitable nesting habitats for a number of species (LaManna et al. 2015), especially primary and secondary cavity nesters (e.g., Lewis's woodpecker, red-naped sapsucker, northern flicker, mountain chickadee, flammulated owl, several bat species) (Bunnell 2013; Marti 1997). Even without increased mortality of aspen, warming and drought may lead to declines in cavity sites by reducing fungal activity important in the formation of cavities (Bunnell 2013; Morelli and Carr 2011). Lower canopy closure can increase solar radiation, causing heat stress and death in some species, as has been observed in northern goshawk fledglings (Barrett 1998; Rhea et al. 2013).

Reduced snow cover in aspen forest can limit year-round habitat for deer (Kovalchik 1987), ruffed grouse (Perala 1977), snowshoe hares (Murray et al. 2008), northern goshawks (Graham et al. 1999), and owls (DeByle 1985a,b). On the other hand, reduced snowfall can allow elk to overwinter longer in aspen stands, increasing the likelihood that elk will cause damage to trees and understory vegetation (Brodie et al. 2012; Howard 1996; Martin 2007; Martin and Maron 2012; Romme et al. 1995). Furthermore, rabbits, hares, pikas, and rodents can girdle aspen sprouts and mature trees, even below snowpack (DeByle 1985b; Howard 1996). Because new growth is palatable to wildlife and livestock, heavy utilization can be detrimental to aspen stands (Brodie et al. 2012; Greenway 1990; Rogers and Mittanck 2014). In turn, this overutilization of understory vegetation can lead to decreased bird abundance (e.g., house wren) in aspen stands (Martin 2015).

Ponderosa Pine Habitat

Many terrestrial species are associated with ponderosa pine habitats (table 9.5). There is potential for an accelerated rate of change in species composition in this habitat as animals respond to shifts in plant community composition. Drought is associated with diminished seed supply, which will adversely affect consumers and dispersers. For example, Clark's nutcrackers eat and cache seeds and are important dispersers of ponderosa pine seeds after wildfire (Hutto et al. 2015). Species that rely on ponderosa pine for nesting, food, and cover (e.g. Lewis's woodpecker, flammulated owl, Abert's squirrel, several songbirds) may be able to tolerate expected changes in these forests. It is unknown whether loss of suitable habitat will exacerbate competitive interactions among species (e.g., for cavities and prey), as is expected for higher elevations. As ponderosa pine forest structure and composition change, primary excavator populations (woodpeckers, sapsuckers) may transition to more favorable habitat, reducing the number of cavities available to secondary-cavity nesters (e.g., flammulated owl, mountain bluebird, western bluebird, nuthatches, squirrels) in remaining forest patches (Bunnell 2013; Casey et al. n.d.).

The direct effects of loss of ponderosa pine at the lower elevation end of its distribution include reduced habitat for flammulated owls (Hayward and Verner 1994) and northern saw-whet owls (Scholer et al. 2014), and loss of cavity-nesting sites for flammulated owls, mountain bluebirds, pygmy nuthatches, and Williamson's sapsuckers (Casey et al. n.d.). Losses of mature ponderosa pine (e.g., to beetles) may reduce roosting sites for fringed myotis (Keinath 2004). Simplification of plant communities may also lead to reduced insect diversity (Gilgert and Vaughan 2011) with downstream effects on pollinator and trophic systems. Early-successional stages of ponderosa pine communities are unsuitable for flammulated owls (Hayward and Verner 1994), northern goshawks (Graham et al. 1999), and Abert's squirrels (Bosworth 2003). However, beetle outbreaks can provide short-term benefits to insectivores and cavity nesters, such as Lewis's woodpeckers (Saab et al. 2014).

Spring advancement is likely to lead to earlier flowering, longer growing seasons, and mismatched phenological behavior (e.g., arrival and abundance of insects and small mammals used as prey for larger mammals) (Both et al. 2010; Parmesan 2006; Steenhof et al. 2006; Thackeray et al. 2010). For example, changes in moth and insect populations resulting from variable temperature and precipitation patterns may affect flammulated owl migration patterns (Linkhart et al. 2016), Lewis's woodpecker breeding patterns (Abele et al. 2004), and fringed myotis (Keinath 2004).

Woodland Vegetation

Pinyon-Juniper Habitat

Pinyon-juniper woodlands provide valuable cover, food, and nesting sites for many species, including bats and reptiles (table 9.6). Mountain lions use this habitat to hunt deer, especially in winter (Laing 1988; Laundre and Hernandez 2003). Pine nuts and juniper berries are important food for small mammals, birds, bears, and bats. Ungulates that find forage and cover in these woodlands include elk, mule deer, bighorn sheep, and pronghorn (Anderson 2002; Zouhar 2001). Pinyon-juniper woodlands are wintering sites for

Table 9.5—Species associated with ponderosa pine habitats; additional species noted in text (Bunnell 2013; Oliver and Tuhy 2010; Pilliod and Wind 2008; Ramsey and West 2009; Rhea et al. 2013).

Birds	White-breasted nuthatch, Steller's jay, Clark's nutcracker, northern flicker, black-backed woodpecker, pileated woodpecker, flammulated owl, Mexican spotted owl, pygmy nuthatch, Merriam's turkey, northern goshawk, northern saw-whet owl, peregrine falcon, Lewis's woodpecker
Large mammals and predators	Mule deer, elk, bighorn sheep, mountain lion, coyote
Small mammals	Kaibab squirrel, red squirrel, porcupine, spotted bat, fringed myotis, Allen's big-eared bat, Mexican vole
Amphibians and reptiles	Long-toed salamander, tiger salamander, rubber boa, many-lined skink, western skink, milksnake, southern alligator lizard, rattlesnake

Table 9.6—Reptile and bat species for which pinyon-juniper is preferred habitat; see text for discussion of pinyon obligate species (Bosworth 2003; Corkran and Wind 2008; Oliver 2000; Oliver and Tuhy 2010; Rhea et al. 2013; Valdez and Cryan 2009).

Reptiles	Speckled rattlesnake, western rattlesnake, plateau striped whiptail, tiger whiptail, western skink, pygmy short-horned lizard, sagebrush lizard, western fence lizard, common side-blotched lizard, gopher snake, nightsnake, striped whipsnake
Bats	Allen's big-eared bat, long-eared myotis, little brown bat, Yuma myotis, fringed myotis, hoary bat, silver-haired bat, western pipistrelle, spotted bat

Box 9.4—Potential Effects of Climate-related Declines in Pinyon-Juniper Habitats

- Loss of trees for stalking cover and deer-kill sites for mountain lions, especially in the winter (Laing 1988; Laundre and Hernandez 2003).
- Loss of wintering sites for Clark's nutcracker (Vander Wall et al. 1981) and mule deer (Evans 1988); loss of cover and food for elk, mule deer, bighorn sheep, pronghorn, upland game birds, coyotes, and small mammals (Anderson 2002; Zouhar 2001).
- Reduced reptile habitat. Many lizards and snakes find food and shelter on and in trees and down woody debris in pinyon-juniper. These sites are a preferred habitat for speckled and western rattlesnakes, plateau striped whiptails, tiger whiptails, western skinks, pygmy short-horned lizards, sagebrush lizards, western fence lizards, common side-blotched lizards, gopher snakes, nightsnakes, and striped whipsnakes (Bosworth 2003; Corkran and Wind 2008; Oliver and Tuhy 2010).
- Impairment of bat foraging and roosting sites, especially in pinyon-juniper near cliffs, caves, and riparian areas. Allen's big-eared bat, long-eared myotis, little brown bat, Yuma myotis, fringed myotis (tree rooster), hoary bat, silver-haired bat (tree rooster), western pipistrelle, and spotted bat may be affected (Bosworth 2003; Oliver 2000; Rhea et al. 2013). However, increased insect outbreaks may benefit some insect-eating species, such as fringed myotis (Keinath 2004).
- Prevention of cones of twoneedle pinyon from opening. These cones do not open during wet springs, making seeds more difficult to reach by birds and small mammals and reducing seed dispersal during wetter years (Floyd and Hanna 1990).
- Potential loss of resources for insects, such as pinyon pitch, which bees use for building nests (Lanner 1981).

Clark's nutcrackers (Vander Wall et al. 1981) and mule deer (Evans 1988). Many lizards and snakes find food and shelter on and in trees, and in down woody debris. Woodlands located near cliffs, caves, and riparian areas provide habitat for peregrine falcons (Craig and Enderson 2004) and several bat species.

Reduced densities of pinyon-juniper could have short-term benefits for browsers where sufficient understory vegetation is present. However, loss of trees or conversion to grass-shrub caused by drought and fire will reduce food, cover, and nest site availability for pinyon-juniper obligate species (box 9.4). For example, loss of food (juniper berries, pine seeds) and sites for breeding and nesting would affect small mammals (chipmunks, jackrabbits, squirrels, woodrats) (Anderson 2002; Zlatnik 1999; Zouhar 2001), ferruginous hawks (Holechek 1981; Bosworth 2003), pinyon jays (fig. 9.2), scrub jays, gray vireos, and gray flycatchers, many of which are already showing population declines (Sauer et al. 2008).

Commensal relationships between twoneedle pinyon and seed eaters are likely to accelerate declines in pinyon because caches by scrub jay, pinyon jay, Steller's jay, and Clark's nutcracker are important for tree regeneration (Evans 1988; Hall and Balda 1988; Ronco 1990; Zouhar 2001). Declines in pinyon-juniper would also be detrimental to obligate species (e.g., pinyon mouse, Stephen's woodrat, pinyon jay, gray flycatcher, western screech-owl, scrub jay, juniper titmouse, gray vireo) (Balda and Masters 1980; Bosworth 2003; Meeuwig et al. 1990; Morrison and Hall 1999; Short and McCulloch 1977), some of which are important prey populations for large mammals and raptors (Zouhar 2001).

Figure 9.2—Pinyon jay. This species, which engages in irruptive movements, is an example of a species that may be able to adjust to local changes in available resources, but would be negatively affected where reduced vigor, reduced cone production, or mortality affects pinyon pines across large landscapes (photo: National Park Service).

Under conditions that would encourage expansion of pinyon-juniper into shrub and grasslands, obligate species may benefit, provided there are no barriers to dispersal, and pinyon-juniper remains present in large enough quantities to support the diverse assemblage of species. Higher temperatures may improve growth and development of young hoary bats that inhabit these areas (Cryan 2003). The pinyon mouse has shown the capacity to follow the downslope migration of pinyon-juniper woodlands, although other small mammals (Great Basin pocket mouse, least chipmunk) are showing range contraction as pinyon-juniper transitions into sagebrush-steppe (Rowe et al. 2010). Expansion and increase in tree density caused by potential increases in precipitation may negatively affect desert bighorn sheep by limiting escape routes from mountain lion predation and could degrade habitat quality for pinyon jays (Ostoja et al. 2013).

Finally, phenological changes would affect species whether pinyon-juniper expands or recedes. Altered arrival of migratory birds, which are prey for peregrine falcons, could have negative impacts for falcon populations that breed near high cliffs (Craig and Enderson 2004). Migration of hoary bats, which forage in pinyon-juniper and are associated with moth abundance (Valdez and Cryan 2009), may also be affected by altered temperature and precipitation. Any change in the availability of water resources near pinyon-juniper woodlands would negatively impact Great Basin spadefoots, tiger salamanders, many-lined skinks, ornate tree lizards, ring-necked snakes, common kingsnakes, and terrestrial gartersnakes (Pilliod and Wind 2008).

Curl-Leaf Mountain Mahogany Habitat

Mountain mahogany woodlands provide food and cover for many species, including browse for deer, bighorn sheep, elk, and livestock (Davis and Brotherson 1991; Olson 1992). Young plants are highly palatable, and old-growth mahogany, often out of reach for browsing, provides shelter during winter and summer extremes (Davis and Brotherson 1991). In an Idaho study, curl-leaf mountain mahogany and antelope bitterbrush were major browse species for nonmigratory bighorn sheep during summer and winter, especially when grassland sites were covered with snow. Mountain mahogany is important browse and shelter for mule deer, especially during winter (Mauk and Henderson 1984; Olson 1992), and provides browse and refuge from predators during summer (Wagner and Peek 2006). Small mammals, such as deer mice and woodrats, consume seeds (Everett et al. 1978; Plummer et al. 1968), leaves, and fruits (Mehringer and Wigand 1987). Woodlands are also important nesting sites for dusky grouse, ruffed grouse, dusky flycatchers, rock wrens, and American kestrels (provided there are cavities) (Steele et al. 1981). Among the many insects that feed on mountain mahogany is the mountain-mahogany looper in Utah, where dense stands exist with bitterbrush (Furniss 1971). Mountain mahogany relies on native bees for pollination (Gilgert and Vaughn 2011).

If the range of mountain mahogany increases, winter browse for ungulates and other associated species will increase. Any loss of mountain mahogany would lead to reduced winter browse and nesting sites (Gucker 2006a,b). This could happen if more frequent wildfires kill mountain mahogany and reduce regeneration (Gruell et al. 1985). Invasive plant species can influence fire regimes and thereby affect plant composition and forage resources for ungulates (Wagner and Peek 2006). Replacement of mountain mahogany by conifer species would reduce cover, hiding spaces, and roosting spots for wildlife. Although Douglas-fir/curl-leaf mountain mahogany habitat types in central Idaho are important breeding and hunting grounds for mountain lions (Steele et al. 1981) and coyotes (Gese et al. 1988), deer kills by mountain lion are higher in conifer and pinyon-juniper habitats than nearby in aspen and mountain-mahogany habitats (Altendorf et al. 2001; Laundre and Hernandez 2003). Ungulates are also sensitive to potential changes in the timing and duration of plant phenology (Senft et al. 1987). In southern Idaho, 45 percent of variation in overwinter mule deer fawn survival was explained by early winter precipitation (negative relationship), and spring and autumn plant phenology. Late summer and fall nutrition (brought on by summer and early-fall precipitation) may positively influence mule deer populations over winter more than spring nutrition (Hurley et al. 2014).

Maple-Oak Habitat

Maple-oak woodlands provide habitat for quail, ring-necked pheasants, scrub jays, black-billed magpies, black-capped chickadees, and spotted towhees (Marti 1977) and support many other species (table 9.7). Acorns are a primary food source for many species, and maple seeds are used by squirrels and chipmunks (Martin et al. 1951). Maple-oak woodlands are also good browse and cover for deer and elk (Mower and Smith 1989) and winter food and cover for porcupines (Stricklan et al. 1995). Ponderosa pine-oak woodlands are important habitat for Mexican

Table 9.7—Habitat components for species that inhabit maple-oak woodlands (Bosworth 2003; Keinath 2004; Martin et al. 1951; Mower and Smith 1989; Patton 1975; Patton and Green 1970; Pederson et al. 1987; Platt 1976; Ramsey and West 2009; Rhea et al. 2013; Simonin 2000; Stauffer and Peterson 1985; Stricklan et al. 1999).

Shelter, cover, nesting	California quail, Merriam's wild turkey, band-tailed pigeon, dusky grouse, ruffed grouse, sharp-shinned hawk, bald eagle, deer, elk, moose, dwarf shrew (riparian woodlands), fringed myotis, Lewis's woodpecker, canyon tree frog, Abert's squirrel, porcupine
Food	Band-tailed pigeon, Merriam's wild turkey, Abert's squirrel

spotted owls (Ganey et al. 1999) and northern pygmy-owls (Woyda and Kessler 1982) and provide nonbreeding habitat for Lewis's woodpecker (Abele et al. 2004), cavity nests for Abert's squirrels (Patton 1975; Patton and Green 1970) and nesting sites for sharp-shinned hawks (Platt 1976).

Oak woodlands generally increase after stand-replacing fires, and maple-oak woodlands have wide ecological amplitude, with a capacity to quickly recover from disturbance. Response of wildlife in these habitats will mirror expected habitat changes, with expansion likely to benefit species that already reside in these areas, such as Lewis's woodpeckers and fringed myotis (Abele et al. 2004; Keinath 2004; Rhea et al. 2013). However, reduced water availabilty in these habitats would negatively affect canyon tree frog populations (Rhea et al. 2013).

Nonforest Vegetation

Sagebrush Habitat

Sagebrush shrublands support many terrestrial species that use sagebrush habitat for part or all of their life cycle. Some of these semi-obligate and obligate and species include greater sage-grouse and Gunnison sage-grouse (the latter is on the ESA threatened list), Columbia sharp-tailed grouse, sagebrush voles, pygmy rabbits, and sage sparrows. Sagebrush provides essential browse and cover for pronghorn, mule deer, elk, and bighorn sheep, especially during the winter. Coyotes and mountain lions also use sagebrush shrublands. Other primary animal associates include migratory birds (e.g., burrowing owl, short-eared owl, Brewer's sparrow, sage thrasher). Sagebrush-associated insects, songbirds, and small mammals are important prey for Swainson's hawks, ferruginous hawks, burrowing owls, and kit foxes (Bosworth 2003; Hayward et al. 1976; Walters and Sorensen 1983).

Any expansion of sagebrush will benefit sagebrush obligate species, provided that regeneration and adaptation of key shrubs and herbaceous plants occur. Alternatively, a decline in sagebrush habitat will reduce browse for ungulates (pronghorn, mule deer) and pygmy rabbits (Gahr 1993; Green and Flinders 1980), resulting in loss of nesting sites for birds (Ramsey and West 2009). Some terrestrial species, such as prairie falcons, northern harriers, rough-legged hawks, golden eagles, and many small mammals, may be able to shift to other habitats or adjust to current changes (conversion to invasive grasses and forbs), (Marzluff et al. 1997; Moritz et al. 2008; Paprocki et al. 2015; Steenhof and Kochert 1988). However, drought, wildfire, and conversion to nonnative grasses will reduce food (insects, forbs, browse, berries) for many species (Miller and Freeman 2001), including forbs and insects that are especially important for sage-grouse chick survival and growth (Connelly et al. 2004; GSRSC 2005) (fig. 9.3).

Warmer winters may allow expansion of invasive fire ant populations, which can reduce survival of burrowing mammals, ground-nesting birds, and native ant species (Ostoja et al. 2013). Mild winters may also disrupt predator-prey relationships and increase nest predation (Yanishevsky and Petring-Rupp 1998). Severe spring and summer storms may impact songbird nesting and brood success, effectively reducing prey species for loggerhead shrikes (Wiggins 2005). Winter precipitation, which is expected to decrease, is positively associated with reproductive success for songbirds in these habitats (Rotenberry and Wiens 1989).

Compositional changes in the distribution of sagebrush subspecies such as Wyoming big sagebrush could mean loss of critical habitat for pygmy rabbit and greater sage-grouse (Still and Richardson 2015). For songbirds, predicted conversion to annual grassland will favor species that require grassland habitat (e.g., horned lark) and deter those needing shrub structure (e.g., Brewer's sparrow, sage sparrow, sage-grouse, sage thrasher, loggerhead shrike) (Paige and Ritter 1999; Williams et al. 2011). Fragmentation of sagebrush breeding habitats may favor songbird nest predation by common ravens, black-billed magpies, and small mammals, and nest parisitism by brown-headed cowbirds (Connelly et al. 2004; Holmes and Johnson 2005; Rotenberry et al. 1999). Many amphibian and reptile species favor the habitat heterogeneity provided by shrub-steppe that includes open, barren spaces between shrubs (Jenkins et al. 2008). Adverse effects are expected for amphibians and reptiles that use shrublands and grasslands, including Great Plains toads, Great Basin spadefoots, tiger salamanders, long-toed salamanders, many-lined skinks, ornate tree lizards, ring-necked snakes, milksnakes, and smooth greensnakes (Jenkins et al. 2008; UDNR 2015). Amphibians that need water for all or part of their life cycle are particularly at risk under more variable weather conditions.

Mountain Shrubland Habitat

Mountain shrublands provide breeding habitat for many bird species, including Columbian sharp-tailed grouse, greater and Gunnison sage-grouse, gray flycatchers, green-tailed towhees, chipping sparrows, gray vireos, eastern kingbirds, and white-crowned sparrows. Mammals associated with this habitat include deer, elk, bighorn sheep, lagomorphs, Merriam's shrews, sagebrush voles, and Yuma myotis. Common reptiles include short-horned lizards, gopher snakes, and terrestrial garter snakes. Mountain snails are also found within mountain shrublands.

The greatest threats facing species that depend on mountain shrublands relate to potential changes in availability and productivity of forbs and insect food sources caused by drought, fire, and conversion to nonnative grasses (Miller and Freeman 2001). For example, insect diversity is expected to decline because of changes in plant composition from climate and nonclimate stressors (Gilgert and Vaughan 2011), with multiple consequences for trophic and pollinator interactions. Reduction in food would have particularly negative impacts for sage-grouse and Columbian sharp-tailed grouse chick survival and population growth (Connelly et al. 2004; GSRSC 2005; Hoffman and Thomas 2007; Miller and Freeman 2001).

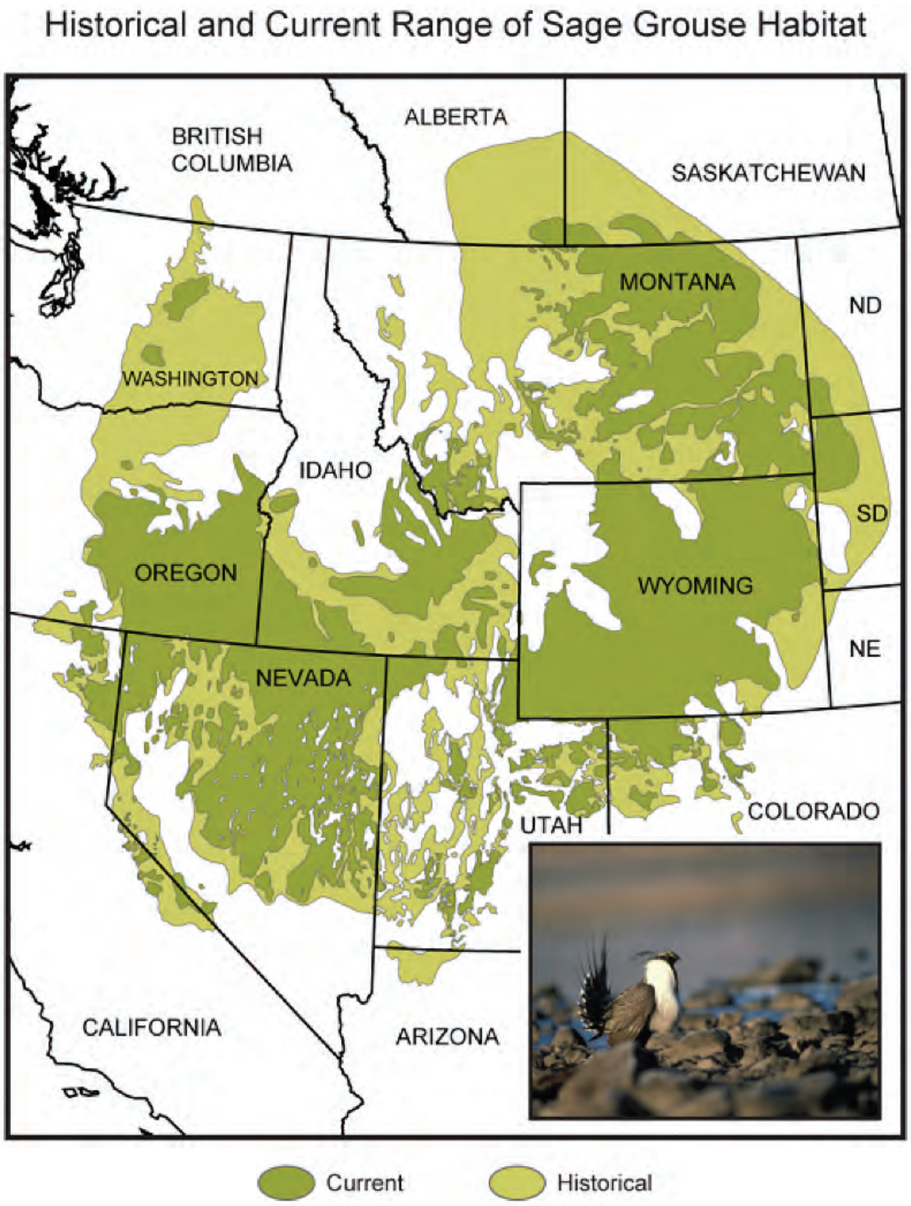

Figure 9.3—Current sagebrush habitat in western North America, which is about 50 percent of its historical extent, as a result of agriculture, livestock grazing, energy development, and other land use practices. Loss of sagebrush across large spatial scales constrains the amount of habitat available for sagebrush-obligate species such as greater sage-grouse (shown in inset) (from Melillo et al. [2014]).

Climate-related effects may also be manifested through changes in habitat features. For many songbirds, climate-related changes in plant species assemblages and productivity will alter breeding habitat, such that a conversion to annual grasses will favor species associated with grassland (e.g., horned lark) and deter those needing shrub structure (e.g., Columbian sharp-tailed grouse) (Hoffman and Thomas 2007; Paige and Ritter 1999). In addition, fragmentation of mountain shrublands may increase songbird nest predation by common ravens, black-billed magpies, and small mammals, and nest parasitism by brown-headed cowbirds (Connelly et al. 2004; Holmes and Johnson 2005; Rotenberry et al. 1999). On drier sites, climate change will probably reduce habitat favored by Columbian sharp-tailed grouse. Reduced snow cover and changes to snow structure caused by warming can alter roosting and cover dynamics for Columbian sharp-tailed grouse in the winter (Hoffman and Thomas 2007). Reduced snowfall may allow browsers to overwinter longer in mountain shrublands, which will increase the likelihood of overgrazing and alter plant community composition (Martin 2007; Martin and Maron 2012). Mild winters may disrupt predator-prey relationships by increasing nest predation (Yanishevsky and Petring-Rupp 1998). Finally, reduction in water sources could have negative consequences for amphibians and reptiles in shrublands and grasslands, including Great Plains toads, Great Basin spadefoots, tiger salamanders, long-toed salamanders, many-lined skinks, ornate tree lizards, ring-necked snakes, milksnakes, and smooth greensnakes (Jenkins et al. 2008; UDNR 2015).

Mountain Grassland/Montane Meadow Habitat

Primary animals in this habitat type include elk, deer, pronghorn, moose, and bighorn sheep, as well as multiple small mammal, reptile, amphibian, and songbird species. In particular, mountain grasslands are critical habitat for northern Idaho ground squirrels (Haak et al. 2003) and Gunnison's prairie dogs (Oliver and Tuhy 2010). Grasslands and wet meadows with year-round water are important foraging and breeding habitats for amphibians and reptiles (e.g., Woodhouse's toad, northern leopard frog, tiger salamander, smooth greensnake) (Oliver and Tuhy 2010; Pilliod and Wind 2008; Smith and Keinath 2007). Spotted bats and fringed myotis forage in mountain grasslands (Bosworth 2003; Oliver 2000). Mountain grassland also provides critical summer and fall food and cover for greater sage-grouse and Gunnison sage-grouse (Connelly et al. 2004; GSRSC 2005; Schroeder et al. 1999).

Mountain grassland may be affected by earlier snowmelt, changes in timing and amount of streamflow, snowpack duration, and thaw dates for soil and snow (Romero-Lankao et al. 2014). In turn, these are likely to lead to earlier greening and flowering and a longer growing season (Settele et al. 2014), with implications for insect pollinators and food sources. Spring advancement can decouple community phenological behavior by affecting emergence from hibernation, insect hatches, predator-prey relationships (Both et al. 2010; Inouye et al. 2000; Parmesan 2006; Thackeray et al. 2010), arrival dates for migratory birds (Inouye et al. 2000; Thorup et al. 2007), and migration and breeding for amphibians (Beebee 1995; Reading 2007). However, earlier snowmelt dates may increase grass production in meadows (Ostler et al. 1982) to the benefit of grazing species.

Mortality of peripherally located trees could lead to expansion of meadows and grasslands (Munroe 2012) and benefit many obligate species. However, drought and warmer temperatures can also favor invasion by drought-tolerant trees, shrubs, and nonnative species, with negative impacts for species that use these habitats (Coop and Givnish 2007) (box 9.5). Increased bare ground may also occur over time from drought-induced loss of plant cover (Debinski et al. 2010).

Salt Desert Shrubland Habitat

Salt desert shrubland habitat is used by wild and domestic ungulates, small mammals, and insects (Blaisdell and Holmgren 1984; Ramsey and West 2009; West 1983). Predators include coyotes, bobcats, kit foxes, badgers, great horned owls, bald eagles, golden eagles, Swainson's hawks, and red-tailed hawks (Fautin 1946; Hancock 1966). Short-eared owls (Walters and Sorensen 1983) and Preble's shrews (Bosworth 2003) have been found in saltbush shrublands in Utah. Winterfat, fourwing saltbush, and budsage are valued forage during winter and drought conditions for mule deer, elk, pronghorn, bighorn sheep, livestock, cottontails, black-tailed jackrabbit, and desert tortoise (Carey 1995; Howard 2003; McArthur et al. 1994). In central Idaho, golden eagles selected sagebrush and salt desert shrublands and avoided grasslands and farmland; the shrublands probably contained their principal prey, black-tailed jackrabbits (Marzluff et al. 1997). Several songbird species, such as black-throated sparrows, horned larks, Brewer's sparrows, loggerhead shrikes, vesper sparrows, lark sparrows, and western meadowlarks, breed and forage in saltbush communities (Bradford et al. 1998; Medin 1986, 1990; Williams et al. 2011). Notable reptiles include prairie rattlesnakes, striped racers, gophersnakes, long-nosed snakes, common side-blotched lizards, desert horned lizards, tiger whiptails, western skinks, long-nosed leopard lizards, and sagebrush lizards (Fautin 1946; Jenkins et al. 2008).

Many animal inhabitants of salt desert shrublands need burrows for nesting, hunting, predator avoidance, and thermoregulation (Kitchen and Jorgensen 1999). Burrowing in shallow soils with a calcareous horizon restricts animals to "shrub islands." Pocket gophers, kangaroo rats, and deer mice are the most common on these islands; other species include badgers, ground squirrels, kit foxes, burrowing owls, reptiles, and arthropods (Blaisdell and Holmgren 1984).

Because natural regeneration and restoration of salt desert shrublands are challenging and confounded by wildfire, urbanization, recreation, and invasive species, there is some risk that these habitats will decline despite projected increases in climate suitability (Ostoja et al. 2013; Rehfeldt et al. 2012) (fig. 9.4). In addition, climates suited to salt

Box 9.5—Potential Effects of Conifer Encroachment into Mountain Grasslands for Terrestrial Animals

- Loss of habitat critical for northern Idaho ground squirrels (Haak et al. 2003) and Gunnison prairie dogs (Oliver and Tuhy 2010).
- Loss of foraging and shelter sites for amphibians and reptiles, especially those that need wet conditions or water features and suitable grasslands and meadows nearby (e.g., Woodhouse's toad, northern leopard frog, tiger salamander, smooth greensnake) (Oliver and Tuhy 2010; Smith and Keinath 2007; Wind 2008).
- Loss of Rocky Mountain bighorn sheep habitat (Beecham et al. 2007) and important elk foraging habitats (Munroe 2012).
- Loss of foraging sites for bats including spotted bat and fringed bat (Bosworth 2003; Oliver 2000).
- Potential loss of summer and fall food and cover (i.e., grasses and forbs in riparian meadows and mountain grass-forb areas) for greater sage-grouse and Gunnison sage-grouse (Connelly et al. 2004; GSRSC 2005; Schroeder et al. 1999).
- Diminished reproductive success of smooth greensnakes if spring temperatures increase (Stille 1954).

Figure 9.4—Oil well pads in the Uinta Basin in southeastern Utah. Energy development fragments salt desert shrubland and other vegetation types at fine spatial scales, greatly reducing the quality of these areas as habitat for many animal species (photo: M. Collier, http://michaelcollierphoto.com).

desert shrublands are also suitable for cheatgrass and other annual plants that facilitate wildfire (Bradley et al. 2016). More frequent fires will kill salt desert shrubs and reduce browse for ungulates and nesting sites for birds (Ramsey and West 2009). Loss of shrub structure from die-off events will reduce reptile habitat (Jenkins et al. 2008), shrub-steppe bird habitat (Paige and Ritter 1999), and cover for many other wildlife species (West 1983). Some terrestrial species, such as prairie falcon, northern harrier, rough-legged hawk, golden eagle, and small mammals, will be able to shift to alternative habitats or adjust to current changes where salt desert declines (Marzluff et al. 1997; Moritz et al. 2008; Paprocki et al. 2015; Steenhof and Kochert 1988). However, models indicate that elk and ground squirrel distributions may shrink, and these species may not be able to relocate to new areas (Johnston and Schmitz 1997).

Invasive plant species can also modify plant composition and recruitment, and thus forage and cover for ungulates, pollinators, and small mammals (Kitchen and Jorgensen 1999). Replacement of salt desert shrubs with nonnative annual species reduces browse and cover for many wildlife species (West 1983), such as badgers (Eldridge 2004) and ground squirrels (Steenhof et al. 2006; Yensen et al. 1992). Desert tortoise habitat has declined where shrubs have been replaced by invasive annual grasses and forbs, which, in combination with habitat degradation, poor nutrition, and drought, are linked to upper respiratory tract disease in the tortoise (Jacobson et al. 1991; USFWS 2011).

Conversion of shrubland to invasive grassland may cause some species to use alternative habitats. Golden eagles will use other habitat types and feed on secondary prey, whereas prairie falcons and rough-legged hawks may increase in sites dominated by invasive annuals and primary prey (small mammals, horned lark, western meadowlark) (Marzluff et al. 1997; Paprocki et al. 2015; Steenhof and Kochert 1988). Drought and warm temperatures lead to lower Piute ground squirrel abundance in grass-dominated habitats than in shrub-dominated habitats, and conversion of shrubland to grassland contributes to fluctuation in ground squirrel populations (Van Horne et al. 1997; Yensen et al. 1992) and to reduced body mass (Steenhof et al. 2006). Conversion from shrubs to grass will also reduce habitat for reptile species that favor the habitat heterogeneity provided by shrub-steppe (Jenkins et al. 2008). Changes in the structure and composition of vegetation will affect songbird breeding habitat, such that a conversion to annual grassland will favor species associated with grassland (e.g., horned lark) and deter those needing shrub structure (Brewer's sparrow, black-throated sparrow) (Bradford et al. 1998; Paige and Ritter 1999; Williams et al. 2011).

Altered species interactions in salt desert habitats are more likely in a warmer climate. Predation by common ravens on tortoises can be high during drought years (Esque et al. 2010). Fluctuations in prey populations will affect birds of prey, including golden eagles, ferruginous hawks, and prairie falcons (Kindschy 1986; Marzluff et al. 1997; Nydegger and Smith 1986; Ogden and Hornocker 1977; Yensen et al. 1992) and prey relationships for kit foxes (Bosworth 2003). There may also be an increase in less desirable species such as fire ants, which reduces survival of burrowing mammals, ground-nesting birds, and native ant species (Ostoja et al. 2013). Early plant senescence caused by drought may trigger immergence for Piute ground squirrels, meaning less food for prairie falcons and other raptors; drought may also cause low abundance of ground squirrels the year following drought (Steenhof et al. 2006).

Alpine Habitat

Year-long residents of alpine habitat include shrews, snowshoe hares, yellow-bellied marmots, pocket gophers, deer mice, voles, weasels, American pikas, wolverines, and white-tailed ptarmigans (Aho et al. 1998; Pilliod and Wind 2008; Ramsey and West 2009; Rawley et al. 1996; Rhea et al. 2013). Relatively cold temperatures during summer provide safe haven for boreal owls, wolverines, and American pikas, which cannot tolerate warm temperatures (Copeland et al. 2010; Hayward and Verner 1994; Smith 1974). Snow cover amount, depth, and duration are important habitat features for snowshoe hares, which, in turn, are important prey for Canada lynx (Murray et al. 2008) and wolverines (Brodie and Post 2009; Copeland et al. 2010; McKelvey et al. 2011; Peacock 2011). Elk and bighorn sheep browse alpine vegetation (Beecham et al. 2007; Zeigenfuss et al. 2011). Alpine forbs are also important for bees and other pollinators (Elliott 2009).

Species reliant on adequate snow cover and specific phenological characteristics are at particular risk of population declines (box 9.6). Risk of hyperthermia and death increases in American pikas with increasing temperatures and snow loss (MacArthur and Wang 1973, 1974; Ray et al. 2016; Smith 1974). Without persistent spring snow cover and denning habitat, wolverine populations may not be able to survive and reproduce successfully (Brodie and Post 2009; Copeland et al. 2010; McKelvey et al. 2011; Peacock 2011). Reduction in spring snow cover effectively fragments and reduces wolverine habitat (Banci 1994; Copeland et al. 2010). In addition, wolverines rely on cool summer temperatures (<72 °F), especially at the southern edge of their range (Copeland et al. 2010; McKelvey et al. 2011; Peacock 2011). The black rosy finch may be adversely affected if warming accelerates melting of snow and glaciers.

Changes in plant phenology, including spring advancement, will affect immergence and emergence of hibernators (Both et al. 2010; Parmesan 2006; Thackeray et al. 2010). In Colorado, early emergence was documented for yellow-bellied marmots in response to early snowmelt (Ozgul et al. 2010). Late-season snowstorms can also delay emergence from hibernation and reduce population growth rates in some species (Lane et al. 2012; Morelli et al. 2012). Warming may cause differences in snow cover patterns and affect the timing of nesting for white-tailed ptarmigans, which nest in snow-free areas (Hoffman 2006). Changes in snow cover patterns may also increase risk of mismatch in pelage change for snowshoe hares (Mills et al. 2013). Phenological mismatches between alpine forbs and pollinators (e.g., bees) may occur (Elliott 2009), and pollinator generalists may be favored over alpine specialists (Inouye 2008). These changes may benefit American pipits, which have experienced earlier onset of egg laying and increased clutch size with earlier snowmelt (Hendricks 2003).

Riparian Forests and Aquatic Habitats

Riparian systems provide essential habitat for many terrestrial species including American beavers, river otters, songbirds, and insects. Riparian vegetation provides nesting and foraging habitat for yellow-billed cuckoos, southwestern willow flycatchers (Hanberg 2000; Johnson et al. 2008; Paxton et al. 2007; Oliver and Tuhy 2010), Lewis's woodpeckers (Abele et al. 2004), and Columbian sharp-tailed grouse (Hoffman and Thomas 2007). Riparian systems provide critical habitat for water-dependent species including frogs (Columbia spotted frog, yellow-legged

Box 9.6—Potential Effects of Reduced Alpine Habitat Caused by Conversion to Subalpine Forests and Uphill Movement of Treeline

- Loss of critical habitat for white-tailed ptarmigans (alpine obligate), which forage on willow buds during winter, use treeline for breeding, and forage on forbs, willows, and insects in spring and summer (Rawley et al. 1996). White-tailed ptarmigans need willow during winter to survive; willow is an important part of their breeding and nonbreeding habitat (Hoffman 2006). It is unclear how willow will respond to climate change at higher elevations.
- Loss of open areas and foraging sites for bighorn sheep (Beecham et al. 2007); opening of habitat suitable for elk and other ungulate browsers, which may exert increased browsing pressure on alpine willows and other plants (Zeigenfuss et al. 2011).
- Loss of habitat and population connectivity for American pikas (Beever et al. 2010, 2011). In addition, declines in alpine plant species will adversely affect American pika populations, which cache alpine vegetation (Aho et al. 1998). Pika declines could also affect plant community composition (Aho et al. 1998).

frog, relict leopard frog [extirpated in Utah]), salamanders, toads (boreal [western] toad, Arizona toad), lizards (many-lined skink, ornate tree lizard, eastern fence lizard), snakes (smooth greensnake, ring-necked snake, milksnake), and turtles (painted turtle) (Olson 2008; Pilliod and Wind 2008). Bald eagles have a strong connection with tall trees (e.g., cottonwoods) in riparian zones and use them for nesting; they also rely on fish year-round (Buehler 2000). Bats (spotted bat, hoary bat, Yuma myotis, western red bat, fringed myotis; see vulnerability assessment, next section) use riparian habitats for foraging and nesting (Luce and Keinath 2007; Oliver 2000; UDNR 2015). Riparian corridors are important to species during migrations, especially for olive-sided flycatchers (Altman and Sallabanks 2000), hoary bats (Valdez and Cryan 2009), and ungulates (pronghorn, elk).

Riparian habitats are expected to decline with warming, drought, and lower streamflows, with the largest declines at lower elevations (Lucas et al. 2014). Changes in riparian plant species composition, structure, and function are expected to affect cottonwood, willow, boxelder, alder, currant, serviceberry, and oak (Glenn and Nagler 2005; Perry et al. 2012) (Chapter 6). Climate-related effects on native species may favor invasion and expansion of saltcedar and Russian olive along riparian corridors, with consequences for water tables, soil salinity, and plant diversity (Bradley et al. 2009; DeLoach et al. 2000; Masters and Sheley 2001; Nagler et al. 2011). Increased wildfire is also likely to disrupt riparian vegetation and water quality, including water temperature, sediment load, pH, and shade (Dwire and Kauffman 2003; Isaak et al. 2010; Miller et al. 2003) (Chapter 6). Riparian habitats will be directly affected by changes in hydrological regimes (Chapter 4), and a change in plant dispersal and regeneration of species dependent on periodic floods is likely (Hupp and Osterkamp 1996; Nilsson and Svedmark 2002) (box 9.7).

Expected changes in quality and more variable availability of water in riparian habitats have many implications. Arizona toads are more sensitive to changes in water availability than to plant community (Degenhardt et al. 1999), and permanent water sources are important to relict leopard frog populations (Jennings et al. 1995). Fires and postfire flooding, which increase sediments in rivers, have direct and indirect effects on fish and their reproduction, thereby affecting species that feed on fish (e.g., osprey, bald eagle, river otter). Water availability affects many species that forage over open-water bodies, including spotted bats and Yuma myotis (Luce and Keinath 2007; Oliver 2000). Mild winters may mean more open water for foraging, but warming and reduced precipitation could lead to a net decline in open water during summer.

Wetlands (Meadows, Emergent Marsh, Seeps/Springs)

Wetlands provide essential habitat for many species including Columbian spotted frogs (Ross et al. 1994; McMenamin et al. 2008), relict leopard frogs (Jennings 1988), blotched tiger salamanders, boreal chorus frogs (McMenamin et al. 2008), boreal toads (Kiesecker et al. 2001; Muths et al. 2003) and smooth greensnakes. Several

Box 9.7—Potential Effects of Loss of Native Riparian Forests for Terrestrial Species

- Loss of tall trees, which will negatively affect bald eagle populations (Buehler 2000).
- Reduced winter habitat for Columbian sharp-tailed grouse, which forages on shrub protruding from snow and roosts under snow for warmth and predator avoidance (Hoffman and Thomas 2007).
- Loss of foraging and nesting sites (cottonwood) for hoary bats, Yuma myotis, western red bats, fringed myotis (Oliver 2000; UDNR 2015), and Lewis's woodpeckers (Abele et al. 2004).
- Loss of forage and dam materials for American beavers.
- Reduced availability of riparian and mesic sites important for Gunnison sage-grouse and greater sage-grouse brood rearing (Connelly et al. 2004; GSRSC 2005).
- Negative impacts for species that use riparian corridors during migration, such as olive-sided flycatcher (Altman and Sallabanks 2000) and hoary bats (Valdez and Cryan 2009).
- Reduced water sources and warmer temperatures, which may affect species with high metabolic rates, such as spotted bats whose reproductive success has been linked to availability of open water (Luce and Keinath 2007).
- Altered growth and reproduction of many animals in response to changes in water regimes (hydrological and fluvial processes) (Catford et al. 2012; Perry et al. 2012).
- Degradation of riparian habitats from livestock grazing and climate change, which has been associated with an increase in nest parasitism of native songbirds by brown-headed cowbirds (Finch et al. 2002).
- Possible exacerbation of interspecific competition and hybridization between Arizona toads (UDNR 2015) and Woodhouse's toads in southern Utah (Oliver and Tuhy 2010) because of disturbances to riparian habitat.
- Possible mismatches in predator-prey relationships due to warming (Parmesan 2006). For example, hoary bat migrations are timed to coincide with moth abundance (Valdez and Cryan 2009), and a warmer climate could alter moth abundance (Singer and Parmesan 2010).

species of mollusks rely on seeps and springs for their entire life cycle (e.g., Utah physa, desert springsnail, fat-whorled pondsnail, Kanab ambersnail) (Oliver and Tuhy 2010). Long-billed curlews and Preble's shrews also depend on wetland habitats (UDNR 2015). Other animal associates include American beavers, songbirds, amphibians, reptiles, insects, elk, moose, deer, and bats. Wetlands provide nesting and foraging habitat for southwestern willow flycatchers (Hanberg 2000; Johnson et al. 2008; Oliver and Tuhy 2010; Paxton et al. 2007) and Lewis's woodpeckers (Abele et al. 2004). Multiple bat and raptor species use wetlands for foraging and nesting (Hayward et al. 1976; Luce and Keinath 2007; Oliver 2000; UDNR 2015). Wetlands are important for Gunnison and greater sage-grouse brood rearing (Connelly et al. 2004; GSRSC 2005). Lowland saline wetlands are important habitat for Preble's shrews (Cornely et al. 1992; Larrison and Johnson 1981).

Changes in precipitation timing and amount (especially monsoons) will alter wetland size and distribution (Matthews 2008). Under wetter conditions, some wetlands will expand (Gitay et al. 2001). However, declines in the long-term persistence of wetlands and other aquatic bodies fed by precipitation, runoff, and groundwater are likely with warmer summers, decreased snowpack and depth, and changes in snowmelt timing (Diffenbaugh and Giorgi 2012; Doeskin et al. 2003; Romero-Lankao et al. 2014). In addition, there may be contraction of groundwater-fed wetlands (Poff et al. 2002; Winter 2000) and an increase in the number of dry ponds (McMenamin et al. 2008). Lower water tables from warming and drought will influence wetland plant communities (Chimner and Cooper 2002, 2003a,b) and associated availability of food and cover for terrestrial species.

Reduction of habitat will negatively affect amphibian and bird species that rely on wetlands for some or all of their life requirements (Jennings 1988; Kiesecker et al. 2001; McMenamin et al. 2008; Muths et al. 2003; Ross et al. 1994) (box 9.8). Direct effects on water quality and temperature will also be important, especially for amphibians for which increased temperatures increase stress and susceptibility to disease and infection (Muths et al. 2008; Pounds et al. 2006). Mild winters may mean more open and available water for foraging species. However, where warming and reduced precipitation lead to less open water, populations of species such as spotted bats and Yuma myotis (Luce and Keinath 2007; Oliver 2000) may be greatly reduced. Possible increases in invasion of native and nonnative plants (e.g., cattail, sawgrass, bulrush, saltcedar, phragmites) could also decrease access to open water (Oliver and Tuhy 2010).

Species Vulnerability Assessment

We conducted an index-based vulnerability assessment of 20 vertebrate species to understand how they may respond to climate change and how this information could be used in conservation efforts (table 9.8). We calculated vulnerability index values with the System for Assessing Vulnerability of Species to climate change (SAVS) to examine and compare vulnerability of individual species (Bagne et al. 2011). SAVS is based on species traits associated with sensitivity and adaptive capacity with respect to projected levels of exposure specific to the region of interest (box 9.9). We generated scenarios of exposure (e.g., habitat loss) based on future climate and habitat projections in the IAP region. Given the large area encompassed, exposure can be highly variable; thus, vulnerability can also vary for widely distributed species. We noted differences within the region, and in one case (bighorn sheep) provided two sets of scores corresponding to different subspecies.

Box 9.8—Potential Effects of Wetland Loss for Terrestrial Species

- Negative impacts for American beavers caused by loss of forage and dam materials (willows, aspen, cottonwood) either from climate factors, fire, or overgrazing by ungulates (elk, cattle, moose) (Bilyeu et al. 2008; Smith and Tyers 2008; Wolf et al. 2007).
- Loss of foraging sites for peregrine falcons (Hayward et al. 1976).
- Loss of wetland sites important for Gunnison sage-grouse and greater sage-grouse brood rearing (Connelly et al. 2004; GSRSC 2005).
- Loss of lowland saline wetlands, which are important habitat for Preble's shrews (Cornely et al. 1992; Larrison and Johnson 1981; UDNR 2015).
- Reduced water sources and warmer temperatures, which may affect species with high metabolic rates; reproductive success of spotted bat is linked to availability of open water (Luce and Keinath 2007).
- Altered growth and reproduction of species in response to changes in hydrological and fluvial processes (Catford et al. 2012; Perry et al. 2012). For example, increased desiccation of breeding habitats for amphibians prevents spawning and causes population declines (Daszak et al. 2005; McMenamin et al. 2008; Winter 2000).
- Reduced cover and connectivity among ponds, which reduces amount and quality of amphibian habitat (Pounds et al. 2006; Whitfield et al. 2007).

Table 9.8—Total score and uncertainty[a] based on projected species vulnerability and resilience from System for Assessing Vulnerability of Species to climate change.

Species (score, uncertainty)	Critical vulnerabilities	Areas of resilience
Birds		
American three-toed woodpecker (0.33, 41%)	Reduced forest area, drier forests, altered timing of beetle development	High mobility, increased tree stress and food resources, irruptive movements
Black rosy finch (5.3, 36%)	Reliance on alpine habitat, association with snow patches, limited breeding window	Ability to travel large distances to track food
Flammulated owl (8.2, 27%)	Loss of dense forests, sensitive to high temperature, relies on environmental cues, migrates	Predators and disease not a big source of mortality, cold limited and potential for expansion northward and up in elevation
Greater sage-grouse (6.1, 32%)	Reduced plant cover (sagebrush, herbaceous), more frequent fires, migration (some populations), increased West Nile virus	Extended breeding season, high mobility
White-headed woodpecker (2.6, 36%)	Winter survival tied to fluctuations in pine seeds, limited breeding	High mobility
Mammals		
American pika (4.3, 32%)	Loss of high-elevation habitat, increasing barriers to dispersal, heat sensitive, cold sensitive, change in growing season	Extended breeding season, food storage, mobility where habitats remain connected
Desert bighorn sheep (5.1, 36%)	Dehydration, drought mortality, loss of water sources, reduced activity in high temperatures, timing of high nutrient availability, reduced plant growth, higher disease risk	High mobility, extended reproductive period
Sierra Nevada and Rocky Mountain bighorn sheep (2.2, 41%)	Dehydration, drought mortality, reduced activity under high temperatures, timing of high nutrient availability, reduced plant growth, higher disease risk	Potential for habitat expansion because of less snow, high mobility, reduced competition on winter range
Canada lynx (4.4, 41%)	Loss of mature forest, reduced snowpack, mismatched timing with snowshoe hare cycles, more variable prey, greater predation risk for kits, increased competition	High mobility
Fisher (5.2, 50%)	Loss of forests, loss of denning and resting sites, increased predation with more open habitats	High mobility, improvement of hunting success with less snow
Fringed myotis (3.4, 45%)	Reliance on temperature cues, one reproductive event per year, loss of open water foraging areas	Potentially increased period of seasonal activity
Northern Idaho ground squirrel (3.2, 32%)	Less snow insulation during hibernation, cold spring weather, altered hibernation and growing season timing, increased plague risk, short breeding season	Expansion of dry meadows, high mobility
Sierra Nevada red fox (5.3, 23%)	Restricted range, increased predation and competition as new species immigrate	Generalist diet, ability to move long distances
Townsend's big-eared bat (3.3, 36%)	Reduced surface water, timing of hibernation, timing of prey peaks	Increased winter foraging
Utah prairie dog (0.33, 36%)	Fewer moist swales, altered hibernation timing, change in growing season, short breeding season	Expansion of shrub-steppe and grassland, facultative torpor, cooperative behavior, high mobility
Wolverine (7.0, 36%)	Loss of alpine and high-elevation forest, reduced annual snow, altered timing and depth of spring snow, reduced caching longevity, increased competition for food	High mobility, higher ungulate populations

Table 9.8—*Continued.*

Species (score, uncertainty)	Critical vulnerabilities	Areas of resilience
Amphibians and reptiles		
Boreal toad (5.0, 27%)	Loss of wetlands, stream and pond drying, loss of protective vegetation, desiccation risk in terrestrial habitats, altered breeding timing, change in risk of chytridiomycosis	Low metabolic rate, explosive breeding, change in risk of chytridiomycosis
Columbian spotted frog (5.9, 41%)	Loss of wetlands, stream and pond drying, use of distinct breeding and winter habitats (some populations), altered breeding timing, increased risk of ranaviruses	Low metabolic rate, improved survival with warmer winter, reduced fish predation, explosive breeding
Great Basin spadefoot (2.2, 41%)	Loss of wetlands, reduced activity, altered breeding timing, increased competition for breeding habitats, desiccation risk, altered hibernation timing	Low metabolic rate, retention and absorption of water, explosive breeding, reduced fish predation
Prairie rattlesnake (4.3, 36%)	Loss of cover for refugia, heat sensitive, changes in active periods, altered hibernation timing, loss of conspecifics for denning, low reproductive rates	Low metabolic rate, higher small mammal populations

[a] Positive scores indicate higher vulnerability, negative scores indicate potentially positive effects, and zero defines a neutral response. Uncertainty is the percentage of questions with no published information or for which information implied opposing or complex predictions.

Box 9.9—System for Assessing Vulnerability of Species to Climate Change

The System for Assessing Vulnerability of Species to climate change (SAVS) divides predictive traits into four categories: habitat, physiology, phenology, and biotic interactions.

- Vulnerability predictors for habitat relate to the degree to which associated breeding and nonbreeding habitat changes, the change in availability of habitat components and habitat quality, reliance on stopover habitat (migrants), and ability to disperse to new habitats.
- Vulnerability predictors for physiology relate to the range of physiological tolerances, susceptibility to or benefits from extreme weather events, temperature-dependent sex ratios, metabolic rate, and adaptations for dealing with resource shortages (e.g., caching, torpor).
- Vulnerability predictors for phenology relate to the likelihood a species will have an increased risk of timing mismatch between important life events (e.g., hatching, arousal from hibernation) and critical resources (e.g., food sources, ponds). Four indicators are important: (1) reliance on temperature or precipitation cues (e.g., spadefoot toad emergence), (2) reliance on resources that are tightly tied to temperature or precipitation (e.g., breeding ponds, deep snow), (3) large spatial or temporal distance between a cue and a critical life event (e.g., migration of songbirds to breeding grounds), and (4) annual duration or number of reproductive opportunities.
- Vulnerability caused by biotic interactions with other species is considered for food resources, predators, symbionts, competitors, and diseases and parasites. To be considered for scoring, the interaction must have a demonstrable effect on populations of the assessed species (e.g., nestling survival correlated to predator abundance).

Future population trends are inferred through the response of a species as measured by the SAVS. Vulnerability scores are estimated given the balance of factors (e.g., more traits predicting lower versus higher survival and reproduction), relative importance of individual effects (e.g., exceeding physiological tolerance or effects of a vegetation shift), and local conditions that alter exposure (e.g., slope or recent fire, which can alter flood risk). Vulnerability scores identify critical issues for individual species, including migration and biotic interactions, providing a consistent method to compare species flexibility for including new information and local knowledge (Small-Lorenz et al. 2013; Sutherst et al. 2007).

Vulnerability was assessed for a group of species that are of management concern for USFS Intermountain Region resource managers over the next 50 years (table 9.8). Species represent a variety of taxonomic groups with diverse traits responsive to climate change effects. Species already at risk of extirpation and extinction may be particularly vulnerable, and opportunities for early intervention could be missed if climate stressors are not recognized (Moyle et al. 2013).

Species Vulnerability

Summary

Flammulated owl, wolverine, and greater sage-grouse were the most vulnerable to population declines as a result of climate change (table 9.8, fig. 9.5). Utah prairie dog and American three-toed woodpecker were the least vulnerable with total scores indicting a relatively neutral response rather than population increase. Most species exhibited some sensitivity to changes in phenology, but habitat and physiology scores were variable among the species assessed. Habitat loss was often an issue for species restricted to high elevation or habitats associated with surface water (table 9.1, Appendix 9).

To interpret vulnerability scores, it is important to consider not just the total scores, but the relative balance of individual traits that represent specific vulnerabilities or adaptive capacity. For example, Townsend's big-eared bat and northern Idaho ground squirrel have a similar overall score of around 3, but the score for the ground squirrel includes both areas of resiliencies and sensitivities, whereas the bat was more consistently sensitive across all criteria (Appendix 9). This suggests that response of the ground squirrel is more uncertain because it depends on the strength and interplay of many factors.

Interpretation of assessment results must consider uncertainty and how it may influence the final scores. A score of 0 is given where information or future response is unknown for a particular trait. Therefore, some species scores may be lower than expected where information was unavailable. As part of the assessment process, we generated uncertainty scores that represent availability of information for each score. As seen in table 9.8, uncertainty is invariably high for these species because their life histories are poorly understood. In particular, information was consistently insufficient for factors related to interactions including disease, competition, and food resources.

American Three-Toed Woodpecker (*Picoides dorsalis*)

Three-toed woodpeckers are attracted to various forest disturbances in relatively large numbers, leading to conspicuous irruptions of an otherwise poorly known species (Leonard 2001; Virkkala 1991). Their diet consists primarily of bark beetles, coinciding with the birds' high mobility and attraction to tree mortality associated with bark beetle outbreaks, fires, pollution, and windthrow (Leonard 2001). Bark beetle populations in most of the region are not expected to increase from direct effects of warming because, in contrast to Canada, current conditions already favor rapid development and low winter mortality (Bentz et al. 2010).

However, indirect effects of climate change on tree vigor and mortality caused by increased heat and drought are likely to increase beetle populations (Chapter 7) and thereby an important food source for the woodpecker. In addition,

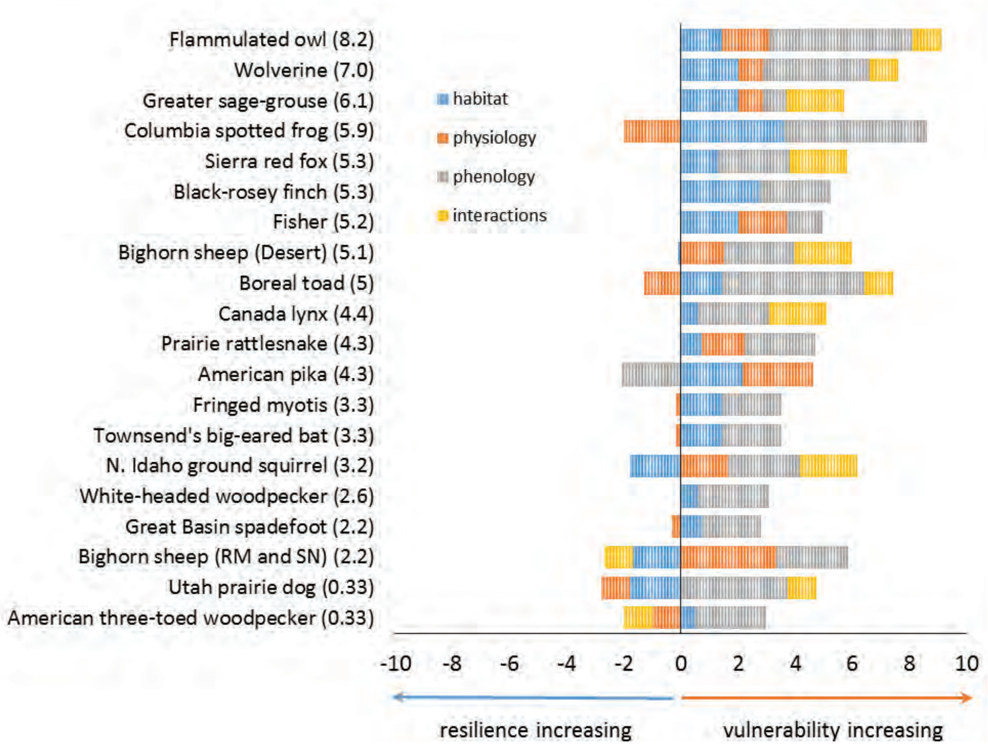

Figure 9.5—Vulnerability scores (value in parentheses) for 20 terrestrial animal species. Positive scores indicate higher vulnerability, negative scores indicate higher resilience, and zero defines a neutral response. Color of bars represents the relative contribution of habitat, physiology, phenology, and biotic interactions to overall vulnerability.

outbreaks are expected to be more severe and cover larger areas (Seidl et al. 2009). Woodpecker populations, in turn, affect beetle populations because during outbreaks, woodpeckers eat large numbers of beetles; thus, these birds can reduce the overall impact of an outbreak (Fayt et al. 2005).

Favorable landscapes for three-toed woodpeckers will be dynamic, varying with disturbance events at small and large scales and over time as snags fall, fuel structure changes, and forests regenerate or are replaced by other vegetation types. It is unknown whether climate-induced shifts in the distribution of different tree species and bark beetle species will negatively or positively affect these birds. However, some projections show declines in the preferred forest habitat for this woodpecker over time.

Black Rosy Finch (Leucosticte atrata)

The black rosy finch is an alpine specialist, associated with areas with at least patchy snow cover. This finch breeds above treeline in cracks or holes in cliffs or rock slides and forages for food around snowfields and on nearby tundra (French 1959; Johnson 2002). During winter storms and periods of deep snow cover, they descend to open or semi-open habitats at lower elevations such as open valleys, mountain parks, and high deserts. The most significant climate effects for this species result from potential loss of alpine habitat, snowfields, and glaciers. Warming conditions are likely to reduce the size and duration of snowfields and glaciers. Some alpine habitats are expected to decline very slowly where trees encroach on alpine habitat.

Other sensitivities include a potential reliance on insects, which may undergo population shifts with spring advancement. Seed food sources may also change with changing plant composition and growing seasons. Breeding cues are unknown, but may be related to when snow cover is reduced to the point where sufficient food is available. If that is the case, altered snowmelt could affect reproductive success. Currently, this species breeds only once per season (laying 3–6 eggs) during short summers at high elevation (French 1959; Johnson 2002), and it is unlikely that this species would be able to take advantage of longer growing seasons by increasing nest opportunities.

The black rosy finch exhibits traits that would allow it to adapt to changing conditions as long as its preferred habitat remains. The finch does not migrate over long distances but is quite mobile and known to wander widely to take advantage of food sources during nonbreeding seasons (French 1959; Johnson 2002). This mobility may lend it some capacity to adapt to local conditions. This species also does not seem to be overly affected by predators or competitors. As one of only a few bird species that breed in alpine habitat, it is unlikely to see any significant changes in competitors during the breeding season. This could change if species from lower elevations move upslope and into black rosy finch habitat in response to warming conditions. However, birds in the nonbreeding season in human-altered habitats may be negatively affected by competition with house sparrows and European starlings for roost sites. The specialized habitat requirements of the black rosy finch will require careful measures to reduce disturbances in areas that are likely to remain suitable for this species. Ultimately, this species will probably disappear from some areas where snowfields and glaciers are lost.

Flammulated Owl (Psiloscops flammeolus)

The flammulated owl has the highest vulnerability score in this assessment because of sensitivities identified in all SAVS vulnerability categories. Wildfire, insects, and changes in climate suitability will probably increase early-seral forest structure over time, conditions detrimental for this species, which prefers mature, open ponderosa pine and other semiarid forests with brushy understories (Linkhart 2001). Reduced availability of critical nesting trees may occur over time, and abundance of arthropod prey needed as food for chicks may be altered (Linkhart and McCallum 2013; Linkhart and Reynolds 2004). Although owls are highly mobile and can disperse long distances (Arsenault et al. 2005), breeding site fidelity is very high among males, which typically occupy the same territory their entire lives (Arsenault et al. 2005; Linkhart et al. 2016). The lower elevational range for owls is determined by maximum daytime temperature or high humidity, and the upper elevational range is limited by minimum night temperatures or high humidity, or both (McCallum 1994). Thus, owls may need to move up in elevation or to the north under warmer temperatures. Like other insectivorous birds, they are vulnerable to late-spring storms, a potential issue with climate change.

Flammulated owls are sensitive to phenological changes. Onset of incubation appears to be correlated with temperature, and owls may already be nesting earlier in response to warmer spring temperatures. High densities of arthropod prey are required for feeding and successfully raising young, so altered insect emergence could decouple with critical times in hatchling development. As with all long-distance migrants, this species is at risk of mismatch between summer and winter habitats (Bagne et al. 2011). Finally, this owl breeds rather late and only once per year (Arsenault et al. 2005; Linkhart and McCallum 2013; Linkhart and Reynold 2004), making it susceptible to reproductive failure in years with unfavorable conditions.

Flammulated owls are a secondary nester, so their well-being is associated with species such as woodpeckers that create cavities (Linkart and McCallum 2013; McCallum 1994). In the short term, primary cavity nesters are likely to benefit under climate change if tree mortality increases. In the long term, snags and large trees may become less common, with a lag between tree loss and establishment after fire and in response to shifting climate. Competition for nesting cavities can be high with other cavity nesters, although it is difficult to predict whether it will increase or decrease for owls. Where habitat declines, flammulated owls may face increased competition for nesting cavities among conspecifics, other owls, woodpeckers, and squirrels. However, this species persists where primary cavity species remain stable and under situations where arthropod abundance increases. Increasing nighttime temperatures coinciding with appropriate humidity levels will also allow flammulated owl to move into new, potentially suitable habitats.

Greater Sage-Grouse (Centrocercus urophasianus)

Vulnerability of greater sage-grouse is linked with the future of sagebrush. Invasion by cheatgrass and tree species (e.g., junipers) degrades sagebrush habitat, resulting in habitat loss (Boyd et al. 2014). Lower elevations are particularly prone to invasion by nonnative grasses, which can fuel frequent wildfires, kill mature sagebrush, and promote a transition from shrubland to grassland (Bradley 2010; Knick et al. 2013). The Great Basin is expected to experience a substantial increase in the probability of large wildfires, which will threaten isolated sage-grouse populations (Brown et al. 2004). Higher elevation sagebrush habitats are prone to conifer encroachment, particularly in northern parts of the region (Knick et al. 2013). Under warmer and drier conditions, sagebrush is expected to decline throughout much of Nevada and Utah (Bradley 2010; Schlaepfer et al. 2012). In addition to habitat loss, drought is expected to reduce forb cover and arthropod abundance (Miller and Eddleman 2000) and increase the likelihood of heat stress (Blomberg et al. 2012), particularly for chicks and juveniles (Miller and Eddleman 2000).

West Nile virus is an emerging infectious disease that is virulent in sage-grouse (Walker and Naugle 2011). Because mosquitoes transmit the virus, transmission of the virus and its prevalence are related to local temperature and precipitation (Walker and Naugle 2011). Warmer summer temperatures increase infection rates by favoring mosquito vectors and accelerating virus replication. Lower annual precipitation and increased drought can increase transmission of the virus by increasing contact between individuals who congregate in remaining mesic habitats and by creating more ephemeral water sources that cannot support mosquito predators (Harrigan et al. 2014; Naugle et al. 2004). Increased presence of West Nile virus is predicted for California, as well as northern Nevada and Idaho, where stronghold sage-grouse populations currently occur (Harrigan et al. 2014). Probability of West Nile virus presence in Utah may decrease (Harrigan et al. 2014). Artificial bodies of water, such as stock tanks and ponds associated with coal-bed natural gas extraction, further enhance West Nile virus transmission and sage-grouse vulnerability (Walker and Naugle 2011).

White-Headed Woodpecker (Picoides albolarvatus)

The white-headed woodpecker breeds in mature coniferous woodlands dominated by pines, most commonly ponderosa pine (Garrett et al. 1996). Preferred habitat is in areas with high numbers of more than one pine species and mature trees with an abundance of large cones with seeds (Hollenbeck et al. 2011; Mellen-McLean et al. 2013) perhaps as a buffer to variation in seed production among species. In the short term, increased beetle activity and increased tree mortality and drought could improve habitat quality, but reliance on pine seeds during winter provides less advantage than for species such as the American three-toed woodpecker. Loss of preferred habitat (e.g., through logging or fires) is the primary threat to this species (Environment Canada 2014) and will be exacerbated by increased wildfire activity. Woodpeckers can thrive in moderately burned areas if suitable habitat remains (Garrett et al. 1996; Latif et al. 2014), although loss of nest sites and food resources over long time periods could lead to population decline. White-headed woodpeckers may also be sensitive to phenological changes in food resources; they appear to breed later in the season than other woodpeckers (Kozma 2009), presumably to coincide with peak abundance of favored prey. This species produces a single clutch per year, which increases susceptibility to reproductive losses caused by fluctuations in food resources and spring storms (Hollenbeck et al. 2011).

White-headed woodpeckers have several sources of resilience. They can move long distances but are rarely found away from breeding areas, so they are not prone to the risks of migrating species. As a resident species, it is well adapted to a wide variety of weather conditions. In addition, warmer temperatures are positively correlated with nesting success associated with increased availability of insects (Hollenbeck et al. 2011). Woodpeckers are known to move short distances (less than 10 miles) to take advantage of exceptional food resources, such as spruce budworm outbreaks. Ultimately, the persistence of this species will be tied to the availability of appropriate forest habitats that can provide adequate food sources.

American Pika (Ochotona princeps)

Some consider the American pika highly vulnerable to a warming climate as its cool mountain habitats shift upward and occupy less area (Beever et. al 2011; Parmesan 2006). Bioclimatic data suggest that if greenhouse gas emissions continue to increase unabated, populations will become increasingly isolated and pikas may be extirpated in some portions of their range including the Great Basin (Galbreath et al. 2009). Pikas are sensitive to both temperature and precipitation changes and are likely to respond to both direct and indirect climate change effects. Physiologically, pikas are not tolerant of very high or very low temperatures, and higher summer temperatures may limit periods when they can actively forage (Beever et al. 2010; Jeffress et al. 2013; MacArthur and Wang 1973). Precipitation, particularly during the growing season, has been positively linked to pika population trends probably through effects on forage availability (Beever et al. 2003, 2013; Erb et al. 2011).

Annual net primary productivity on a broad scale, as a measure of forage quantity, may be enhanced by carbon dioxide fertilization in more northerly regions, and changes in precipitation may reduce annual productivity in southern regions (Reeves et al. 2014). Projected expansion of cheatgrass at low-elevation sites in northern parts of the IAP region may increase vulnerability of resident pika populations, but effects of cheatgrass have not been studied (Beever et al. 2008; Bradley 2010). Pikas are considered to be dispersal limited, with movements restricted to short distances or along continuous elevational gradients where lowlands do not need to be crossed. Thus, pikas in some locations will have difficulty tracking a geographic shift in habitat. Movement may be facilitated by favorable weather conditions, such as years of high precipitation (Castillo et al. 2014; Franken and Hik 2004; Jeffress et al. 2013; Smith 1974), although the frequency of such conditions in the future is unknown.

Several areas of potential resilience to climate change have been noted for pikas, although the nature of this resilience varies according to landscape context. Although not tolerant of high heat, pikas have recently been found to occur at lower elevations than previously thought, suggesting a broader range of temperature tolerance (Beever et al. 2008; Collins and Bauman 2012; Millar and Westfall 2010). In warm climates, pikas may seek sites with favorable microclimates where temperature is buffered locally (e.g., lava tubes, talus interstices) (Jeffress et al. 2013; Millar and Westfall 2010). In addition, pikas are active year round and can produce more than one litter per year, which may help this species take advantage of longer growing seasons (Bagne et al. 2011). At lower elevation sites, pikas may not have the same requirements for snow cover, which provides insulation against cold winter temperatures at higher elevation sites (Simpson 2009). Thus, lower elevation populations may be less vulnerable to reduced snowpack, but may still suffer physiological stress from high temperature.

Pikas will be the most vulnerable on isolated mountaintops, at lower elevations where they may already be near their physiological tolerance, and where primary productivity is expected to decline. Accordingly, populations in the southern Great Basin are probably the most vulnerable in the IAP region. Across the species range, resilient populations are likely to occur in locations that support loosely arranged rocks (rock-ice features, lava tubes) and deep rock features, and that are close to wetlands or other high-quality forage (Millar and Westfall 2010; Ray and Beever 2007).

Bighorn Sheep (Ovis canadensis)

We calculated vulnerability for the desert (*Ovis canadensis nelsoni*) and Sierra Nevada/Rocky Mountain (*O. c. sierra/O. c. canadensis*) bighorn sheep subspecies. Different parts of the IAP region, and thus different bighorn subspecies, will be subject to differential changes in climate linked to bighorn sheep population dynamics. A warmer climate will facilitate establishment of more arid vegetation types and reduce primary productivity within the southern portions of the region occupied by the desert subspecies (Reeves et al. 2014). Desert bighorn sheep will also be more vulnerable to increasing drought and high temperatures that reduce forage and standing water. Populations in the most arid, low-elevation areas and without access to dependable springs are most vulnerable (Epps et al. 2005).

Fluctuations in precipitation that affect spring forage availability and timing may have significant impacts on bighorn sheep (Portier et al. 1998). In general, areas with more topographic relief and fewer natural or anthropogenic barriers may be more resilient to negative impacts on year-round forage availability. Expected reductions in snowpack could increase winter range for Sierra Nevada and Rocky Mountain subspecies (Maloney et al. 2014). Forage quality may decline in mountainous habitats where warmer springs encourage faster green-up (Pettorelli et al. 2007; Wagner and Peek 2006). Changes in snowpack, in conjunction with nitrogen deposition, can also reduce selenium content of forage, resulting in deficiency that can lead to population declines (Flueck et al. 2012; Williams et al. 2002).

Bighorn sheep regularly undergo large mortality events that counter recovery efforts to reverse declining population trends. Endemic and introduced diseases are important drivers, but interactions with livestock, habitat quality, weather, predation, and infectious agents make it difficult to identify a single cause of these die-offs (Miller et al. 2012). Parasites that cause scabies and lungworm may expand with warmer temperatures as suitable habitats expand and parasite and host populations develop more rapidly (Hoberg et al. 2008). Potential climate-related changes in the prevalence of scabies and predation within winter ranges are of particular concern for bighorn sheep populations in the Sierra Nevada (USFWS 2007). Drought, severe weather, and vegetation changes can increase contact with infected individuals and facilitate transmission of pathogens such as those that cause brucellosis (Hoberg et al. 2008; Wolfe et al. 2010b).

Predation affects how bighorn sheep use habitats (Festa-Bianchet 1988). Mountain lions have been implicated in declines of sheep in the Sierra Nevada (USFWS 2007), but it is unclear whether predation pressure will increase under climate change. A longer growing season in mountainous areas may benefit bighorn sheep by allowing it to maintain proximity to escape terrain at higher elevations for a greater proportion of the year. Shifts in winter range could also potentially reduce contact with domestic livestock and competing ungulates. How the benefits of longer growing seasons and enhanced access to escape terrain will balance potential loss of forage quality and more frequent drought is unclear. Because several agents of disease may be enhanced under warmer temperatures, and because many bighorn populations in the region are small, factors related to high rates of infection and morbidity will affect efforts to increase populations.

Canada Lynx (Lynx canadensis)

Canada lynx is a specialist predator expected to be vulnerable to climate change through a variety of mechanisms. Projecting change to lynx habitat in the IAP region is difficult because of the complexity of interactions among climate, wildfire, and insect outbreaks across a diverse landscape. Drought-related mortality may affect some tree species and late-seral forests used by lynx for breeding (Bigler et al. 2007; McDowell and Allen 2015). Nonbreeding habitats, which typically contain a variety of seral stages and well-developed understory, may increase in areas with mixed-severity fires but decline in drier areas where more extensive wildfires favor homogeneity (McKenzie et al. 2004).

Canada lynx depends on snowshoe hares as a primary food source, although a variety of prey species are taken, particularly in summer (Interagency Lynx Biology Team 2013; Squires and Ruggiero 2007). Lynx and snowshoe hare populations are linked and fluctuate with climate; thus, the magnitude and timing of climatic events are noteworthy. Lynx will be vulnerable to projected reductions in snowpack (Maloney et al. 2014), which will reduce its competitive advantage over other predators in winter (Interagency Lynx Biology Team 2013; Ruggiero 1999). Alternate prey species such as grouse or tree squirrels are smaller and may not compensate for reduced snowshoe hare populations (Ruggiero et al. 1994). Conversely, lynx may experience increased hunting success where white-coated snowshoe hares are unable to match molting cycles to more rapid and earlier snowmelt (Mills et al. 2013) (fig. 9.6). This short-term advantage is unlikely to compensate for the negative impacts of increasingly variable hare populations. Habitat fragmentation and lynx hybridization with bobcats are also threats (Interagency Lynx Biology Team 2013) that could increase as habitat quality declines and changing conditions induce dispersal. Lynx are expected to be more resilient where dense understory vegetation and large forest patches are maintained, whereas more vulnerable populations will be found where forests are drying and at high risk for wildfire or insect outbreaks.

Figure 9.6—Snowshoe hare. If pelage change for snowshoe hares does not keep pace with early snowmelt in a warmer climate, they will be susceptible to increased predation by Canada lynx and other species (photo: U.S. Fish and Wildlife Service).

Fisher (Pekania pennanti)

The fisher relies on the physical structure of forest habitat rather than a specific forest type. A modeling analysis suggests that probability of fisher occurrence is highest for mesic forest types with tall trees, high annual precipitation, and mid-range winter temperatures (Olson et al. 2014). Given the expected effects of an altered fire regime on the extent and pattern of late-seral forests (Littell et al. 2009, 2010; McKenzie et al. 2011), the extent, quality, and connectivity of fisher habitat in the IAP region will probably decrease in response to climate change. Habitat change will be driven largely by increasing area burned, which will reduce late-seral forest habitats.

Fishers are probably not dispersal limited, so they can move from unfavorable to favorable habitat as needed. They are opportunistic predators, primarily of snowshoe hare, squirrels (*Tamiasciurus, Sciurus, Glaucomys,* and *Tamias* spp.), mice (*Microtus, Clethrionomys,* and *Peromyscus* spp.), and birds (numerous species) (Powell 1993). They also consume carrion and plant material (e.g., berries). No clear trends are projected for the effects of climate change on availability of prey species.

Fringed Myotis (Myotis thysanodes)

Although the fringed myotis is relatively rare, it can be abundant in local populations and inhabits most of the western United States (Hester and Grenier 2005; Keinath 2004). The fringed myotis frequents a fairly broad range of habitats (Keinath 2003), but is typically associated with oak, pinyon, and juniper woodlands or ponderosa pine forests at mid-elevations (Keinath 2003). Caves, abandoned mines, and buildings can be used for maternity colonies, hibernacula, and solitary day and night roosts. Fringed myotis appears to exhibit high breeding site fidelity, returning to the same geographic areas year after year (Keinath 2004). Although this species regularly roosts underneath bark and inside hollows of tree snags, roosts in relatively permanent structures (e.g., caves, buildings, rock crevices) seem to elicit high fidelity, whereas roosts in trees do not (Keinath 2003). Winter range is poorly known for this species (Hester and Grenier 2005; IDFG 2005; Oliver 2000; USDA FS 2014).

Like other bats, fringed myotis inhabits environments where persistent sources of water are readily available (Hester and Grenier 2005; Keinath 2004). Roost sites are usually located close to stream channels. In addition, most bats need open, still bodies of water to drink, and lactating females have additional water requirements (Keinath 2004). Bats are small and have a high ratio of surface area to volume, making them prone to losing large amounts of water through evaporative loss. A long-term study demonstrated that water availability was crucial to the reproductive effort of insectivorous bats (Adams 2010). Several species (including fringed myotis) showed a threshold-type response to decreased streamflow rates, with reproductive output decreasing rapidly as stream discharge declined. The number of nonreproductive females captured increased as mean high temperatures increased. Instead of abandoning traditional roost sites impacted by detrimental environmental conditions, fringed myotis responded by reducing their reproductive output. Slower ontogeny may jeopardize survival of both young and adult females by shortening the window needed for increasing body mass for hibernation or migration (Adams 2010).

Fringed myotis exhibits some traits that increase resilience to climate-related changes. Because it is agile in flight, very small watering holes may be sufficient for water supplies (Keinath 2004). It is also somewhat opportunistic, feeding on diverse insect species when they are abundant, although beetles are normally a large portion of their diet. Finally, migration events are relatively fast, synchronous, and closely tied to breeding and seasonal weather patterns, so fringed myotis can respond quickly to changing conditions. Resilience will be highest in areas where water sources continue to be associated with roost sites.

Northern Idaho Ground Squirrel (Urocitellus brunneus brunneus)

Recent declines in the northern Idaho ground squirrel have been partly attributed to livestock grazing and encroachment of young trees facilitated through fire exclusion (Sherman and Runge 2002). Higher frequencies of wildfire projected for the IAP region (Peterson and Littell 2012) could increase the quantity of suitable habitat and availability of dispersal corridors. This ground squirrel has a long hibernation period, requiring accumulation of fat stores and hibernacula insulated by snowpack. The species can suffer winter mortality when snow is not deep enough to provide insulation (Sherman and Runge 2002; USFWS 2003). Assuming that snowpack will decrease (Maloney et al. 2014), overwinter mortality may increase, particularly for juveniles.

Primary productivity is expected to increase across the current range of northern Idaho ground squirrels (Reeves et al. 2014), potentially increasing seed production but perhaps at the cost of plant species diversity (Suttle et al. 2007), which could reduce the availability and timing of preferred forage species. Earlier snowmelt, longer growing seasons, nonnative plant species, increasing fires, and altered pollinator populations all affect plant species composition and seed set (Alward et al. 1999; Inouye and McGuire 1991; Sherman and Runge 2002). Timing and availability of fat-laden seeds are likely to affect ground squirrel response, but it is difficult to project how food sources will change in the future.

Ground squirrel populations in the IAP region are small, isolated, and vulnerable to additional stress related to climate and other factors. Individual squirrels are capable of dispersing to new areas in pace with habitat change (Sherman and Runge 2002), but small populations and human-caused barriers constrain movement (USFWS 2003). Plague is a potential threat but has not been recorded in these populations, although climate is expected to become more favorable for plague transmission in Idaho (Nakazawa et al. 2007). Improved habitat through increased productivity may benefit northern Idaho ground squirrel, but short-term drought, cold spring weather, and disease, as well as nonclimatic factors (overgrazing, recreational shooting, land development) may be significant stressors.

Sierra Nevada Red Fox (Vulpes vulpes necator)

The Sierra Nevada red fox is adapted to snowy, high-elevation habitats (Buskirk and Zielinski 2003; USFWS 2015), and altered snowpack is the biggest threat to fox persistence through its effects on species interactions. This fox subspecies appears to have habitat and distribution limitations and is not as common as other subspecies (Perrine et al. 2010). Even in favorable habitat, red fox has been reported in small numbers, and several studies have noted population declines (Buskirk and Zielinski 2003; SNRFIWG 2010). It is a USFS sensitive species in California and a candidate for listing with the U.S. Fish and Wildlife Service in California and Nevada (USFWS 2015). Many populations are small and isolated and at risk of inbreeding depression and stochastically driven local extinctions (USFWS 2015).

Climate change may alter forest habitat through increased wildfires, drought stress, and insect outbreaks (USFWS 2015). In addition, low snowpack in the Sonora Pass area may be increasing competition and predation from coyotes (Perrine 2005; Perrine et al. 2010). Red foxes tend to avoid areas frequented by coyotes, which may be an important factor in restricting it to higher elevations. Hybridization between the two species is occurring at the Sonora Pass area (USFWS 2015) and could increase if climate facilitates range shifts. This fox is susceptible to several communal diseases (elokomin fluke fever, sarcopic mange, canine distemper, rabies), but it is unclear whether climate-related changes in habitat and behavior would affect transmission among individuals. Where red foxes are negatively affected, recovery tends to be slow because they have only one breeding season per year. Low reproductive capacity also makes it susceptible to climate-related fluctuations in prey species.

Living in remote mountain habitats, red foxes are sensitive to the presence of humans (Buskirk and Zielinski 2003; SNRFIWG 2010), although they can move long distances and could migrate into new habitats if available. Habitat management that improves prey availability and reduces coyote pressure can improve resilience of Sierra Nevada red fox populations.

Townsend's Big-Eared Bat (Corynorhinus townsendii)

Two subspecies of Townsend's big-eared bat (ssp. *townsendii* and *pallescens*) may occur in the IAP region (Pierson et al. 1999), and shifts in distributions of subspecies may occur under climate change. Use of a variety of forest, shrub, and woodland habitats by big-eared bats confers some resilience to habitat change. Although many shrub habitats are expected to remain or expand (Chapters 6, 7), increasing wildfires and proliferation of nonnative grasses could degrade habitats and reduce prey availability (Pierson et al. 1999) (Chapter 8). Northern portions of Nevada may be especially prone to cheatgrass invasion (Bradley 2010).

This insectivorous bat species needs access to surface water, especially during lactation (Adams 2003; Neuweiler 2000), and expected changes in snowpack and higher evaporation rates will probably reduce water availability in summer (Maloney et al. 2014). Although little is known about how the quality of various habitats relates to bat survival and reproduction, changes in proximity of suitable roost sites to foraging grounds will probably make big-eared bats vulnerable. Spread of white-nose fungus into the IAP region is expected by the 2020s, with earlier arrival in the north than south (Maher et al. 2012). Warmer weather and torpor characteristics are associated with frequent arousal, which may mitigate effects of fungal infection (Bernard et al. 2015; Johnson et al. 2012).

Although big-eared bats feed heavily on moths that are sensitive to climate, there is no evidence that generalist and specialist moth populations would decline synchronously across all species (Wilson and MacLean 2011). Rising temperatures will affect phenology related to foraging, breeding, torpor, and movement in bats while also affecting moth life cycles and distributions, which could lead to a mismatch in prey availability and bat energy requirements (Both et al. 2006). Because of a relatively sedentary nature and cave-roosting habits, this bat species is less likely than others to be vulnerable to wind turbine collisions (Johnson 2005). Disturbance at roost sites is an important stressor (Humphrey and Kunz 1976; Pierson et al. 1999) and is pertinent to climate change adaptation strategies that include roost monitoring. Managers will also need to consider the effect of phenological shifts on the timing of seasonal cave closures. Bats may be more resilient in landscapes where more roosts are available, surface water is available year round, and risk of cheatgrass invasion is low.

Utah Prairie Dog (Cynomys parvidens)

Little information is available on the potential effects of climate change on the Utah prairie dog. Increasing wildfires and invasive grasses may play a role in local habitat change, although the ultimate outcome for prairie dogs is unclear. Plague transmission in Utah is not expected to change based on past climate relationships (Nakazawa et al. 2007), but future climate relationships are unclear for the complex dynamics of outbreaks, such as climate effects on short-term disease reservoirs and flea species (Salkeld et al. 2010; Webb et al. 2006).

Prairie dogs will be vulnerable to changes in resource timing, such as availability of forage during lactation and before onset of hibernation. Drought is of particular concern because it has been implicated in past population declines through limitations related to food availability and water balance (Collier and Spillet 1975). Specialized traits pertaining to colonial living, such as communal nursing (Hoogland 2009), predator evasion (Hoogland 1981), and habitat manipulation (Bangert and Slobodchikoff 2006), may offer some resilience to changing conditions. More resilient populations will be those that are near persistent, moist swales and with few barriers to dispersal. Response of Utah prairie dogs to climate change is important because their presence on the landscape has implications for a diversity of mammal, bird, and reptile species (Kotliar et al. 1999).

Wolverine (Gulo gulo)

Climate-induced changes that reduce suitable habitat, especially snowpack, will have negative impacts on wolverine populations in the IAP region, although response to these changes is uncertain because of limited information (Ruggiero et al. 1994; Curtis et al. 2014). Wolverines depend on high-elevation forests and alpine habitats, which are likely to contract gradually in the future. Wolverine range is closely tied to areas with high snow levels (Schwartz et al. 2009), where the animals' large feet allow them to travel more easily than many other species (Ruggerio et al. 1994). Reduced snowpack, which is projected for most lower elevations in western North America, may be less severe in the Sierra Nevada than in other locations (Curtis et al. 2014; Maloney et al. 2014), although little is known about wolverine populations there (Moriarty et al. 2009). More precipitation falling as rain rather than snow and earlier spring snowmelt will restrict wolverine movement across the landscape (Aubry et al. 2007), fragment its habitat (McKelvey et al. 2011), increase competition with other predators, and reduce availability of cold food-caching and denning sites (Inman et al. 2012).

Wolverines have low reproductive rates that may decline further with loss of spring snow associated with preferred den sites. Loss of snow cover may also expose kits to increased predation (Ruggerio et al. 1994). Strong avoidance of human disturbance, including roads, may also limit the ability of this species to respond to change, particularly in its southern range, where habitats are more restricted (Fisher et al. 2013; McKelvey et al. 2011). This makes protection of narrow corridors for dispersal in Wyoming and Utah a priority (Schwartz et al. 2009).

Wolverines may be fairly resilient to food resource fluctuations because of their relatively broad diet and food caching behavior (Inman et al. 2012), but only within areas that otherwise remain suitable under future climate. Ungulates are an important scavenging item; thus, ungulate populations and hunting success of predators will affect food availability (Ruggerio et al. 1994). Reduced depth and duration of snow cover may benefit certain ungulate species, and hence may increase prey, but could also increase competition with other predators and scavengers. Despite a few resilient traits, wolverines will probably decline because of low populations (Schwartz et al. 2009) and the number of anticipated negative impacts from climate change.

Boreal Toad (*Anaxyrus boreas boreas*)

The boreal toad contains considerable genetic diversity, with eastern populations in Utah and southeastern Idaho considered distinct from western populations in Nevada and California (Center for Biological Diversity 2011; Federal Register 2012, 77 FR 21920) (fig. 9.7). Recent population declines have occurred throughout its range, including within unaltered habitats (Drost and Fellers 1996; Wente et al. 2005), coinciding with the introduction of chytrid fungus, although chytridiomycosis may be just one of many drivers of decline (Hof et al. 2011; Pilliod et al. 2010). Warmer temperatures are associated with spread of the fungus in cool, high-elevation habitats, but precipitation and humidity are also important, with limited infections in warm, dry areas (Berger et al. 2016; Puschendorf et al. 2009). Seasonality of prevalence and intensity of infection are affected by temperature, with high severity in summer for temperate climates (Berger et al. 2016). Warmer and drier climates have been associated with a lower occurrence of chytrid fungus in Australia and Costa Rica, but die-offs of Arizona lowland leopard frogs illustrate that chytrid can impact amphibians in dry climates as well (Berger et al. 2016). Some seasonal drying of habitats within levels that toad species can tolerate may benefit toad populations (Bielby et al. 2008) by discouraging the establishment of chytrid fungus and the fish and bullfrogs that are predators and carry the fungus (Berger et al. 2016; Puschendorf et al. 2009).

Although the mechanism is unclear, boreal toads appear to respond positively to wildfire, at least in the short term, and may benefit from climate-driven increases in fire frequency (Hossack and Pilliod 2011). Like all amphibians, boreal toads are sensitive to water balance as affected by rainfall, high temperatures, and drought (Bagne et al. 2011; Friggens et al. 2013). These factors affect when and where the toads can be active. A study in Idaho projected significant reductions in activity periods and growth under warmer conditions, especially in more open habitats where desiccation risk is higher (Bartelt et al. 2010). Toads generally select refuge within landscapes with favorable microclimates and relatively high humidity (Long and Prepas 2012).

Figure 9.7—Boreal toad. This amphibian species will probably have less wetland habitat in a warmer climate, although the manner in which climate affects chytrid fungus, and in turn vigor and mortality of toad populations, may determine future abundance and distribution (photo: U.S. Forest Service).

Juvenile toads are more diurnal (Lillywhite et al. 1973) and may be at an increased risk of reduced growth due to decreased activity under warmer conditions. Warmer temperatures may increase the rate of metamorphosis but can reduce pond longevity, causing tadpole mortality. Warmer temperatures also lead to increased livestock activity at water bodies, increasing the risk of trampling and loss of vegetative cover in breeding habitats (Bartelt 1998; DelCurto et al. 2005). Timing and duration of water availability, plus sufficient refuge from predation, cold, and desiccation, will help identify locally vulnerable or resilient habitats.

Columbia Spotted Frog (*Rana luteiventris*)

Climate change may exacerbate the major cause of historical declines in the Columbia spotted frog through alteration and fragmentation of aquatic habitats. Drought, warmer temperatures, altered precipitation regimes, and reduced snowpack will alter the timing of peakflows in streams, transform some permanent reaches to ephemeral, and reduce duration of temporary waters for breeding (Maloney et al. 2014; Seager et al. 2007). Warmer temperatures may increase suitability of some oviposition sites (Pearl et al. 2007), but greater evaporation can increase reproductive failure, which occurs when ponds become desiccated before metamorphosis is complete (McMenamin et al. 2008). Although spotted frogs can disperse relatively long distances, previous habitat changes have left some populations isolated (Bull and Hayes 2001; Funk et al. 2005; Pilliod et al. 2002). Fragmentation of habitat may be intensified by drier conditions, particularly in southern portions of the IAP region.

Chytridiomycosis has not been clearly linked to population declines (Russell et al. 2010), and there is no clear evidence that infection rates and pathology would increase in this species with climate change (Pearl et al. 2009; Wilson et al. 2005). Columbia spotted frogs appear susceptible to malformations caused by larval trematodes transmitted by birds, fish, and snails (*Planorbella* spp.). Host snail populations are known to increase with shrinking water sources and eutrophication, and are often associated with artificial water sources (e.g., stock tanks), which may become more common under drier conditions (Blaustein et al. 2005; Johnson et al. 2002).

Because stressors such as pollution, ultraviolet-B radiation, and habitat change can interact with pathogens, disease outbreaks can cause rapid widespread mortality

(Blaustein and Kiesecker 2002). Disease-climate interactions are poorly known for this species, and monitoring to detect early signs of outbreaks would be prudent. Livestock grazing, which was also implicated in recent declines (DelCurto et al. 2005; but see Adams et al. [2009]), may have an increased impact on this species as drier conditions concentrate livestock at water sources (DelCurto et al. 2005; Reaser 2000). One source of resilience is the expansion of potential habitat as high-elevation areas become more viable in warmer winters (McCaffery and Maxell 2010). Overall, Columbian spotted frogs will be more resilient where water sources are reliable, dispersal corridors are intact, and they coexist with few fish and Planorbella snails.

Great Basin Spadefoot (Spea intermontana)

The Great Basin spadefoot occurs in a wide variety of vegetation types, which provides some resilience to climate change, but its reliance on temporary and permanent ponds for breeding makes this species vulnerable to changes in precipitation and increased evaporation rates. Long-distance dispersal by spadefoots is irregular and limited by presence of ponds and habitat fragmentation (Semlitsch 2000). Movement in response to climate-induced habitat shifts will be further limited by occurrence of friable soils and burrows. Cheatgrass, which is projected to expand (Bradley 2010), grows best on the same sandy soils used by burrowing spadefoot and may degrade habitats. Fibrous roots of cheatgrass remove soil moisture, reduce permanency of water sources, and restrict burrowing activity (Buseck et al. 2005).

Breeding spadefoots will be most vulnerable to longevity of pools and ponds. Summer and monsoon precipitation are expected to decrease (Maloney et al. 2014). The collective impact of reduced summer precipitation, more variable precipitation patterns, and higher temperatures may reduce the number and duration of ephemeral ponds typically used for breeding. However, high breeding capacity, rapid tadpole development, and flexible breeding seasons improve the likelihood that this species will be able to successfully respond to changes in pond availability (O’Regan et al. 2014). Spadefoot is more resilient during nonbreeding periods because of its generalist diet and ability to aestivate in burrows for long periods. Biotic interactions with other species are poorly known. Competitive interactions with other amphibians may increase where pond availability is reduced, but an accompanying shift to ephemeral water sources could decrease predation by fish. Great Basin spadefoot populations are likely to be more vulnerable in areas where they rely more on ephemeral than permanent pools (Morey 1994), and in the southern portion of the species range where more frequent drought will have a major impact on breeding ponds (Maloney et al. 2014).

Prairie Rattlesnake (Crotalus viridis)

Rattlesnakes in eastern Idaho were recently grouped as part of the eastern clade along with Hopi rattlesnake, which occurs in southeastern Utah and may itself be a distinct subspecies (Douglas et al. 2002; Goldenberg 2013). For this assessment, we focus on projected changes for the prairie rattlesnake in Idaho, which probably includes more than one subspecies. This species may be vulnerable to climate change because it has low fecundity, long generation times, and low dispersal ability (Gibbons et al. 2000). Sensitivity to human predation and roads (Clark et al. 2010) further reduces adaptive capacity. Although modeling suggests that suitable climate for prairie rattlesnakes will shrink (but will persist in Idaho to 2100) (Lawing and Polly 2011), this projection does not include the potentially significant effects of fire or biotic interactions. Extreme events such as flooding can reduce prey and damage habitats (Seigel et al. 1998). Refugia under down woody debris and shrubs provide favorable microclimates (Harvey and Weatherhead 2006) and would be reduced by frequent fires, which pose a moderate to high risk in central Idaho.

Warmer temperatures could reduce time spent in hibernacula, thereby decreasing time needed to build fat stores, could shorten digestion time, and could positively influence reproductive success (Beck 1996; Gannon and Secoy 1985; Graves and Duvall 1993). Several important activities, including hibernation, breeding, basking, and foraging, are closely timed with temperature conditions (Gannon and Secoy 1985; King and Duvall 1990), and mismatched timing of those activities could create considerable stress (Bagne et al. 2011). Projections of increased primary productivity in Idaho (Reeves et al. 2014) may increase rodent populations, depending on habitat, which would benefit snakes in the area. Prairie rattlesnakes may be more resilient where microclimate refugia (e.g., low fire risk, rocky terrain) remain and habitats are not fragmented.

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Appendix 3—List of Common and Scientific Names for Species in Chapter 9

Amphibians

Arizona lowland leopard frog (*Lithobates yavapaiensis*)
Arizona toad (*Anaxyrus microscaphus*)
blotched tiger salamander (*Ambystoma tigrinum melanostictum)*
boreal chorus frog (*Pseudacris maculata*)
boreal toad (*Anaxyrus boreas boreas*)
canyon tree frog (*Hyla arenicolor*)
Columbia spotted frog (*Rana luteiventris*)
Great Basin spadefoot (*Spea intermontana*)
Great Plains toad (*Anaxyrus cognatus*)
long-toed salamander (*Ambystoma macrodactylum*)
northern leopard frog (*Lithobates pipiens*)
relict leopard frog (*Lithobates onca*)
tiger salamander (*Ambystoma tigrinum*)
Woodhouse's toad (*Anaxyrus woodhousii*)
yellow-legged frog (*Rana muscosa & R. sierrae)*

Birds

Allen's hummingbird (*Selasphorus sasin*)
American kestrel (*Falco sparverius*)
American robin (*Turdus migratorius*)
American pipit (*Anthus rubescens*)
American three-toed woodpecker (*Picoides dorsalis*)
bald eagle (*Haliaeetus leucocephalus*)
band-tailed pigeon (*Patagioenas fasciata*)
Bewick's wren (*Thryomanes bewickii*)
black rosy finch (*Leucosticte atrata*)
black swift (*Cypseloides niger*)
black-backed woodpecker (*Picoides articus*)
black-billed magpie (*Pica hudsonia*)
black-capped chickadee (*Poecile atricapillus*)
black-throated sparrow (*Amphispiza bilineata*)
blue grosbeak (*Passerina caerulea*)
bluebird species (*Sialia* spp.)
boreal owl (*Aegolius funereus*)
Brewer's sparrow (*Spizella breweri*)
brown creeper (*Certhia americana*)
brown-headed cowbird (*Molothrus ater*)
burrowing owl (*Athene cunicularia*)
California quail (*Callipepla californica*)
calliope hummingbird (*Selasphorus calliope*)
Cassin's finch (*Haemorhous cassinii*)
chickadee species (*Poecile* spp.)
chipping sparrow (*Spizella passerina*)
chukar (*Alectoris chukar*)
Clark's nutcracker (*Nucifraga columbiana*)
Columbian sharp-tailed grouse (*Tympanuchus phasianellus columbianus*)
common nighthawk (*Chordeilis minor*)
common raven (*Corvus corax*)
Cooper's hawk (*Accipiter cooperii*)
crossbill species (*Loxia* spp.)
dark-eyed junco (*Junco hyemalis*)
downy woodpecker (*Picoides pubescens*)
dusky flycatcher (*Empidonax oberholseri*)
dusky grouse (*Dendragapus obscurus*)
eastern kingbird (*Tyrannus tyrannus*)
ferruginous hawk (*Buteo regalis*)
flammulated owl (*Psiloscops flammeolus*)
flycatcher spp. (*Tyrannidae* spp.)
golden eagle (*Aquila chrysaetos*)
gray flycatcher (*Empidonax wrightii*)
gray vireo (*Vireo vicinior*)
great gray owl (*Strix nebulosi*)
great horned owl (*Bubo virginianus*)
greater sage-grouse (*Centrocercus urophasianus*)
green-tailed towhee (*Pipilo chlorurus*)
Gunnison sage-grouse (*Centrocercus minimus*)
hairy woodpecker (*Picoides villosus)*
hermit thrush (*Catharus guttatus*)
horned lark (*Eremophila alpestris*)
house wren (*Troglodytes aedon*)
hummingbird species (*Trochilidae* spp.)
juniper titmouse (*Baeolophus ridgwayi)*
kinglet species (*Regulus* spp.)
lark sparrow (*Chondestes grammacus*)
lazuli bunting (*Passerina amoena*)
Lewis's woodpecker (*Melanerpes lewis*)
Lincoln's sparrow (*Melospiza lincolnii*)
loggerhead shrike (*Lanius ludovicianus*)
long-eared owl (*Asio otus*)
MacGillivray's warbler (*Geothlypis tolmiei*)
Merriam's wild turkey (*Meleagris gallopavo merriami*)
Mexican spotted owl (*Strix occidentalis lucida*)
mountain bluebird (*Sialia currucoides*)
mountain chickadee (*Poecile gambeli*)
northern flicker (*Colaptes auratus*)

northern goshawk (*Accipiter gentilis*)
northern harrier (*Circus cyaneus*)
northern hawk owl (*Surnia ulula*)
northern pygmy-owl (*Glaucidium gnoma*)
northern saw-whet owl (*Aegolius acadicus*)
nuthatch species (*Sitta* spp.)
olive-sided flycatcher (*Contopus cooperi*)
osprey (*Pandion haliaetus*)
owl species (*Strigiformes* spp.)
Pacific wren (*Troglodytes pacificus*)
peregrine falcon (*Falco peregrinus*)
pileated woodpecker (*Dryocopus pileatus*)
pine grosbeak (*Pinicola enucleator*)
pine siskin (*Spinus pinus*)
pinyon jay (*Gymnorhinus cyanocephalus*)
prairie falcon (*Falco mexicanus*)
purple martin (*Progne subis*)
pygmy nuthatch (*Sitta pygmaea*)
red crossbill (*Loxia curvirostra*)
red-breasted nuthatch (*Sitta canadensis*)
red-naped sapsucker (*Sphyrapicus nuchalis*)
red-tailed hawk (*Buteo jamaicensis*)
ring-necked pheasant (*Phasianus colchicus*)
rock wren (*Salpinctes obsoletus*)
rosy finch species (*Leucosticte* spp.)
rough-legged hawk (*Buteo lagopus*)
ruffed grouse (*Bonasa umbellus*)
sage sparrow—now split to sagebrush sparrow (*Artemisiospiza nevadensis*) and Bell’s sparrow (*Artemisiospiza belli*)
sage thrasher (*Oreoscoptes montanus*)
sapsucker species (*Sphyrapicus* spp.)
scrub jay—now split to Woodhouse’s scrub-jay (*Aphelocoma woodhouseii*) and California scrub-jay (*Aphelocoma californica)*
sharp-shinned hawk (*Accipiter striatus*)
short-eared owl (*Asio flammeus*)
song sparrow (*Melospiza melodia*)
southwestern willow flycatcher *Empidonax traillii extimus*)
spotted towhee (*Pipilo maculatus*)
spruce grouse (*Falcipennis canadensis*)
Steller’s jay (*Cyanocitta stelleri*)
Swainson’s hawk (*Buteo swainsoni*)
Swainson’s thrush (*Catharus ustulatus*)
thrush (*Turdidae* spp.)
Townsend’s solitaire (*Myadestes townsendii*)
tree swallow (*Tachycineta bicolor*)
vesper sparrow (*Pooecetes gramineus*)
warbling vireo (*Vireo gilvus*)
western bluebird (*Sialia mexicana*)
western meadowlark (*Sturnella neglecta*)
western screech-owl (*Megascops kennicottii*)
western tanager (*Piranga ludoviciana*)
white-crowned sparrow (*Zonotrichia leucophrys*)
white-headed woodpecker (*Picoides albolarvatus)*
white-tailed ptarmigan (*Lagopus leucura*)
white-throated swift (*Aeronautes saxatalis*)
Williamson’s sapsucker (*Sphyrapicus thyroideus*)
woodpecker species (*Picidae* spp.)
yellow warbler (*Setophaga petechia*)
yellow-billed cuckoo (*Coccyzus americanus*)
yellow-rumped warbler (*Dendroica coronata*)

Insects

fire ant (*Solenopsis invicta*)
forest tent caterpillar (*Malacosoma disstria*)
Morand’s checkerspot (*Euphydryas anicia morandi*)
mountain pine beetle (*Dendroctonus ponderosae*)
mountain-mahogany looper (*Iridopsis clivinaria*)
Mt. Charleston blue butterfly (*Icaricia shasta charlestonensis*)
Spring Mountains acastus checkerspot (*Chlosyne acastus robusta*)

Mollusks

desert springsnail (*Pyrgulopsis deserta*)
fat-whorled pondsnail (*Stagnicola bonnevillensis*)
Kanab ambersnail (*Oxyloma haydeni kanabense* or *Oxyloma kanabense*)
Utah physa (*Physella utahensis*)

Mammals

Abert’s squirrel (*Sciurus aberti*)
Allen’s big-eared bat *(Idionycteris phyllotis*)
American beaver (*Castor canadensis*)
American marten (*Martes americana*)
badger (*Taxidea taxus*)
bat species (*Chiroptera* spp.)
bighorn sheep (*Ovis canadensis*)
black bear (*Ursus americanus*)
black-tailed jackrabbit (*Lepus californicus*)
bobcat (*Lynx rufus*)
bushy-tailed woodrat (*Neotoma cinerea*)
Canada lynx (*Lynx canadensis*)
chipmunk species (*Tamias* spp.)
common gray fox (*Urocyon cinereoargenteus*)
cottontail species (*Sylvilagus* spp.)
coyote (*Canis latrans*)
deer mouse (*Peromyscus* spp.)

dwarf shrew (*Sorex nanus*)
elk (*Cervus canadensis*)
fisher (*Martes pennant*)
fringed myotis (*Myotis thysanodes*)
golden-mantled ground squirrel (*Spermophilus lateralis*)
Great Basin pocket mouse (*Perognathus parvus*)
grizzly bear (*Ursus arctos*)
ground squirrel species (*Scuiridae* spp.)
Gunnison's prairie dog (*Cynomys gunnisoni*)
hoary bat *(Lasiurus cinereus*)
kangaroo rat (*Dipodomys* spp.)
kit fox (*Vulpes macrotis*)
least chipmunk (*Tamias minimus*)
little brown bat (*Myotis lucifugus*)
long-eared myotis (*Myotis evotis*)
Merriam's shrew (*Sorex merriami*)
moose (*Alces alces*)
mountain goat (*Oreamnos americanus*)
mountain lion (*Felis concolor*)
mouse species (*Muridae* spp.)
mule deer (*Odocoileus hemionus*)
northern flying squirrel (*Glaucomys sabrinus*)
northern Idaho ground squirrel (*Urocitellus brunneus brunneus*)
pika (*Ochotona princeps*)
pinyon mouse (*Peromyscus truei*)
Piute ground squirrel (*Urocitellus mollis*)
pocket gopher species (*Geomyidae* spp.)
porcupine (*Erethizon dorsatum*)
Preble's shrew (*Sorex preblei*)
pronghorn (*Antilocapra americana*)
pygmy rabbit (*Brachylagus idahoensis*)
rabbit species (*Leporidae* spp.)
red fox (*Vulpes vulpes*)
red squirrel (*Tamiasciurus hudsonicus*)
red-backed vole (*Myodes gapperi*)
river otter (*Lontra canadensis*)
rodent (*Rodentia* spp.)
sagebrush vole (*Lemmiscus curtatus*)
shrew (*Soricidae* spp.)
Sierra Nevada red fox *(Vulpes vulpes necator)*
silver-haired bat (*Lasionycteris noctivagans*)
snowshoe hare (*Lepus americanus*)
spotted bat (*Euderma maculatum*)
squirrel (*Sciurus* spp.)
Stephens' woodrat (*Neotoma stephensi*)
Townsend's big-eared bat (*Corynorhinus townsendii*)
Utah prairie dog (*Cynomys parvidens*)
vole (*Cricetidae* spp.)
weasel (*Mustela* spp.)
western pipistrelle (*Parastrellus hesperus*)
western red bat (*Lasiurus blossevillii*)
white-tailed deer (*Odocoileus virginianus*)
wolverine (*Gulo gulo*)
woodland caribou (*Rangifer tarandus caribou*)
woodrat (*Neotoma* spp.)
Yuma myotis (*Myotis yumaensis*)
yellow-bellied marmot (*Marmota flaviventris*)

Reptiles

common kingsnake (*Lampropeltis getula*)
common side-blotched lizard (*Uta stansburiana*)
desert horned lizard (*Phrynosoma platyrhinos*)
desert tortoise (*Gopherus agassizii*)
eastern fence lizard (*Sceloporus undulatus*)
gopher snake (*Pituophis catenifer*)
greater short-horned lizard (*Phrynosoma hernandesi*)
Hopi rattlesnake (*Crotalus viridis nuntius*)
long-nosed leopard lizard (*Gambelia wislizenii*)
long-nosed snake (*Rhinocheilus lecontei*)
many-lined skink (*Plestiodon multivirgatus*)
milksnake (*Lampropeltis triangulum*)
nightsnake (*Hypsiglena torquata*)
ornate tree lizard (*Urosaurus ornatus*)
painted turtle (*Chrysemys picta*)
plateau striped whiptail (*Aspedoscelis velox*)
prairie rattlesnake (*Crotalus viridis*)
pygmy short-horned lizard (*Phrynosoma douglasii*)
rattlesnake (*Crotalus* spp.)
ring-necked snake (*Diadophis punctatus*)
sagebrush lizard (*Sceloporus graciosus*)
smooth greensnake (*Opheodrys vernalis*)
southern alligator lizard (*Elgaria multicarinata*)
speckled rattlesnake (*Crotalus mitchellii*)
striped racer (*Masticophis lateralis*)
striped whipsnake (*Masticophis taeniatus*)
terrestrial garter snake (*Thamnophis elegans*)
tiger whiptail (*Aspidoscelis tigris*)
western fence lizard (*Sceloporus occidentalis*)
western rattlesnake (*Crotalus oreganus*)
western skink (*Plestiodon skiltonianus*)

Plants

alder (*Alnus* spp.)
antelope bitterbrush (*Purshia tridentata*)
aspen (*Populus tremuloides*)
bitterbrush (*Purshia* spp.)
boxelder (*Acer negundo*)

bristlecone pine (*Pinus longaeva*, *P. aristata*)
budsage (*Picrothamnus desertorum*)
bulrush (*Cyperaceae* spp.)
cattail (*Typha* spp.)
cheatgrass (*Bromus tectorum*)
chokecherry *(Prunus virginiana*)
cottonwood (*Populus* spp.)
curl-leaf mountain mahogany (*Cercocarpus ledifolius*)
currant (*Ribes* spp.)
Douglas-fir (*Pseudostuga menziesii*)
Engelmann spruce (*Picea engelmannii*)
fourwing saltbush (*Atriplex canescens*)
huckleberry species (*Vaccinium* spp.)
juniper species (*Juniperus* spp.)
lodgepole pine (*Pinus contorta*)
maple (*Acer* spp.)
mountain big sagebrush (*Artemisia tridentata vaseyana*)
oak (*Quercus* spp.)
phragmites (*Phragmites* spp.)
ponderosa pine (*Pinus ponderosa*)
Russian olive (*Elaeagnus angustifolia*)
saltcedar (*Tamarix* spp.)
sawgrass (*Cladium* spp.)
serviceberry (*Amelanchier alnifolia*)
skunkbush sumac (*Rhus trilobata*)
snowberry (*Symphoricarpos albus*)
subalpine fir (*Abies lasiocarpa*)
Torrey's milkvetch (*Astragalus calycosus*)
twoneedle pinyon (*Pinus edulis*)
whitebark pine (*Pinus albicaulis*)
willow (*Salix* spp.)
winterfat (*Krascheninnikovia lanata*)
Wood's rose (*Rosa woodsii*)
Wyoming big sagebrush (*Artemisia tridentata wyomingensis*)

Other

chytrid fungus (*Batrachochytrium dendrobatidis*)
plague (*Yersinia pestis*)
trematode (*Ribeiroia ondatrae*)
West Nile virus (*Flavivirus*)
white-nose fungus (*Pseudogymnoascus destructans*)

Appendix 4—Summary of System for Assessing Vulnerability of Species to Climate Change Scores for Selected Species in the Intermountain Adaptation Partnership Region

The following table summarizes scores from the System for Assessing Vulnerability of Species to climate change (SAVS) for 20 terrestrial animal, bird, and amphibian and reptile species in the Intermountain Adaptation Partnership region. Positive scores indicate higher vulnerability, whereas negative scores indicate potentially positive effects; zero defines a neutral response. Uncertainty about the SAVS scores for each species is also indicated. See Bagne et al. (2011) for full scoring system.

Species		H1	H2	H3	H4	H5	H6	H7	PS1	PS2	PS3	PS4	PS5	PS6	PH1	PH2	PH3	PH4	I1	I2	I3	I4	I5
	Uncertainty (%)	Breeding habitat	Nonbreeding habitat	Breeding Habitat component	Nonbreeding habitat components	Habitat quality	Dispersal ability	Additional habitat (migrant)	Thresholds	Sex ratio	Disturbances	Activity periods	Resource fluctuations	Metabolic rate	Cues	Critical events	Proximity	Breeding	Food	Predators	Symbionts	Disease	Competitors
American pika	32	1	1	0	0	0	1	0	1	0	0	1	1	0	0	1	-1	-1	0	0	0	0	0
Bighorn sheep (desert)	36	0	0	0	1	0	-1	0	1	0	1	1	-1	0	0	1	0	1	1	0	0	1	0
Bighorn Sheep (Rocky Mountain, Sierra Nevada)	41	0	-1	0	0	0	-1	0	1	0	1	1	1	0	0	1	0	1	-1	0	0	1	-1
Canada lynx	41	1	0	0	1	0	-1	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	1
Fisher	50	1	1	1	1	0	-1	0	1	0	0	0	1	0	0	0	0	1	-1	1	0	0	0
Fringed myotis	45	0	0	1	0	1	0	0	0	0	0	-1	1	0	1	1	-1	1	0	0	0	0	0
N. Idaho ground squirrel	32	-1	-1	0	1	0	-1	0	0	0	1	0	1	0	1	0	0	1	1	0	0	1	0
Sierra red fox	23	1	1	0	0	1	-1	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	1
Townsend's big-eared bat	36	0	0	1	1	0	0	0	0	0	0	-1	1	0	1	1	-1	1	0	0	0	0	0
Utah prairie dog	36	-1	-1	0	0	1	-1	0	0	0	0	0	-1	0	1	1	0	1	1	0	0	0	0
Wolverine	36	1	1	1	1	0	-1	0	0	0	0	0	1	0	0	1	1	1	-1	1	0	0	1
American three-toed woodpecker	41	1	1	0	1	-1	-1	0	0	0	0	0	-1	0	0	1	0	1	-1	0	0	0	0
Black rosy finch	36	1	1	1	1	1	-1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
Flammulated owl	27	0	0	1	0	0	0	1	1	0	1	0	0	0	1	1	1	1	0	0	0	0	1
Greater sage-grouse	32	1	1	1	0	0	-1	1	0	0	1	0	0	0	1	1	0	-1	1	0	0	1	0
White-headed woodpecker	36	0	0	1	1	0	-1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
Boreal toad	27	0	0	1	0	1	0	0	1	0	-1	1	-1	-1	1	1	1	1	0	0	0	1	0
Columbia spotted frog	41	1	1	1	1	0	0	1	-1	0	0	0	0	-1	1	1	1	1	0	-1	0	1	0
Great Basin spadefoot	41	0	0	1	0	0	0	0	1	0	0	1	-1	-1	1	1	-1	1	0	-1	0	0	1
Prairie rattlesnake	36	0	0	0	1	0	0	0	1	0	0	1	1	-1	1	0	0	1	-1	0	1	0	0