Chapter 9: Climate Change and Wildlife in the Northern Rockies Region

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How Climate Affects Wildlife

Temperature and moisture affect organisms through their operational environment and the thin boundary layer immediately above their tissues, and these effects are measured at short time scales. When a human (a mammal) wearing a dark insulative layer walks outdoors on a cold but sunny day, he or she feels warm because energy from the sun is interacting with the dark clothing, creating a warm boundary layer to which his or her body reacts. Conditions beyond that thin boundary layer are physiologically irrelevant. Walk into the shade, and suddenly one is cold because the warm boundary layer has been replaced with one at the ambient temperature of the air. This example demonstrates many factors to consider when evaluating the degree to which a change in climate will affect an organism. Climate is defined as the long-term average of temperature, precipitation, and wind velocity. "Long term," when applied to climate, is a relative term and can refer to periods of weeks to centuries. In the context of climate models, results are generally reported as averages across 30-year intervals, which for many animal species represent multiple generations. Our ability to infer the biological effects of projected long-term changes in temperature and precipitation relies both on our ability to directly relate these multiyear averages to biological responses, and the trophic distance between climate-induced ecological change and its effects on specific biological relationships.

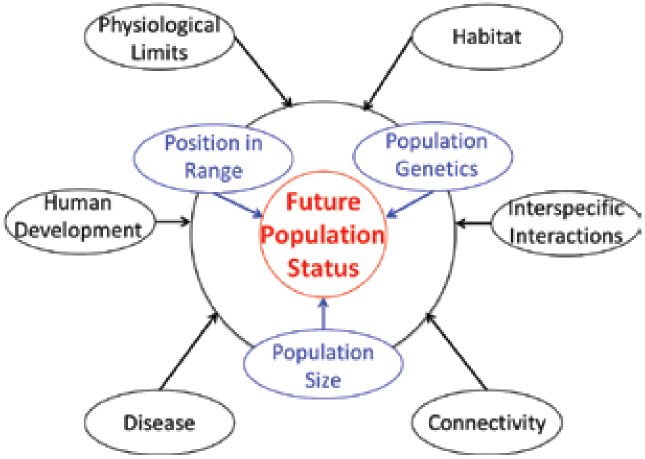

Figure 9.1—Visual summary of workshop discussions on the influence of climate on wildlife populations in the Northern Rockies Adaptation Partnership. Pathways of climate influence (black) interact with population characteristics (blue) to affect the future population status (red). A given pathway affects multiple species, and multiple pathways affect a given species.

As just noted, a human's response to change in radiant energy is fast, measured in seconds to minutes, so its relation to 30-year average temperature is obscure. Climate changes the frequency of weather events, which in turn change the frequency of nearly instantaneous shifts in boundary layer conditions around one's body. In aggregate, these changes in frequency lead to conditions that an individual either can navigate and tolerate—or cannot. This is further complicated for endotherms (warm-blooded animals), which maintain a constant body temperature. Cold or excessive heat affects endotherms by requiring them to burn more calories to maintain the required core temperature. Thus, endotherms can function in a wide variety of environmental conditions if they have enough food to supply the necessary energy. Fish, reptiles, and amphibians are ectotherms (cold-blooded organisms), which react to the cold not by feeling cold and metabolizing energy to maintain core temperature, but by having their metabolism slow until they are torpid.

Many of the species described here occupy terrestrial habitats. Terrestrial organisms can manipulate their operational environment in a myriad of ways, choosing to stand in the sun or shade, moving uphill or down, changing aspect, or seeking cooler or warmer environments by digging into a burrow in the ground or under the snow. Endothermic animals can change the thickness of the boundary layer by modifying their hair or feathers, both seasonally and on a short-term basis, thus responding to variable thermal conditions while minimizing energy expenditures. The ability of terrestrial organisms to manipulate their operational environment contrasts with aquatic organisms, which have a harder time avoiding adverse temperatures because water is an excellent conductor of heat. In addition, aquatic ectotherms have no way to avoid overheating when water temperatures rise, so it is more straightforward to evaluate the effects of climate change for fish with known warm-water limits than it is for terrestrial endotherms (see Chapter 5).

Terrestrial endotherms are more likely to experience effects associated with changes in precipitation amounts and types than effects associated with changes in temperature. These species have less flexibility in dealing with changes in precipitation patterns than with changes in temperature

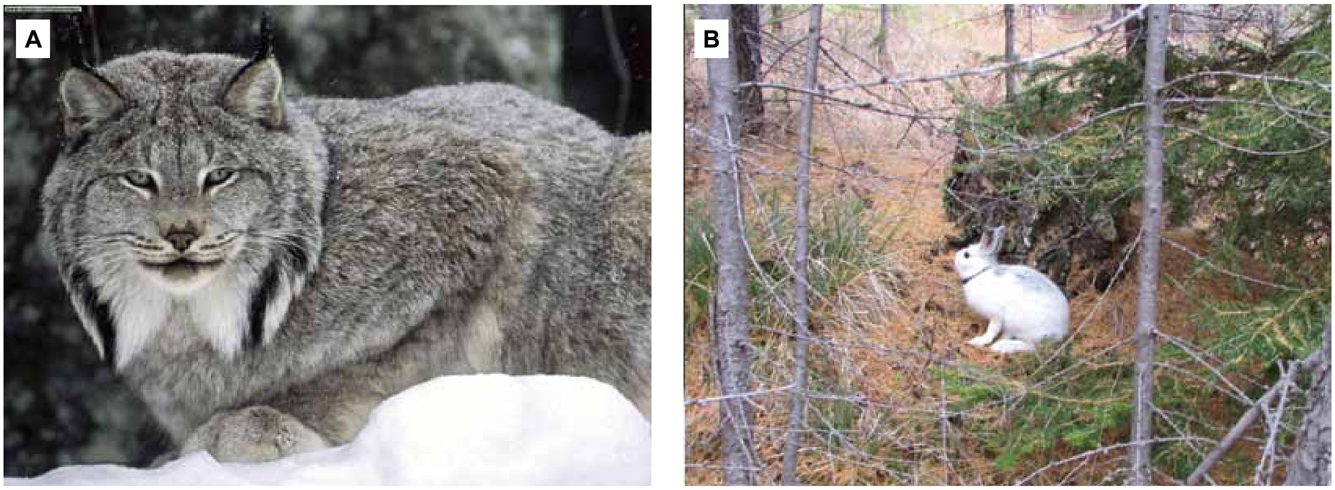

Figure 9.2—Canada lynx (a) have snow-specific adaptations (oversized feet, long legs, and a thin, light skeleton), and snowshoe hares (b) dominate their diets. Snowshoe hares undergo seasonal pelage changes from brown to white, and the effectiveness of this strategy depends on synchrony with snow cover. A mismatch between the hare's fur color and its environment would make it more vulnerable to predation by lynx (photo (a): U.S. Fish and Wildlife Service; (b) photo: L. Scott Mills, used with permission).

because water produces physical features that serve as habitat for which they are specifically adapted. In the Northern Rockies region, and in other areas with cold winters, snow provides physical habitat for which a number of organisms have specific adaptations. An obvious adaptation is seasonal color change in pelage: being white in a snowy landscape enhances the likelihood of escaping detection if the animal is prey, and approaching prey if the animal is a predator. Therefore, white pelage in winter confers specific fitness advantages if pelage change is properly timed to coincide with snow cover. But it is a disadvantage if mistimed (see discussion of snowshoe hare [*Lepus americanus*] later in this chapter) (fig. 9.2). Specific morphological features such as oversized feet, long legs, and light bone structures also provide benefits in snow-covered landscapes but may be disadvantageous in environments without snow.

Deep snow provides a relatively warm, stable environment at the interface between snow and soil; soils in areas characterized by deep snow generally remain above freezing throughout the winter (Edwards et al. 2007), and the subnivean environment (beneath the snow surface) is used by many organisms to den or feed. For organisms that depend on a stable subnivean environment or that have specific phenological adaptations to snow, reduced snowpack caused by a shift in precipitation from snow to rain represents a loss of critical habitat (see later discussion of American pika [*Ochotona princeps*]). Similarly, water bodies are the physical habitats for a wide variety of animals, providing sources of prey, temperature control, and safety from predation. In addition, open or flowing water can provide important microclimates. For example, pikas can be found in what appear to be hot, dry environments if water flow beneath the talus produces cool microsites (Millar and Westfall 2010a).

Physical features associated with snow and water integrate across longer time periods and are therefore closely associated with projected climate. For example, depth of snowpack integrates seasonal moisture and temperature. Seeps, springs, bogs, and persistent streams dependent on continuous sources of groundwater can integrate longer climatic periods. In some areas, water features are dependent on glaciers, which integrate seasonal weather and long-term climate. Therefore, areas with these features and the species that depend on them are vulnerable to climate change, reacting at time scales reasonably consistent with the temporal projections of global climate models (GCM) and providing opportunities to project effects on habitats and species.

As noted earlier, terrestrial endotherms have many options for controlling both their operational environments and the physiological effects of these environments. Terrestrial plants are stationary ectotherms and, lacking the behavioral and physiological plasticity of endothermic animals, are more directly affected by climate changes (see Chapter 6). Therefore, climate effects on wildlife will frequently occur due to changes in plant assemblages that constitute wildlife habitat. For predators, these effects may be either direct (e.g., changes in the number and locations of vegetation boundaries used by predators) or indirect through changes in prey densities or prey availability to predators. Climate-induced changes in trophic structures are expected to be common, complex, and interactive, but are at least one step removed from climate (e.g., Post et al. 1999).

The effects of habitat changes on a specific animal are difficult to project and require specific understanding of the functional roles that ecological attributes play in the life history of the animal, and the consequences associated with alternative life history strategies. These types of data are often lacking, and although current behaviors can be studied, they may not be informative relative to climate change effects, and responses may be novel and unanticipated. For example, polar bears (*Ursus maritimus*) are historically adapted to pack-ice hunting for seals, but with recent reductions in pack ice, they have in some areas shifted to feeding on the eggs of snow geese (*Chen caerulescens*) (Rockwell and Gormezano 2009), whose populations have erupted because of their ability to feed in agricultural fields (Fox et al. 2005).

In addition to changes in vegetation and prey, trophic effects include the presence and abundance of disease and parasitic organisms. For example, for greater sage-grouse (*Centrocercus urophasianus*), the potential spread of West Nile virus (*Flavivirus* spp.) associated with climate change may increase stress in grouse populations (Schrag et al. 2011), but the effect is difficult to project. For many organisms, current ranges are often strongly limited by human activities. For example, greater sage-grouse range is limited by conversion of native sagebrush (*Artemisia* spp.) habitat to agricultural uses (Connelly et al. 2004; Miller and Eddleman 2001).

Last, climate change is likely to alter the nature and location of human activities that affect wildlife. In the western United States, changes in water availability and the amounts required for irrigation can be expected to have profound effects on human activity and settlement patterns (Barnett et al. 2005). In addition, societal effects associated with local changes will occur within the context of societal changes across much larger spatial domains. Changes in technology, standards of living, infrastructure, laws, and the relative impacts of climate changes in other areas, will all affect local human activities.

In summary, the ways that climate change affects endothermic terrestrial species are likely to be complex and difficult to project. In addition to the uncertainty of future climate itself (see Chapter 3), effects on most species will be indirect through proxies such as ecological disturbance, habitat structure, prey availability, disease dynamics, and shifts in human activities.

The Importance of Community in Defining Habitat

Our understanding of wildlife ecology, particularly at broad spatial scales, is generally limited to the correlation of occurrence patterns to landscape features rather than direct studies of those factors that limit species distributions. In some cases, patterns of occurrence are clear, consistent, and highly correlated with climate (see later discussion on wolverine [*Gulo gulo*]), but the causal relationships remain obscure. For instance, many passerine birds nest only in specific habitats; an example is Brewer's sparrow (*Spizella breweri*) (see later discussion), which is obligate to sagebrush. Although the pattern is clear and invariant, the nature of the obligate links to sagebrush is unknown. Species such as ruffed grouse (*Bonasa umbellus*) (see later discussion) clearly have northern distributions, but the factors that define the southern limits of their current distributions are not well understood (Lowe et al. 2010).

This lack of causal understanding may be unimportant for current management of these species because management takes place only in areas where the species currently occurs or where it occurred in the recent historical past. Based on observed patterns of use and distribution, enough information exists to identify and manage current habitat. However, it cannot be assumed that measured correlations will persist in an altered climate. We typically characterize habitat elements within the context of assemblages of mostly unmeasured plants and animals. For example, assume that an organism's occurrence is strongly correlated with mature Douglas-fir (*Pseudotsuga menziesii*) forests. These forests contain other tree and understory species, animal communities, and successional trajectories (e.g., habitat types; Daubenmire [1952]). However, Douglas-fir projected onto a future landscape may be associated with different plant and animal communities. Due to the correlational nature of most of our habitat knowledge, it is difficult to know which of these community members are critical to habitat quality for a target species and thus the habitat quality of novel species assemblages.

In addition, factors identified as important are restricted to those that currently limit behavior. Therefore, in correlation-based habitat relationships, changes in non-limiting but essential factors will not produce strong correlations with behaviors. For example, distance to water may be a strong habitat correlate in desert environments but may not be correlated with habitat quality in a rainforest. Water may be no less important in the rainforest, but it is currently not limiting. As climate change alters biophysical attributes of landscapes, limiting factors and definitions of what constitutes habitat may change. Water availability might become the most critical habitat attribute in a previously wet environment that has become dry. For the most part, these important but latent habitat attributes will remain unknown until exposed by changes in climate.

In addition to potentially changing vegetation communities and limiting factors, the effects of climate on future habitats are further complicated by altered disturbance regimes. Regeneration, growth, and disturbance patterns collectively create landscapes that provide habitats. Changing disturbance dynamics (see Chapter 8) alter the characteristics of landscape mosaics and fundamentally alter habitats. As climate change causes shifts in plant and animal distributions, a temporal mismatch between decrease of current habitat and increase of new habitat may occur, a mismatch that will be exacerbated by increased levels of disturbance. Wildfire can destroy current habitat in a day, but generation of new habitat may require centuries, depending on the time necessary to create critical elements through regeneration, growth, and succession. The fisher provides an example of these uncertainties. In Idaho and Montana, fishers are currently limited to mature forests in the Inland Maritime climatic zone. However, GCMs indicate that this zone will move to the east, and mature forest may take a century or more to grow in these new locations, creating uncertainty about the future range of fisher (see later discussion).

Given the uncertainty associated with determining likely trajectories of species and their habitats under climate change, assessments of general vulnerability and projected changes can best be viewed as hypotheses to be tested. Therefore, it is desirable to develop proactive management strategies that maintain valued species and landscape attributes, including objectives such as creating resilience to disturbance. Prioritizing which things are measured can improve the connection between environmental change and management. A monitoring program designed to test specific hypotheses associated with specific organisms (Nichols and Williams 2006) can improve our understanding of relationships between climate change and landscapes, providing data that inform science-based management.

Evaluating Sensitivity of Species to Climate Change

Evaluating the potential effects of climate change on animal species begins with determining which species are of interest, collecting biological information about them, and paying special attention to biological traits that might lead to changes in distribution and abundance in a warmer climate (e.g., Glick et al. 2011). Some species have received significant attention, and this interest has generated peer-reviewed articles that formally analyze the effects of climate change, although this is relatively uncommon.

Foden et al. (2013) identify three dimensions associated with climate change vulnerability—sensitivity, exposure, and adaptive capacity—and apply a framework based on assessing these attributes to nearly 17,000 species. Other expert systems have been developed to evaluate the relative degree of climate sensitivity and vulnerability for various species including the Climate Sensitivity Database (Lawler and Case 2010) and NatureServe Climate Change Vulnerability Index (NatureServe n.d.). These tools do not seek to understand specific responses of animals to climate, but rather to identify species that are likely to be vulnerable based on current habitat associations, life history traits, and distributions (Foden et al. 2013). Bagne et al. (2011) formalized this process in the System for Assessing Vulnerability of Species (SAVS). In SAVS, species are assessed based on a large number of traits associated with habitat (seven traits), physiology (six traits), phenology (four traits), and biotic interactions (five traits). For each of these 22 traits, a score of –1, 0, or 1 is assigned; positive scores indicate vulnerability, and negative scores indicate resilience. The raw scores are multiplied by correction factors associated with the number of traits in a category and possible scores across traits to achieve a standardized score between –20 and 20 that indicates the relative vulnerability of the species.

Formalizing traits that can lead to vulnerability provides a framework for collecting biological data associated with a species and for considering the effects of climate change. However, existing expert systems cannot be used to infer that sensitivities for disparate topics such as habitat and phenology are proportionally important or that estimated vulnerability has quantitative meaning (Bagne et al. 2011; Case et al. 2015). Even if these issues were considered unimportant, accurately identifying vulnerability for most of the species evaluated here would not be possible given current biological understanding. Because data on climate-species relationships are so sparse, this assessment focuses primarily on evaluation of each trait as it relates to the biology of animal species.

Following are assessments for animal species identified as high priority by Forest Service, U.S. Department of Agriculture (USFS) Northern Region resource specialists, and for additional species identified by participants in five workshops convened by the Northern Rockies Adaptation Partnership (see Chapter 1). Species were not necessarily chosen based on their perceived level of vulnerability. In many cases, species are associated with specific habitats that were considered vulnerable; for example, some species are associated with sagebrush communities, others with snow depth and cover, and others with dry forests that have large trees. These assessment summaries contain projections of climate change effects based on interpretation of the pertinent literature. Level of detail differs considerably among species and is mostly driven by the degree to which the species have been evaluated in the context of climate change. Species are listed in alphabetical order within each taxonomic class.

Mammals

American Beaver

American beavers (*Castor canadensis*), like their European counterpart (*C. fiber*), tend to spend most of the winter in their lodges or swimming to retrieve food, so climate may be more influential during spring through autumn than during winter (Jarema et al. 2009). However, body weights of juvenile European beavers were lighter when winters were colder (Campbell et al. 2013). The cost of thermodynamic regulation may be greater for juveniles because they have higher surface area-to-volume ratios than adults (on whom winter temperature had no effect) (Campbell et al. 2013).

In Quebec, beaver density was highest in areas with the highest maximum spring and summer temperatures (Jarema et al. 2009). Conversely, European beavers in Norway achieved heavier body weights when spring temperatures were lower, and the rate of vegetation green-up was slower (Campbell et al. 2013). This apparent contradiction may have been caused by the timing and measurement of climate and response variables. Although beavers create and require ponds, survival and body weight in European beavers have been linked to lower, and more consistent, precipitation

Figure 9.3—Maintenance and restoration of American beaver populations are adaptation tactics for maintaining water on the landscape. Although beavers are not particularly climate sensitive themselves, the structures beavers create and their effects on aquatic habitats and floodplains may help to ameliorate the effects of climatic change on cold-water fish species and other aquatic organisms (photo: E. Himmel, National Park Service).

from April through September (Campbell et al. 2012, 2013). Higher water levels during high precipitation years were thought to lead to decreased riparian plant growth caused by waterlogging (Campbell et al. 2012).

Climate can indirectly influence beavers through effects on vegetation. Climate change and climate-driven changes in streamflow are likely to reduce the abundance of dominant early-successional tree species in riparian habitats (Perry et al. 2012), reducing food and building materials for beaver. Beavers can be used as a management tool to buffer riparian systems from drought (Lawler 2009) (fig. 9.3). Beaver ponds increase the amount of open water (Hood and Bayley 2008), and beaver management can be used as a surrogate for amphibian conservation (Stevens et al. 2007).

American Pika

The American pika (*Ochotona princeps*) is a small (5–8 ounces) lagomorph that often inhabits rocky alpine areas in western North America (Smith and Weston 1990) (fig. 9.4). The species has been extensively studied in the Great Basin, where pika habitat typically occurs as small islands near mountaintops. Relatively little study of pikas had occurred in the Northern Rockies until recently, with the exception of research on occupancy and abundance in relation to microclimate, topography, and vegetation in the Bighorn Mountains and Wind River Range (Wyoming) (Yandow 2013). Studies are in process in the Bridger-Teton National Forest and Greater Yellowstone Area (Erik Beever, U.S. Geological Survey, Northern Rocky Mountain Science Center, Bozeman, MT, August 2014, personal communication).

Research suggests that pikas depend on moist, cool summer conditions and winter snow (Beever et al. 2011), and on low water-balance stress and green vegetation (Beever et al. 2013). Across paleontological time scales (Grayson 2005) and during the 20th century, pikas across the Great Basin have reacted to increasing temperature by moving upslope or becoming locally extirpated when the climate becomes hot and dry (Beever et al. 2011). Results from field research from 2012 through 2014 in the Great Basin indicate that local extirpations and retractions are continuing (Erik Beever, U.S. Geological Survey, Northern Rocky Mountain Science Center, Bozeman, MT, August 2014, personal communication). Local changes in pika distribution have also been recorded in Utah, the southern Sierra Nevada, and southern and central Cascade Range (Beever et al. 2011 and references therein).

In the Great Basin, pika extirpation (1994–2008) occurred in microsites that were generally hotter in summer (more frequent acute heat, and hotter average temperature across the whole summer) and were more frequently very cold in winter than in locations where pikas persisted. In the latter case, warming reduced insulating snow, causing near-ground temperatures to decrease (Beever et al. 2010). Furthermore, density of pikas in surveys from 2003 through 2008 was best predicted by maximum snow water equivalent and growing-season precipitation (Beever et al. 2013). Some extirpations have occurred at sites with low annual precipitation (Beever et al. 2011, 2013), reinforcing study results in the southern Rocky Mountains (mostly Colorado), where surveys indicated that 4 pika extirpations (among 69 total sites with historical records) occurred at the driest sites (Erb et al. 2011).

Winter snowpack not only insulates pikas during cold periods, but also provides water during the summer, when plant senescence at drier sites occurs earlier in the year, eliminating available metabolic water for pikas. Surveys, mostly in the Sierra Nevada, found that pika extirpations

Figure 9.4—The American pika is a small lagomorph that collects grass and herbs throughout the summer as winter food and remains active throughout the winter. It depends on the relatively warm subnivean environment associated with deep winter snowpack (photo: Will Thomson, U.S. Geological Survey).

were associated with sites with higher maximum temperatures and lower annual precipitation (Millar and Westfall 2010b). Chronic stresses (average temperature during summer, maximum snowpack, and growing-season precipitation), acute temperature stresses (hot and cold), and vegetation productivity apparently contributed to pika declines in the Great Basin (Beever et al. 2010, 2011, 2013).

Individual mountain ranges are thought to act as discrete areas without any pika migration between adjacent ranges across valley bottoms (Castillo et al. 2014), although disjunct metapopulations of pikas separated by short distances may exist. In a study of pika populations in ore dumps separated by tens to hundreds of yards, individual populations that were extirpated were recolonized, and abundance across all ore piles remained constant (Smith 1980). This process apparently occurs only at very short distances because habitats isolated by more than 1,150 feet were generally unoccupied. Connectivity of pika populations apparently depends on context, with lower connectivity between sites that occur in hotter, drier landscapes (Castillo et al. 2014; Henry et al. 2012). Thus, recolonization may occur at distances less than 0.5 mile and in areas where between-population dispersal occurs within cool, moist landscapes, whereas recolonization at longer distances is rare. In the Great Basin, once pikas have been extirpated from a site, they have never been detected in subsequent surveys across 21 years of contemporary research (Beever et al. 2011).

At the broadest spatial scales, there is genetic evidence for historical isolation; pikas across the Intermountain West separate into five distinct groups (Galbreath et al. 2010). At smaller scales, inbreeding and high levels of genetic structure exist between high and low elevation populations in British Columbia, even when the populations are geographically proximal. Castillo et al. (2014) found that gene flow is restricted primarily by topographic relief, water, and west-facing aspects, suggesting that physical restrictions related to small body size and mode of locomotion, as well as exposure to relatively high temperatures, limited pika dispersal.

Studies in the Sierra Nevada (Millar and Westfall 2010a,b) and southern Rocky Mountains (Erb et al. 2011), at sites in which pikas were common and not generally subject to extirpation across most of the landscape, indicated that physiological limits for this species had not been reached. This will probably be the case for most pika populations in the Northern Rockies region in the near term. Although hot, dry climate may limit pika distributions, local moisture sources, rock-ice features, aspect, and the physical structure of talus fields may climatically buffer pikas from macroclimatic stresses (Millar and Westfall 2010a). Existence of pikas at Lava Beds National Monument, Craters of the Moon National Monument, and the Columbia River Gorge—all of which have warm, dry climates—underscores the importance of microclimate for species vulnerability assessments, and indicates that microclimate and macroclimate are decoupled in some locations (Rodhouse et al. 2010; Simpson 2009; Varner and Dearing 2014).

Because pikas are sensitive to high temperature, we expect that pika populations will respond to climate change in the Northern Rockies region. However, site-specific factors contribute to highly variable microclimates, so response to climate change will vary considerably over space and time. A large amount of data has been collected on this species over the past decade, and it should be possible to develop more-accurate projections of population response as monitoring data continue to accrue.

Canada Lynx

The Canada lynx (*Lynx canadensis*) is a mid-sized cat with several specific adaptations that allow it to travel across soft snow. The most obvious adaptation is oversized feet: foot loading is 0.5 times that of the similar sized bobcat (*L. rufus*) (Buskirk et al. 2000). Canada lynx prey nearly obligately on snowshoe hares (fig. 9.2). Not only do snowshoe hares constitute 33 to 100 percent of lynx diet (Mowat et al. 2000), but a low proportion of hares in the diet indicates scarcity of hares, not diet plasticity (Mowat et al. 2000). Studies of lynx winter diet in the Clearwater River watershed (western Montana) found 94 to 99 percent of the diet consisted of snowshoe hares (Squires and Ruggiero 2007). Snowshoe hares are also specially adapted to snowy environments. When compared to similar sized leporids, they have oversized feet. They also exhibit seasonal pelage change from brown to white. Because lynx and hares have a close association and have specialized adaptations to allow survival in snowy environments, climate relationships for both species are explored in this section.

The Canada lynx is found exclusively in North America, its distribution extending across the interior of Canada and Alaska and northward into tundra vegetation. In the conterminous United States, both current and likely historical populations are located in the extreme northern portions of this region: Maine, historically New York and New Hampshire, Minnesota north of Lake Superior, western Montana, and northern Washington (McKelvey et al. 2000). A tiny population existed and may still exist in the Greater Yellowstone Area. Periodically, in the years immediately after major population eruptions in the north, lynx distributions expand; lynx were found ephemerally in North Dakota, and populations temporarily increased in Montana (McKelvey et al. 2000). Bobcats and lynx were not well differentiated in the fur market (Novak et al. 1987)—with large bobcats often recorded as "lynx"—so trapping records are typically untrustworthy (McKelvey et al. 2000). Recently, a population was translocated to Colorado, and appears to be persisting; after initial high mortality rates, annual survival has exceeded 90 percent (Devineau et al. 2010). However, the historical evidence for lynx in Colorado is weak, with most of the verified records occurring in years consistent with immigration from the north (McKelvey et al. 2000). Hare densities in Colorado are generally less than the threshold of 0.5 hare per acre (Ivan et al. 2014) thought to be the minimum hare density associated with stable lynx populations (Mowat et al. 2000).

When evaluating the potential distribution of lynx, it is important to note that large populations of lynx are located in the interior of the continent. Lynx are common in Alberta and Saskatchewan, where more than 20,000 were trapped per year in recent eruptions (Novak et al. 1987), but they are and were rare along both the Atlantic and Pacific coasts. Lynx are more common in areas with a northern continental climate, probably because soft powdery snow is more common there.

Maintaining population connectivity is central to lynx conservation. However, maintaining connectivity may become increasingly difficult as southern populations of boreal species become more isolated with climate change (van Oort et al. 2011). This is of particular concern because disturbance processes that include wildfire, insects, and disease make some boreal forests vulnerable to climate change (Agee 2000; Carroll et al. 2004; Fishlin et al. 2007; Fleming et al. 2002; Intergovernmental Panel on Climate Change [IPCC] 2007a,b; Logan et al. 2003).

In the Northern Rockies region, lynx exist in only a few areas: the Clearwater River watershed, Bob Marshall Wilderness, and the northwestern corner of Montana. A few lynx were known to inhabit the Greater Yellowstone Area in 2000 (Squires and Laurion 2000), but their current status is unknown. Dens are located in boulder fields and spruce-fir forests with high horizontal cover and abundant coarse woody debris. Eighty percent of dens are in mature forest and 13 percent in mid-seral regenerating stands (Squires et al. 2008). For winter foraging, lynx preferentially forage in mature, multilayer spruce-fir forests composed of larger diameter trees with high horizontal cover, abundant snowshoe hares, and deep snow (Squires et al. 2010). During summer, lynx occupy young forests with high horizontal cover, abundant total shrubs, abundant small diameter trees, and dense spruce-fir saplings (Squires et al. 2010). Lynx select home ranges with vegetative conditions consistent with those identified for foraging and denning, primarily at mid-elevations (Squires et al. 2013). Assuming that preferences for movement between home ranges are similar to those associated with moving within the home range, dispersal pathways consist of areas with similar properties to those used for foraging (Squires et al. 2013).

The range of snowshoe hare (Hall and Kelson 1959) is more extensive than that of lynx, extending into the mid-Sierra Nevada and areas such as the Olympic Peninsula, where there are no records of lynx occurrence (McKelvey et al. 2000). The more extensive hare distribution, which includes areas with limited snow (e.g., the Pacific coast), is probably caused by greater genetic differentiation for snowshoe hares than for lynx. Across the continent, lynx exist in a single, largely panmictic (random mating) population (Schwartz et al. 2004), whereas hares are subdivided into six subspecies (Wilson and Reeder 2005).

Hares exhibit variation in timing of pelage change across western North America, but variation is low in any specific location, and timing appears to be genetically controlled and linked to photoperiod (e.g., Hall and Kelson 1959; Zimova et al. 2014). Timing of pelage change is critical for hare survival, because mismatches—a white hare on a dark background and vice versa—cause most hares to die from predation (Hodges 2000) (fig. 9.2). Initiation of pelage change is apparently driven by photoperiod rather than background color, so the ability of hares to shift the timing of pelage change to match patterns of snow cover is limited (Mills et al. 2013). Given projections of snow cover by 2100 (see chapters 3 and 4), current patterns of pelage change in the Northern Rockies region will be mismatched with the period of snow cover. Unless a significant change occurs in the population genetics of hares, they will be the wrong color for about 2 months per year (one month in spring, one month in fall) in the region (Mills et al. 2013).

Both lynx and hares require specific amounts and duration of winter snow. An example of this for lynx occurs in Minnesota, where current and historical populations are limited to the "arrowhead" north of Lake Superior (McKelvey et al. 2000; Schwartz et al. 2004). This area is characterized by lake-effect snow, and outside of it, bobcats dominate and lynx are not found. Both lynx and hares require forests with dense understory canopies. In western Montana, lynx and hares use older spruce-fir forests. If climate change and associated disturbance reduce the abundance of these forest types, habitat loss could be significant, reducing populations of lynx and hares.

Fisher

The fisher (*Martes pennanti*) is a mid-sized, forest-dwelling mustelid. The range of the fisher covers much of the boreal forest in Canada, a broad area of the northeastern United States extending from the Lake States to Maine, and a scattered distribution in the western United States. Males and females are similar in appearance, but the males are larger. Males are 35 to 47 inches long and weigh 8 to 13 pounds; females are 30 to 37 inches long and weigh 4 to 6 pounds (Powell 1993).

Fishers are common in the eastern United States and are often associated with urban environments, but they are uncommon in the western United States and apparently have very specific habitat associations. Although the current distribution of fishers is reduced from the historical range, populations have typically been disjunct. Genetic studies have shown that fisher populations in California have been historically isolated from those in Washington, and fishers in the southern Sierra Nevada have been isolated from those in the Klamath region (Tucker et al. 2012). Fishers in Montana contain unique haplotypes (DNA variations that tend to be inherited together) not found elsewhere (Schwartz 2007; Vinkey et al. 2006) and therefore were apparently isolated both from large populations in northern British Columbia and from coastal populations in Washington. Common attributes for resting sites across eight studies of western fishers were steep slopes, cool microclimates, dense forest canopy cover, high volume of logs, and prevalence of large trees and snags (Aubry et al. 2013). Although these features are important for managing fisher habitat, they do not necessarily explain the fragmented historical distribution in the West (Tucker et al. 2012).

Fishers have long been thought to have specific climatic associations. Krohn et al. (1995) compared fisher and marten (*Martes americana*) distributions in the Sierra Nevada, and found that areas occupied predominantly by marten were closely associated with forested areas with the deepest snow (>9 inches per winter month), whereas areas occupied predominantly by fishers were forested areas with low monthly snowfall (<5 inches). There is direct evidence that fishers avoid deep snowpack (Krohn et al. 1995, 2005; Raine 1983) and that deep snow can limit fisher dispersal (Carr et al. 2007). Fishers also avoid dry habitats (Jones and Garton 1994; Schwartz et al. 2013).

Presence in warmer, wetter forests is apparently common in distributions of fishers at both the macroscale and fine scale in the western United States, although large populations in northern interior British Columbia and Alberta are not associated with these specific climates. Therefore, defining fisher habitat in climatic terms and projecting future habitat is more challenging than for animals with more obvious climatic associations (Copeland et al. 2010; McKelvey et al. 2011).

In a recent modeling study of fisher habitat in an area consistent with its distribution in the Northern Rockies, Olson et al. (2014) built occurrence models for fisher populations in northern Idaho and western Montana that included variables such as canopy cover, climatic variables such as minimum winter temperature, and topographic variables such as slope. They found that most of the variability in the model was explained by mean annual precipitation (34 percent), topographic position index (29 percent), and mean temperature of the coldest month (27 percent). Therefore, fisher habitat was projected to be best in areas with high annual precipitation, low relief, and mid-range values for mean temperature in the coldest month. Krohn et al. (1997) and Olson et al. (2014) projected similar areas of fisher habitat and in similar places.

Olson et al. (2014) used downscaled data from a single GCM (Hadley Centre Coupled Model, version 3; Collins et al. 2001) and two emissions scenarios (A2-high, B2-low; IPCC 2007b), projecting habitat for 2030, 2060, and 2090. At the macroscale, results for both scenarios are similar: In the near term, habitat currently occupied by fishers might improve, but by 2090, habitat in areas that are currently occupied (primarily central Idaho) decline sharply, and new habitat is created to the east in northwestern Montana. The primary difference between the scenarios at this level of detail is the rate at which changes occur. The change is visibly apparent by 2060 in the A2 scenario, but not in the B2 scenario. As habitat shifts, it becomes increasingly fragmented, and the amount of usable habitat is strongly affected by how acceptable minimum patch size is defined (Olson et al. 2014).

Olson et al. (2014) bracketed the emissions scenarios, providing some measure of the potential range of results, but between-model variability exceeds variability between emissions scenarios. In addition, the performance of specific GCMs varies considerably at the regional scale (Mote and Salathé 2010), and the Hadley family of GCMs is considered to be on the hot-dry side of climate projections for the Northern Rockies region (Alder and Hostetler 2014). As a result, details within the model can influence patterns of projected habitat.

There are other uncertainties about the ability of habitat components to track climate. Given that fishers are associated with mature forests, significant time lags may exist between the loss of current habitat and formation of new habitat in areas that currently are unsuitable. If large trees cannot survive the shift in climate, mature forests may become rare for many decades. In climatic zones suitable for fishers, forests may be dominated by young trees and shrubs whose suitability for fisher habitat is unknown. Therefore, projections in Olson et al. (2014) are an optimistic view of habitat availability under climate change, and it is uncertain if fishers would disperse into new habitat should such changes occur.

Moose

Unlike Canada lynx or snowshoe hares, not all species with northern distributions have cold-weather related traits. Some organisms with broad historical distributions are currently limited to northern distributions because of southern extirpation, such as gray wolves (*Canis lupus*) and brown bears (*Ursus arctos*). These species are not considered to be strongly climate limited. Indirectly, cold climates lead to low densities of human populations in boreal forests and tundra, and interaction with large carnivores is therefore minimal. Were climates to warm, and people to relocate into these northern systems, this would obviously affect species such as wolves and brown bears.

For a second group of species, northern ranges are not defined by human impacts, but direct and indirect climate limits may not have been identified. Moose (*Alces alces*) are an example of a well-studied animal that has a northern distribution but whose dependence on boreal environments is not immediately obvious. We suspect that other species with northern distributions may exhibit similar constraints that define the southern extents of their ranges.

A limited amount of climate change research has been conducted on moose (Murray et al. 2006, 2012). Several factors have been identified as influencing the biogeographical distribution of moose including food supply, climate, and habitat. Based on metabolic research, moose are intolerant of heat but well adapted to cold, and summer temperatures may define their southerly distribution (Renecker and Hudson 1986). When winter temperatures were greater than 23 °F or summer temperatures were greater than 57 °F, moose showed an increase in metabolism and heart and respiration rates (Renecker and Hudson 1986, 1990), reduced feed intake (Belovsky and Jordan 1978; Renecker and Hudson 1986), and reduced body weight (Renecker and Hudson 1986). When ambient air temperatures exceeded 68 °F, moose resorted to open-mouthed panting to regulate core body temperature (Renecker and Hudson 1986). Heat stress was particularly apparent in the spring when moose were still in their winter coats (Schwartz and Renecker 1997).

However, moose may be able to avoid being exposed to high midday summer temperatures. In Minnesota, Lenarz et al. (2009) found that temperature was highly correlated with moose survival, but winter temperature was more critical than summer heat. High temperatures in January were inversely correlated with subsequent survival and explained more than 78 percent of variability in spring, fall, and annual survival. In northern Minnesota, moose populations were not viable, largely because of disease- and parasite-related mortality (Murray et al. 2006). In nearby southern Ontario, however, moose populations were apparently viable with favorable growth rates (Murray et al. 2012). Warming temperatures favor white-tailed deer (*Odocoileus virginianus*) expansion into moose range, and increased transmission of deer parasites to moose (Lankester 2010). Given both physiological and biological stressors, separating direct and indirect climate effects is difficult (Murray et al. 2012).

Northern Bog Lemming

As the name implies, northern bog lemmings (*Synaptomys borealis*) inhabit wet meadows, bogs, and fens within several overstory habitat types (Foresman 2012). Generally these wetlands have extensive sphagnum (*Sphagnum* spp.), willow (*Salix* spp.), or sedge components. These mammals were likely to occupy places that retained high water levels after the last glacial retreat (Foresman 2012). Given their dependence on wet habitats, it follows that climate changes that decrease the amount of surface water will probably have negative impacts on northern bog lemmings. Management practices that maintain surface water may therefore be beneficial. However, documented studies of climate and management effects are lacking.

Pronghorn

The pronghorn (*Antilocapra americana*) is an ungulate native to the prairies, shrublands, and deserts of the western United States and occupying a broad range of climatic conditions from southern Canada (Dirschl 1963) to Mexico (Buechner 1950). Although pronghorns occupy a broad climatic region and their diet is generalized, they are prone to epizootic diseases, notably bluetongue (a viral disease transmitted by midges [*Culicoides* spp.]) (Thorne et al. 1988). Bluetongue is thought to be cold-weather limited, and recent extensions of bluetongue in Europe have been attributed to climatic warming (Purse et al. 2005). Given their current range and food habits, the emergence of new disease threats caused by a warmer climate probably poses the greatest risk to pronghorns.

Pygmy Rabbit

The pygmy rabbit (*Brachylagus idahoensis*) is one of the smallest leporids in the world and is endemic to big sagebrush (*Artemisia tridentata*) (Katzner and Parker 1997), which is critical for food and cover. In southeastern Idaho, areas selected by pygmy rabbits had a significantly higher woody cover and height than other areas, with lower quantities of grasses and higher quantities of forbs. Sagebrush was eaten throughout the year, composing 51 percent of the diet in summer and 99 percent in winter (Green and Flinders 1980). These findings are similar to those reported for southern Wyoming (Katzner and Parker 1997) and Utah (Edgel et al. 2014). In addition, areas used by pygmy rabbits accumulate more snow than unused areas, and rabbits use the subnivean environment to reach food and avoid predators (Katzner and Parker 1997). The presence of significant snow for thermal protection may be important for winter survival, because of small body size, lack of metabolic torpor, and lack of food caching (Katzner and Parker 1997).

Structural characteristics of sagebrush are considered more important than food availability for pygmy rabbits (Green and Flinders 1980; Katzner and Parker 1997). Although large, dense sagebrush would be expected to be associated with older stands, Edgel et al. (2014) found no difference in age between occupied and unoccupied sites; structure was important, but age was not. As a result, processes that reduce the size and density of sagebrush are likely to have negative effects on pygmy rabbits, and processes that fragment sagebrush stands may decrease habitat quality. For example, Pierce et al. (2011) found that burrows, observed rabbits, and fecal pellets decrease in density with proximity (<300 feet) to edges.

Paleoecological studies show that both sagebrush and pygmy rabbits are sensitive to climate change. Both species decreased in the mid-Holocene, characterized in the Great Basin by extreme aridity (Grayson 2000). Big sagebrush is sensitive to fire, and 100 percent mortality and complete stand replacement after burning are common (Davies et al. 2011; see Chapter 7). In addition, big sagebrush cannot resprout from the root crown after a fire, so recruitment of sagebrush relies on wind dispersal of seeds from adjacent seed sources and on composition of the seedbank in the soil (Allen et al. 2008; Ziegenhagen and Miller 2009). Mountain big sagebrush (*A. tridentata* ssp. *vaseyana*) required 13 to 27 years after spring prescribed burning to return to conditions suitable for pygmy rabbit habitat (Woods et al. 2013). In areas where fire has been suppressed for many decades, sagebrush habitat can be displaced by conifer incursion (Miller and Rose 1999).

Pygmy rabbits are likely to be sensitive to climate change for several reasons. First, they depend on a single species (big sagebrush) and habitat condition (tall, dense stands). Climatic variability has affected sagebrush communities and pygmy rabbits in the past (Grayson 2000), and this could happen again in the future. Second, pygmy rabbit habitat is sensitive to altered disturbance. Increased fire frequency and area burned are projected as the climate continues to warm (see chapters 6, 7, and 8). Finally, changes in winter snow depth could affect overwinter survival by altering the protection provided by the subnivean environment.

Townsend's Big-Eared Bat

Climate change can affect foraging ability, drinking water availability, and timing of hibernation in bats (Sherwin et al. 2013). Townsend's big-eared bats (*Corynorhinus townsendii*) generally require cavern-like structures for diurnal, maternal, and hibernation roosting, although they also use large tree cavities, buildings, and bridges (Gruver and Keinath 2003). They forage for insects along riparian and forest edge habitats (Fellers and Pierson 2002). Their distribution is apparently limited by the availability of suitable roosting sites, as western populations have declined (O'Shea and Vaughan 1999) coincidental with mine closings (Gruver and Keinath 2003). Townsend's big-eared bats are not able to produce highly concentrated urine (Geluso 1978) and therefore require daily access to water sources for drinking (Gruver and Keinath 2003). Constructed water holes and mining ponds may serve as water sources (Geluso 1978); metal contaminants in the latter may cause some bat mortality (Pierson et al. 1999).

Bioaccumulation of pesticides in fat tissue apparently is one cause of declines in Townsend's big-eared bat populations (Clark 1988). Human activities that reduce moth populations can also negatively affect bat populations because moths are a primary food source of Townsend's big-eared bats (Burford and Lacki 1998; Whitaker et al. 1977). Bats may be especially sensitive to human disturbance during hibernation (Thomas 1995).

In Colorado, the reproductive success of bats of the *Myotis* genus declined during warmer and drier conditions, which are projected to be typical of future climatic conditions (Adams 2010). However, in other instances, warmer spring temperatures have led to earlier births, which promotes juvenile survival (Lucan et al. 2013). Higher summer precipitation may reduce reproductive success (Lucan et al. 2013). Future warming may also reduce the effectiveness of some bat echolocation calls (Luo et al. 2014).

Ungulates (Elk, Mule Deer, White-tailed Deer)

Rocky Mountain elk (*Cervus canadensis*), Rocky Mountain mule deer (*Odocoileus hemionus hemionus*), and white-tailed deer (*O. virginianus*) provide the core of big game hunting in the Northern Rockies region. All three have very broad ranges in North America. The current range for elk, which includes most of the Rocky Mountain West, also includes areas in the eastern and southwestern United States that were historically occupied by other subspecies. Rocky Mountain mule deer extend from the Yukon to northern Arizona. White-tailed deer extend across most of North America and into northern South America and include 38 recognized subspecies (De la Rosa-Reyna 2012).

Based on their broad ranges, it is clear that all three species exhibit a high degree of flexibility toward habitat. Habitat use by elk in forested areas is associated with edges (Grover and Thompson 1986; Irwin and Peek 1983; Thomas et al. 1979, 1988) in which areas containing high-quality forage and areas with forest cover are in proximity. In open habitats, they select areas of high vegetative diversity with intermixed patches of shrubs and grasslands (Sawyer et al. 2007). Both patterns of habitat use are apparently maximized by a disturbance regime with spatial heterogeneity at relatively fine scales.

A study of Rocky Mountain mule deer found that home range size increased in areas with few large patches and was smallest in fine-grained vegetation mosaics (Kie et al. 2002). Mule deer depend on disturbance to create forage (e.g., Bergman et al. 2014), but the size and juxtaposition of patches are important. Fine-grained disturbance mosaics are apparently optimal for white-tailed deer, especially in areas where thermal cover is important. In the Northern Rockies region, thermal cover prevents heat loss during winter, although in warmer climates, thermal cover reduces daytime heating. In Texas, male white-tailed deer chose areas with high cover and poor foraging opportunities during the midday, but chose areas with higher forage quantities during crepuscular and nocturnal periods (Wiemers et al. 2014).

Ungulates generally respond positively to disturbance (fig. 9.5), but the types of disturbance and the resulting landscape condition and species composition are equally important. Just as wildfire intensity affects patchiness in the postfire landscape, it also affects which plant species are likely to revegetate burned areas. For example, Emery et al. (2011) found that at lower temperatures several native plant species exhibited enhanced germination, whereas nonnative plant species did not. Vegetation growth after disturbance is important where nonnative species are common. For example, Bergman et al. (2014) found that treatments that removed trees and controlled weeds produced better mule deer habitat than treatments that removed only trees.

Climate change is expected to alter fire regimes, but for ungulates the exact nature of those changes will be critical.

Figure 9.5—Ungulates generally respond favorably to wildfires that create patchy habitat, especially if forage availability improves, as shown in this photo of an elk browsing adjacent to a recently burned lodgepole pine forest (photo: Jeff Henry, National Park Service).

For example, in the Greater Yellowstone Area subregion, wildfires are infrequent, large, and intense. If climate change causes more frequent fires (Westerling et al. 2011), then the landscape will be patchier compared to the current condition, and the distribution and abundance of forest species could change. In the short term, novel fire-climate-vegetation relationships can be expected. In the long term, the effects of altered vegetation on ungulate populations are uncertain, but it is unlikely that there will be highly negative consequences.

Wolverine

The wolverine (*Gulo gulo*) is the largest mustelid, occurring throughout the Arctic, as well as subarctic areas and boreal forests of western North America and Eurasia. At the southern extent of its distribution in North America, populations occupy peninsular extensions of temperate montane forests. Monitoring programs in Fennoscandia (Flagstad et al. 2004) and surveys in Canada (Lofroth and Krebs 2007) inform our understanding of wolverine occurrence in those regions, but the limits of wolverine distribution in other portions of its range are less understood.

Wolverines are often considered to be generalists with respect to habitat, and their occurrence has been associated with great distance from human development (Banci 1994; May et al. 2006; Rowland et al. 2003). However, unlike brown bear and gray wolf, whose northern distributions are the result of recent human hunting and habitat alteration, there is no historical evidence for wolverine presence in areas not characterized by arctic or boreal conditions (Aubry et al. 2007). Fossil evidence is consistent with this understanding (Alvarez-Lao and Garcıa 2010), and wolverines apparently have always been associated with cold northern climates.

Wolverines den in snow, and deep snow throughout the denning period is thought to be essential (Magoun and Copeland 1998). The strong, perhaps obligate, relationship between wolverine den selection and deep snow in the late spring has been reinforced by recent study results (Copeland et al. 2010; Dawson et al. 2010; Inman et al. 2012). A proxy for spring snowpack (areas where snow persisted through mid-May) effectively describes den site selection, current range limits, and year-round habitat use at the southern periphery of the wolverine range (Copeland et al. 2010). These areas are associated with successful dispersal (Schwartz et al. 2009) and historical range (Aubry et al. 2007). Although not all biological aspects of this association are understood, its universal nature in both space and time indicate that snow persistence will be associated with future distributions as well. The association applies to populations in Alaska, Idaho, and Scandinavia, and it describes both historical and contemporary distributions. Wolverines apparently travel within these areas when dispersing and strongly minimize travel through low elevation habitat, so we can project both current and future travel routes based on altered snowpack.

McKelvey et al. (2011) modeled future spring snowpack within the Columbia, Upper Missouri, and Colorado River basins, and projected changes in habitat and connectivity associated with future landscapes based on existing wolverine habitat relationships (Copeland et al. 2010) and dispersal preferences (Schwartz et al. 2009). A projection derived from an ensemble mean of 10 GCMs under an intermediate emissions scenario (A1B) (Mote and Salathé 2010) was used to produce climate projections (Elsner et al. 2010; Littell et al. 2011). Historical data across the area were reconstructed following methods in Hamlet and Lettenmaier (2005), and changes from historical patterns were modeled by using the “delta” method of downscaling, resulting in regionally averaged temperature and precipitation change for 2030–2059 and 2070–2099. Downscaled climate data were used as inputs to the Variable Infiltration Capacity (VIC) model (Hamlet and Lettenmaier 2005; Liang et al. 1994), which was used to project snowpack. Historical modeled snowpack depth was fit to most closely match the persistent snow cover data from Copeland et al. (2010), and this fit was then used to identify areas of future habitat for wolverines.

In the Columbia and Upper Missouri River basins, where most of the Northern Rockies region is located, snowpack projection indicated a loss of 35 and 24 percent, respectively, for spring snow by the mid-21st century, and 66 and 51 percent, respectively, by the end of the century. Central Idaho was projected to lose nearly all snow by the end of the century, whereas northern Montana, the southern Bitterroot Mountains, and the Greater Yellowstone Area retained significant spring snow (McKelvey et al. 2011). The ensemble mean model output was similar to results associated with the Parallel Climate Model (a cool extreme; U.S. Department of Energy and National Science Foundation 2004), but at the warm extreme, little spring snow was retained at the end of the century. A connectivity model (Schwartz et al. 2009) in conjunction with ensemble climate model projections indicated that all remaining habitat would be genetically isolated by the end of the 21st century (McKelvey et al. 2011).

The threshold between rain and snow causes estimates of snowpack loss to differ greatly between GCMs because timing of moisture and the temperature when it occurs affect model performance. Cool models (e.g., Goddard Institute for Space Studies model E; Schmidt et al. 2006) indicate increases in January snowpack at high elevation (e.g., Yellowstone Plateau, Colorado) through the mid-21st century, whereas warmer models (e.g., Model for Interdisciplinary Research on Climate; Watanabe et al. 2011) show large losses in snowpack across all regions (Alder and Hostetler 2014). All models, including the coolest and wettest, indicate a continuing reduction in spring snow, a pattern that has been ongoing since at least the 1950s (Mote et al. 2005).

Birds

Brewer's Sparrow

Brewer's sparrow (*Spizella breweri*) is apparently a sagebrush obligate during the nesting period when nest occupancy is positively related to tall, dense stands of sagebrush (Petersen and Best 1985; Reynolds 1981) (fig. 9.6). In areas where other sagebrush-obligate species exist (e.g., sage thrasher [*Oreoscoptes montanus*]), these sparrows may compete for nest locations (Reynolds 1981). In many areas, however, Brewer's sparrow is the most abundant bird species (Norvell et al. 2014). Some consider the closely related timberline sparrow (*S. breweri taverneri*) to be a separate species (i.e., *S. taverneri*) or subspecies but, in any case, no genetic mixing occurs between the alpine and sagebrush variants (Klicka et al. 1999).

Reasons for the obligate relationship of Brewer's sparrow with sagebrush are obscure. Although this relationship appears to be robust, especially patterns of nest occupancy (Petersen and Best 1985), evidence for why Brewer's sparrow nests in sagebrush rather than in other brush species is lacking. Therefore, we rely on correlative associations to project climate change effects and cannot speculate as to the flexibility of this species to shift to alternative shrub species should sagebrush become scarce.

Brewer's sparrow populations appear to be reasonably stable range-wide, although they have been in decline in some areas in Colorado (USGS 2013). Although Brewer's sparrow selects for areas with tall, dense sagebrush, sparrow abundance was unaffected by treatments designed to modify sagebrush cover and improve habitat for greater sage-grouse (Norvell et al. 2014). Similarly, a study of the effects of (nonnative) smooth brome (*Bromus inermis*) found that nest success was higher in areas with brome establishment (Ruehmann et al. 2011). In general, the effects of climate change on Brewer's sparrow will probably depend to a great degree on changes in the distribution, abundance, composition, and structure of sagebrush communities. Increased wildfire is likely to reduce the distribution, abundance, and age of sagebrush stands in a warmer climate. Within sagebrush communities, Brewer's sparrows do exhibit flexibility in response to nest predation, shifting locations of sequential nests in response to previous predation (Chalfoun and Martin 2010).

Flammulated Owl

The flammulated owl (*Otus flammeolus*) is a nocturnal owl, approximately 6 inches long with a 14-inch wingspan. It is migratory but breeds in montane areas across much of western North America, ranging from southern British Columbia to central Mexico (Ridgely et al. 2003). It is a cavity nester, associated with mature forests with large diameter

Figure 9.6—Because climate change is expected to reduce the extent of mature sagebrush through increased wildfire, sagebrush-obligate species such as Brewer's sparrow (shown here) and greater sage-grouse may have less nesting habitat in the future (photo: Tom Koerner, U.S. Fish and Wildlife Service).

trees. It is also associated with open forests, but does not appear to be specific to any particular tree species. In New Mexico, it is found in pinyon pine (*Pinus edulis*) (McCallum and Gehlbach 1988), ponderosa pine (*P. ponderosa*) (Bull et al. 1990; Linkhart et al. 1998), and Douglas-fir (Powers et al. 1996; Scholer et al. 2014) forest. In the Sierra Nevada, it has been associated with (from low to high elevation) black oak (*Quercus kelloggii*), mixed-conifer, Jeffrey pine (*P. jeffreyi*), white fir (*Abies concolor*), and red fir (*A. magnifica*) forest (Stanek et al. 2011).

Flammulated owls are thought to be obligate secondary cavity nesters, although it has been anecdotally observed to nest in the ground (Smucker and Marks 2013). Flammulated owls feed almost exclusively on insects, primarily Lepidoptera, which they gather from trees, on the ground, or in flight (Linkhart et al. 1998). During the nesting period, males are single-trip, central-place foragers, so the energetics of prey selection are important; distance traveled and energy content of prey differ by forest type. Little information is available on the diet of flammulated owls and their relationships to forest habitat. Interactions with other owl species are apparently minimal (Hayward and Garton 1988).

The extensive latitudinal range of flammulated owls, lack of specific forest associations, and generalized insect diet indicate that straightforward links to specific climatic regimes are unlikely. If climate change is to affect flammulated owls, then it will most likely be through disturbance processes that remove large diameter trees. Shifts to denser forest structure would be problematic for this species, but there is little evidence that this would occur, because drought and wildfire are projected to increase throughout the Northern Rockies (Alder and Hostetler 2014). As with other long-lived owl species (Linkhart and Reynolds 2004), flammulated owl populations will be very sensitive to adult survival (Noon and Biles 1990).

Greater Sage-Grouse

Greater sage-grouse (*Centrocercus urophasianus*) is the largest grouse in North America (Mezquida et al. 2006). It is considered an obligate with sagebrush (Miller and Eddleman 2001). Its distribution is currently about half of its presettlement range (Schroeder et al. 2004), and many populations have been steadily declining in recent decades (Braun 1998; Connelly and Braun 1997; Connelly et al. 2004). In some areas, land conversion that eliminated sagebrush apparently has caused the declines (Connelly et al. 2004; Miller and Eddleman 2001). Extirpation of sage-grouse is more likely in areas with high human population densities, land conversion to cropland, severe droughts (Aldridge et al. 2008), sagebrush displacement by conifers, and corvid predation. It is also more likely in areas with less than 25 percent sagebrush cover near the edge of the historical range.

Declines in sage-grouse have also occurred in areas still dominated by sagebrush (Miller and Eddleman 2001). In addition to reduced sagebrush cover, declines have been attributed to nonnative plants (Connelly et al. 2004; Knick et al. 2003; Wisdom et al. 2002), energy exploration and extraction (Braun et al. 2002; Doherty et al. 2008; Holloran et al. 2005; Lyon and Anderson 2003; Walker et al. 2007a), grazing (Beck and Mitchell 2000; Hayes and Holl 2003), altered fire regimes (Connelly et al. 2000, 2004), and a warmer climate (Neilson et al. 2005). In recent years, West Nile virus has also been implicated (Naugle et al. 2004, 2005; Walker et al. 2007b).

Assessing the effects of climate change on this species is challenging because so many factors potentially affect sage-grouse population dynamics. Nevertheless, Schrag et al. (2011) produced a detailed climate change assessment for greater sage-grouse that evaluated changes in distribution of sagebrush and transmission of West Nile virus. They first built bioclimatic models for sagebrush distribution, then modeled West Nile spread based on temperature thresholds. They used six GCMs and one emissions scenario (A1B), and GCM output was statistically downscaled to 7.5-mile pixels. Both the envelope model and temperature thresholds were projected to 2030 based on the downscaled GCM output. Results varied greatly across models, but it was concluded that the cumulative effects of projected climate change on both sagebrush and West Nile virus transmission would reduce suitable sage-grouse habitat in the Northern Rockies and northern Great Plains (Schrag et al. 2011). Sage-grouse require large areas of mature sagebrush, so future increases in wildfires are expected to significantly reduce habitat.

Creutzburg et al. (2015) evaluated the likely trajectory of greater sage-grouse habitat in southeastern Oregon. They simulated the effects of climate change, disturbance, and cheatgrass (*Bromus tectorum*) invasion by coupling a linked dynamic global vegetation model, climate envelope model, and state-and-transition simulation model, based on three climate models chosen to cover a range of possible futures. In the near term, loss of sagebrush from wildfire and cheatgrass invasion leads to habitat deterioration. In all three climate projections, however, native shrub-steppe communities increased circa 2070, leading to habitat improvement. In this simulation, all projected climate futures had better long-range prospects for sage-grouse than was simulated based on current climate.

Harlequin Duck

Harlequin ducks (Histrionicus histrionicus) in the Intermountain West breed and summer on fast-flowing mountain streams and winter on rocky coastal areas (Robertson and Goudie 2015). In Grand Teton National Park, breeding pairs used streams with dense shrubs along the banks (Wallen 1987). During summer they feed primarily on larval insects on stream bottoms and in winter on a variety of small food items including snails, small crabs, barnacles, and fish roe (Robertson and Goudie 2015). They are relatively rare in Montana, with a concentration in Upper McDonald Creek in Glacier National Park (Reichel 1996). Climate change may alter the timing, duration, and levels of streamflows. In Glacier National Park, harlequin duck reproductive success declined with higher and less predictable streamflows (Hansen 2014).

Mountain Quail

The mountain quail (*Oreortyx pictus*) is a small ground-dwelling bird that occupies upland forest and woodland habitats in the western United States and northern Mexico (Brennan et al. 1987). In the Pacific Northwest, its range extends into deep canyons such as Hells Canyon of the Snake River (Pope and Crawford 2004), where populations of the species have been declining. Population augmentation through translocation is common. Population studies have focused on survival, but connections to climate-related change are minimal. Stephenson et al. (2011) found that climate-related variables were important to survival, with lower survival being linked both to hot, dry conditions and to cold winter weather. Seasonal movements to avoid snowpack led to increased rates of movement, which were also important predictors of survival.

Pygmy Nuthatch

The pygmy nuthatch (*Sitta pygmaea*), a bird about 4 inches long, is found throughout montane coniferous forests in western North America and as far south as central Mexico (McEllin 1979; Ridgely et al. 2003). It is a cavity nester, often associated with ponderosa pine forests (McEllin 1979) but also found in other forest types such as quaking aspen (*Populus tremuloides*) (Li and Martin 1991). Pygmy nuthatches can exhibit a social structure of cooperative breeding in which "helpers" aid breeding birds by feeding the incubating female, feeding nestlings and fledglings, and defending nesting territory (Sydeman et al. 1988).

Pygmy nuthatches nest in cavities in both live and dead trees, as observed at a study site in Arizona (Li and Martin 1991), and population responses to disturbance are modest. For example, Hurteau et al. (2008) found that population densities across a variety of thinning and fuels treatments at a study site in Arizona remained constant except in thin-and-burn treatments, where densities increased by more than 500 percent. In a study of the interior western United States, Saab et al. (2007) found that nuthatches showed a negative response to fire the first year after wildfire, but a neutral response in subsequent years. Due to their apparent neutral response to disturbance, coupled with flexibility in habitat and wide latitudinal range, it is difficult to project whether they will respond positively or negatively to climate change. Extirpation of the pygmy nuthatch due to climate change appears unlikely, other than from the effects of land-use conversion from forest to nonforest.

Ruffed Grouse

Ruffed grouse (*Bonasa umbellus*) are characterized by a boreal distribution that includes peninsular extensions into the Rocky Mountains and Appalachian Mountains (USGS 2014). Throughout much of their range, ruffed grouse occupy quaking aspen (*Populus tremuloides*) forest (Kubisiak 1985; Stauffer and Peterson 1985; Svoboda and Gullion 1972), which provides important food sources (Jakubas and Gullion 1991). Although ruffed grouse exist in forests that contain no aspen (e.g., oak-dominated forest) (Haulton et al. 2003), they are mostly limited to aspen habitats in many areas of the West (e.g., Mehls et al. 2014). Ruffed grouse were identified as a species of concern in the Northern Rockies in the context of aspen-dominated forest, so we focus here on the use of aspen by ruffed grouse.

In central Wisconsin, ruffed grouse densities were highest in young (<25 years) aspen stands (Kubisiak 1985). Similarly, ruffed grouse preferred stand structures characteristic of early successional stages in Idaho (Stauffer and Peterson 1985) but also use aspen stands of all ages (Mehls et al. 2014). Thus, optimal grouse habitat consists of aspen forests with stands in a variety of age classes, including a large component of young stands.

Aspen may be sensitive to heat and drought in some locations (Anderegg et al. 2013; Huang and Anderegg 2011). Although higher temperatures are expected to cause increased stress in aspen, differences in forest structure and age affect the relationship between aspen mortality and drought (Bell et al. 2014), and mortality can be reduced by controlling stand densities and ages and limiting competition from conifers. If climate change causes decreased extent of aspen in the Northern Rockies region, reduced habitat would have detrimental effects on ruffed grouse populations. However, significant options exist to mitigate these changes through silviculture that favors aspen over conifers and through active manipulation of stand densities and ages.

Amphibians

Columbia Spotted Frog

The Columbia spotted frog (*Rana luteiventris*) breeds in montane ponds throughout western North America (Green et al. 1996, 1997) (fig. 9.7). Funk et al. (2008) built a phylogeny for this species based on samples across western North America. Populations separated into three distinct clades; within the Northern Rockies region, all samples were associated with the northern clade and were fairly closely related. The effects of climate change on Columbia spotted frogs are unclear. In Utah, the frog was more likely to occur in persistent, shady ponds that maintained constant temperatures (Welch and MacMahon 2005). In Yellowstone National Park, pond desiccation led to sharp declines in frog populations (McMenamina et al. 2008).Throughout their range, populations in large stable water bodies were doing well, whereas those in smaller more ephemeral ponds were subject to rapid declines (Hossack et al. 2013). In Montana, warmer winters were associated with improved reproduction and survival of Columbia spotted frogs (McCaffrey and Maxell 2010). This species does not appear to be sensitive to stand-replacing fires (Hossack and Corn 2007).

Columbia spotted frog populations are stable in areas with stable water supplies, and are capable of rapid population expansion into restored wetlands (Hossack et al. 2013). However, the amphibian chytrid fungus (*Batrachochytrium dendrobatidis*, hereafter referred to as Bd), is prevalent in many populations (Pearl et al. 2009; Russell et al. 2010) and warming waters would, in most systems, favor Bd (see discussion on western toad). Although the fungus is common, the population effects of infection are unclear.

Western Toad

Western toads (*Anaxyrus boreas*) are montane amphibians broadly distributed across the western United States (Muths et al. 2008); in the southern Rocky Mountains, the subspecies boreal toad (*A. b. boreas*) is recognized. The western toad has suffered apparently widespread declines, particularly at the southern extent of its range (Corn et al. 2005), a phenomenon well documented in Colorado (Carey 1993). This species suffers from amphibian chytrid fungus, which is often fatal. Laboratory studies of Bd have found that it grows optimally at 63 to 77 °F, and colonies are killed at 86 °F (Piotrowski et al. 2004). Although Bd can grow in temperatures as cold as 39 °F, warming waters would increase its prevalence.

In a study across Colorado, Wyoming, and Montana, Bd was consistently found in western toad tissues, and was more prevalent in warmer, lower elevation sites (Muths et al. 2008). A warmer climate may allow Bd to spread to higher elevations and become even more widespread. But there is some question about how susceptible the western toad is to the effects of Bd because increased mortality is not always associated with high infection rates. Recent studies indicate that the skin of the toad contains bacterial colonies that inhibit Bd (Park et al. 2014).

Figure 9.7—Warmer air temperature and less snowpack are expected to decrease the presence of shallow water during the summer, reducing habitat for the Columbia spotted frog (shown here) and western toad. Higher air and water temperatures may also increase infections from amphibian chytrid fungus (photo by Roger Myers, Alaska Department of Fish and Game).

Assessing Subregional Differences in Vulnerability

When considering how climate change would affect wildlife populations in their subregion, Northern Rockies Adaptation Partnership (NRAP) workshop participants tended to think in terms of pathways through which climate could exert an influence (fig. 9.1, black text and arrows). These pathways can interact with each other, and with population characteristics (fig. 9.1, blue text and arrows) to produce an effect on the population of interest (fig. 9.1, red text). However, a given pathway influences multiple species, and multiple pathways influence a given species. Following is a summary of the subregional workshop discussions.

Upper temperature thresholds for moose were discussed for the Greater Yellowstone Area (GYA) subregion. This was the only species and subregion with a discussion of direct physiological sensitivities to climate. However, it was noted in all subregions that there is a general lack of understanding of direct physiological sensitivities to climate for most wildlife species. Even when these sensitivities have been measured (e.g., the lower thermoneutral limits for wolverines [e.g., Iversen 1972]), however, it is unclear how this laboratory-derived knowledge can be interpreted in the context of habitat use and demographic performance.

Position within a species' niche can influence population vulnerability. Some species are at the climatic limits of their range in particular subregions. Exposure to climate change in these places is likely to have a strong effect on the ability of a species to persist, whereas the same amount of change in the center of its range probably would have less effect. The Western Rockies and Central Rockies subregions are at the junction of maritime and continental climates, and many species are at the edges of their ranges. For example, participants in the Central Rockies workshop discussed how future climate change is expected to increase habitat suitability for the fisher, such that this species may expand its range into the subregion.

Some species had different habitat associations in different subregions. For example, in the GYA, ruffed grouse was linked to aspen habitat but was associated with a broader range of habitats in the Central Rockies subregion. Therefore, ruffed grouse was seen as more sensitive to climate effects on aspen in the GYA than in the Central Rockies.

The importance of previous habitat loss, potentially caused by recent warming, differed across the subregions. In the Eastern Rockies subregion, extensive lodgepole pine (*Pinus contorta* var. *latifolia*) mortality has been caused by mountain pine beetle (*Dendroctonus ponderosae*); amplified pine beetle outbreaks are probably the result of warmer winters (Bentz et al. 2010). Cavity nesting birds were thought to be more sensitive to potential future habitat loss because they have already lost a substantial portion of their habitat. Prior habitat loss was not discussed in the other subregions.

Another pathway for habitat loss discussed in the Central Rockies workshop was an increase in invasive species. For example, flammulated owls feed on insects that depend on understory plant composition, and that composition could be altered by increased abundance of invasive plants such as cheatgrass.

Negative effects on wildlife populations from an increase in disease occurrence and transmission caused by climate change (e.g., West Nile virus) were discussed in three of the five subregions. Participants also noted that relatively little is known about disease ecology and the future potential for disease to affect wildlife populations.

Connectivity was a primary concern in four of the five subregions. Participants considered different scales of connectivity to be important: the ability for individuals to move through the landscape to meet their daily needs, the ability to complete seasonal migrations, and the ability to track potentially shifting habitat. Numerous indirect influences on each of those scales of connectivity were discussed.

Indirect pathways that increase vulnerability to climate change can also arise when a changing climate influences landscape configurations such that species are then more at risk from other stressors. Participants discussed the need to understand how potential shifts in residential development (e.g., into riparian habitats) in the GYA and Central Rockies subregions could affect wildlife. Changing demands for energy sources and the influence of energy development on wildlife habitat were discussed in the Central Rockies and Grassland subregions.

Another source of variation within the Northern Rockies region was the importance of multiple collaborative efforts focused on conservation issues in the Central Rockies subregion. USFS participants stated that these collaboratives increased their range of achievable management tactics.

There were differences in the amount of climate change expected (exposure), the response of individuals and populations to that change (sensitivity), and the ability of organisms and organizations to adapt to that change (adaptive capacity) across Northern Rockies subregions. However, participants agreed on the lack of understanding about mechanisms of climate influence. Identifying and contrasting the importance of *pathways* of climate influence across subregions can suggest potential *mechanisms* of climate influence. Hypotheses can be developed to account for these mechanisms, and management actions can be monitored to test those hypotheses. Based on the results of those tests, decisions can be made to continue with management actions, or develop new actions or hypotheses, creating an adaptive monitoring program (Lindenmayer and Likens 2009) and increasing knowledge of the needs and climate sensitivities of species (table 9.1). Sensitivities listed in tables 9.2 through 9.9 provide a starting point for identifying potential hypotheses.

Adapting Wildlife Management to the Effects of Climate Change

Adaptation to climate change for wildlife resources in NRAP subregions was focused on maintaining adequate habitat and healthy wildlife populations, and increasing knowledge of the needs and climate sensitivities of species. Workshop participants identified the major habitats in their subregion and then developed adaptation strategies for species they regarded as important and for which they believed viable management options exist. For example, participants in the GYA workshop discussed climate sensitivities of American pika, but decided not to work through adaptation options because they did not see how management efforts could influence pika population viability. Participants tended to address species or habitats that had not been covered in prior workshops, even if some were important in their subregion. Adaptation options are summarized according to major habitats (tables 9.2 through 9.7), which can then be associated with individual species (table 9.1).

Riparian habitats are important across the Northern Rockies region. The primary strategy for improving riparian habitat resilience is maintaining healthy American beaver populations (table 9.2). Beaver complexes can buffer riparian systems against both low and high streamflows, and provide habitat structure and foraging opportunities for multiple species. Nonriparian wetlands were discussed as important habitats, but no adaptation strategies were developed.

Quaking aspen habitats are common in the four western subregions and occur occasionally in the Grassland subregion. Aspen was identified as important because of its high productivity, role in structural diversity, and habitat for cavity nesting birds. In the GYA, ruffed grouse were identified as strongly tied to aspen habitats. Reduction in the distribution and abundance of aspen is projected for some locations (especially lower elevation) in a warmer climate (see Chapter 6). The most common tactics for promoting aspen resilience were allowing wildfire or using prescribed fire in older aspen stands, providing protection from grazing, and reducing conifer encroachment in any age stand (table 9.3).

Dry ponderosa pine forests are common in the Central Rockies and Eastern Rockies subregions and provide habitat for cavity nesting birds such as the flammulated owl. Douglas-fir has encroached on these habitats as a result of fire exclusion, increasing vulnerability of pine to future fires. Tactics for promoting ponderosa pine resilience included reducing competition from Douglas-fir through understory burning and cutting, protecting mature stands, and planting ponderosa pine where it has been lost (table 9.4).

The Western Rockies and Central Rockies subregions support older, mesic forests because they experience a maritime climate influence (see Chapter 3). These forests, which provide important habitat for fisher, may have younger age classes (caused by increased disturbance; see Chapter 8) and different species composition in a warmer climate (see Chapter 6). Adaptation strategies included restoring historical structure, conserving current structure, and promoting potential future mesic forest habitats (table 9.5).

Mountain sagebrush-grassland habitat occurs in all regions except the Grassland. In the Western Rockies subregion, mountain sagebrush-grassland habitats are unique in that they have less of a sagebrush component, primarily occur in

Table 9.1—Species included in the Northern Rockies Adaptation Partnership vulnerability assessment, including species discussed at subregional workshops.

Habitat/Species	Western Rockies	Central Rockies	Eastern Rockies	Greater Yellowstone Area	Grassland
Dry forest					
Flammulated owl		X		X	
Pygmy nuthatch		X	X	X	
Riparian/wetland					
American beaver		X	X	X	
Moose				X	
Northern bog lemming				X	
Townsend's big-eared bat		X	X	X	
Harlequin duck		X		X	
Columbia spotted frog		X		X	
Western toad		X		X	
Quaking aspen					
Avian cavity nesters		X	X	X	
Ruffed grouse				X	
Sagebrush grasslands					
Pronghorn				X	
Pygmy rabbit			X		
Brewer's sparrow				X	
Greater sage-grouse				X	X
Mountain grasslands					
Mountain quail	X				
Mesic old-growth forest					
Fisher		X		X	
Snow-dependent species					
American pika				X	
Canada lynx		X		X	
Wolverine		X		X	

steep mountain canyons, and support populations of mountain quail. Differences in aspect have a strong influence on climate in these canyons. In a warmer climate, these habitats could lose some of their forb component, making them vulnerable to increased abundance of nonnative species (see Chapter 7). Specific tactics for restoring historical habitat and maintaining current habitat included managing fire, controlling nonnative species, and restoring formerly cultivated lands (table 9.6).

Sagebrush habitats are common in the Eastern Rockies, GYA, and Grassland subregions, supporting gallinaceous birds (greater sage-grouse, greater prairie chicken [*Tympanuchus cupido*], sharp-tailed grouse [*T. phasianellus*]), and pygmy rabbits, among other species. Tactics for maintaining adequate sagebrush habitat included managing fire, controlling nonnative species, preventing fragmentation, and restoring degraded habitat (table 9.7). Current focus on conservation of greater sage-grouse within sagebrush habitat in the western United States will benefit from including a climate-smart approach to management.

Developing on-the-ground management tactics requires understanding how climate change will influence species. In all subregions, and independent of habitat association, participants identified the need for better understanding of species requirements and the mechanisms of climate change impacts. In addition, connectivity and the potential for increases in disease were identified as important processes affecting multiple habitats and species in each subregion, although climate sensitivities of diseases are not well understood. Accordingly, several adaptation strategies were suggested to fill knowledge gaps (table 9.8). There is wide agreement on the need to better understand the mechanisms of climate sensitivities relative to the life histories of individual species. Examples of tactics to accomplish this objective include analyzing female Canada lynx home ranges to determine the necessary distribution and size of habitat patches, quantifying and monitoring pygmy rabbit distribution, and understanding sagebrush succession after fire. The influence of low snow years on wolverine

Table 9.2—Adaptation options that address climate change effects on riparian habitat and associated wildlife species in the Northern Rockies.

Sensitivity to climatic variability and change: Decreased streamflow reduces riparian vegetation, affecting food supply and habitat structure for multiple species.

Adaptation strategy/approach: Improve riparian habitat by maintaining healthy beaver populations on the landscape.

	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Inventory current and potential habitat (include multiple factors).	Restore riparian habitat e.g. plant willows, manage grazers, raise water level.	Translocation, manage trapping
Where can tactics be applied? (geographic)	Range-wide	Suitable habitats range-wide	Suitable habitats range-wide

Table 9.3—Adaptation options that address climate change effects on quaking aspen habitat and associated wildlife species in the Northern Rockies.

Sensitivity to climatic variability and change: A warmer climate will lower water tables, leading to loss of quaking aspen.

Adaptation strategy/approach: Promote aspen resilience.

	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Promote disturbance (fire, cutting) in older aspen stands.	Protect from grazing (fencing, manage grazing).	Reduce conifer competition (fire, cutting) in any age aspen stand.
Where can tactics be applied? (geographic)	Range-wide	Range-wide	Range-wide

denning success is an example of a mechanistic relationship with climate that needs more data.

Connectivity, although not tied to a particular habitat type, is considered an important conservation strategy for most species in all Northern Rockies subregions, although climate influences on connectivity are uncertain. Several forms of connectivity were identified: daily, seasonal, dispersal, and range shift. Connectivity can be affected by changes in water supply, habitat loss, habitat shifts, vegetation phenology shifts, human population expansion and redistribution, and snowpack dynamics. Specific tactics for increasing knowledge that would enable the maintenance of connectivity include monitoring connectivity with genetic, tracking, and remote-sensing tools; identifying dispersal habitats; and identifying and removing or mitigating barriers to connectivity (table 9.9).

Disease is also important in most subregions, not tied to a particular habitat, and not well understood. Specific tactics for addressing disease include monitoring the presence of white-nose syndrome (caused by the fungus *Pseudogymnoascus destructans*) in bat hibernacula (ongoing through collaboration of the USFS, other agencies, and Northern Rocky Mountain Grotto), monitoring disease trends in moose and bighorn sheep, and coordinating with State agencies to monitor West Nile virus.

More specific details on adaptation strategies and tactics that address climate change effects on wildlife in each NRAP subregion are in Appendix 9A.

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Table 9.4—Adaptation options that address climate change effects on dry forest (ponderosa pine) habitat and associated wildlife species in the Northern Rockies.

Sensitivity to climatic variability and change: A warmer climate will potentially convert drier ponderosa pine to grassland; in addition, many ponderosa stands have converted to Douglas-fir because of fire exclusion and are susceptible to projected increases in fire frequency.

Adaptation strategy/approach: Promote ponderosa pine resilience

	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**	**Specific tactic – D**
Tactic	Reduce competition from Douglas-fir and grand fir (thin, burn) in current mature ponderosa pine stands.	Frequent understory burning.	Retain current mature and older ponderosa pine stands.	Plant ponderosa pine where it has been lost.
Where can tactics be applied? (geographic)	Range-wide	Range-wide	Range-wide	Range-wide

Table 9.5—Adaptation options that address climate change effects on old-growth, mesic forest habitat and associated wildlife species in the Northern Rockies.

Sensitivity to climatic variability and change: A warmer climate will create drier conditions and cause more wildfire, potentially eliminating old forest structure and mesic habitat.

Adaptation strategy/approach: Maintain current habitat, restore historical habitat, and promote potential future inland maritime forest habitat.

	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**	**Specific tactic – D**
Tactic	Conserve current old-growth western redcedar and western larch, but reduce density to increase resilience to drought.	Restore western white pine with a western redcedar understory to create future habitat.	Maintain or create necessary structure in modeled future fisher habitat.	Conserve current old-growth western redcedar and western larch, but reduce density to increase resilience to drought.
Where can tactics be applied? (geographic)	Northern Idaho, Kootenai, Bitterroot divide Where risk of loss is greatest (edge of range) Need redundancy across landscape to buffer against future fire or drought mortality.	Northern Idaho, Kootenai, Bitterroot divide. Need redundancy across landscape to buffer against future fire or drought mortality.	Mission side of Swan Range. Need redundancy across landscape to buffer against future fire or drought mortality.	Northern Idaho, Kootenai, Bitterroot divide Where risk of loss is greatest (edge of range) Need redundancy across landscape to buffer against future fire or drought mortality.

Table 9.6—Adaptation options that address climate change effects on mountain sagebrush-grassland habitat and associated wildlife species in the Northern Rockies.

Sensitivity to climatic variability and change: A warmer climate will dry soils, reducing the forb component of mountain sagebrush-grassland habitat.			
Adaptation strategy/approach: Maintain current and restore historical habitat.			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Manage fire to maintain desired habitat.	Control invasive vegetation.	Restore formerly cultivated land.
Where can tactics be applied? (geographic)	Range-wide	Range-wide	Range-wide

Table 9.7—Adaptation options that address climate change effects on sagebrush habitat and associated wildlife species in the Northern Rockies.

Sensitivity to climatic variability and change: A warmer climate and increased wildfire will reduce the distribution and abundance of sagebrush habitat.				
Adaptation strategy/approach: Maintain adequate sagebrush habitat.				
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**	**Specific tactic – D**
Tactic	Manage fire to maintain desired habitat.	Control invasive vegetation.	Restore formerly cultivated land.	Prevent fragmentation of sagebrush habitat (roads, energy development lines).
Where can tactics be applied? (geographic)	Range-wide	Range-wide	Range-wide	Range-wide

Table 9.8—Adaptation options that address knowledge gaps in climate change effects on wildlife populations in the Northern Rockies.

Sensitivity to climatic variability and change: Species requirements and/or climate sensitivities are largely unknown for many species.				
Adaptation strategy/approach: Increase knowledge of species needs and climate sensitivities				
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**	**Specific tactic – D**
Tactic	Analyze female lynx home ranges to determine necessary mix of habitat patches: distribution and size.	Update and expand knowledge of existing pygmy distribution.	Understand climate influences on pygmy rabbits.	Understand succession after fire in sagebrush.
Where can tactics be applied? (geographic)	Range-wide	Range-wide	Range-wide	Range-wide
Sensitivity to climatic variability and change: Loss of connectivity can be caused by changes in water supply and snowpack dynamics, habitat loss, habitat shifts, vegetation phenology shifts, and human population expansion and redistribution.				
Adaptation strategy/approach: Maintain multiple levels of connectivity (daily, seasonal, dispersal range shift).				
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**	**Specific tactic – D**
Tactic	Monitor connectivity using genetics, tracking, remote sensing tools (e.g., multi-carnivore genetic monitoring across the Northern Continental Divide Ecosystem with multiple partners.	Compile table of connectivity vulnerability by species (daily through range shift).	Identify dispersal habitat requirements for selected species (e.g., wolverine).	Identify and remove or mitigate barriers.
Sensitivity to climatic variability and change: Disease transmission may increase with warmer temperatures.				
Adaptation strategy/approach: Increase knowledge of disease-climate relationships.				
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**	
Tactic	Monitor environmental conditions at bat hibernacula to understand environmental conditions that promote white-nose syndrome.	Monitor moose and bighorn sheep disease trends to determine if there are climatic drivers.	Work with the State wildlife departments to monitor West Nile virus.	
Where can tactics be applied? (geographic)	Region-wide	Region-wide	Region-wide	

Table 9.9—Adaptation options that address climate change effects on connectivity for wildlife populations in the Northern Rockies.

Sensitivity to climatic variability and change: Connectivity depends multiple factors, including water supply, habitat shifts, vegetation phenology, snow pack dynamics, and human population expansion and redistribution.

Adaptation strategy/approach: Maintain connectivity.

	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Monitor connectivity through genetics, tracking, and remote sensing.	Compile table of known connectivity vulnerabilities by species.	Identify and remove barriers.
Where can tactics be applied? (geographic)	Region-wide	Region-wide	Region-wide

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Appendix 9A—Adaptation Options for Wildlife in the Northern Rockies.

The following tables describe climate change sensitivities and adaptation strategies and tactics for wildlife, developed in a series of workshops as a part of the Northern Rockies Adaptation Partnership. Tables are organized by subregion within the Northern Rockies. See Chapter 9 for summary tables and discussion of adaptation options for wildlife.

Table 9A.1—Adaptation options that address climate change effects on wildlife in the Central Rockies subregion.

Sensitivity to climatic variability and change: Potential conversion to grassland type; many ponderosa pine forests have converted to Douglas-fir types with fire exclusion and are therefore more susceptible to future fires (putting dry forest cavity nester habitat at risk).

Adaptation strategy/approach: Restore fire-adapted ponderosa pine stand conditions for dry forest cavity nesters.

Strategy objective: Promote resilience.

	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Reduce competition from Douglas-fir and grand fir (thin, burn) in current mature ponderosa pine stands.	Conduct frequent understory burning.	Retain current mature and older ponderosa pine stands and plant where it has been lost.
Tactic effectiveness (risks)	High	High	High
Implementation urgency	Near term	Near term	Near term
Where can tactics be applied? (geographic)	Low elevations with emphasis on where compatible with wildland urban interface (WUI) objectives; need redundancy across the landscape to buffer against future fire or drought mortality	Has to follow tactic A in the WUI, not necessarily in non-developed areas; need redundancy across the landscape to buffer against future fire or drought mortality	Wherever they occur; need redundancy across the landscape to buffer against future fire or drought mortality
Opportunities for implementation	Collaboration with other landowners	Collaboration with other landowners	Collaboration with other landowners
Cost	Low in places with market size Douglas-fir, otherwise moderate.	Moderate, depending on location	Low for retaining, moderate for planting
Barriers to implementation	Some	Major	None

Table 9A.2—Adaptation options that address climate change effects on wildlife in the Central Rockies subregion.

Sensitivity to climatic variability and change: Drying of inland maritime forest types that fishers depend on.

Adaptation strategy/approach: Maintain current, restore historical, and promote potential future fisher habitat. Conserving fisher habitat preserves cool wet forest types that provide habitat for multiple other wildlife species.

Strategy objective: Promote resilience, facilitate transition

	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Conserve current old-growth cedar and larch, but reduce density to increase resilience to drought.	Restore white pine with a cedar understory to create future habitat.	Maintain or create necessary structure in modeled future fisher habitat.
Tactic effectiveness (risks)	Moderate	Uncertain	Unknown (will that be habitat) and uncertain (can the conditions be effectively created)
Implementation urgency	Near term	Near term	Near term
Where can tactics be applied? (geographic)	Northern ID, Kootenai, Bitterroot divide; where risk of loss is greatest (edge of range); need redundancy across the landscape to buffer against future fire or drought mortality.	Northern ID, Kootenai, Bitterroot divide; need redundancy across the landscape to buffer against future fire or drought mortality.	Mission side of Swan; need redundancy across the landscape to buffer against future fire or drought mortality.
Opportunities for implementation	Fits with Collaborative Forest Landscape Restoration Program (CFLRP) objectives	Fits with CFLRP objectives	Fits with CFLRP objectives
Cost	Inexpensive	Moderate	Varies
Barriers to implementation	Major	None	Some

Table 9A.3—Adaptation options that address climate change effects on wildlife in the Central Rockies subregion.

Sensitivity to climatic variability and change: Snow melt occurring earlier in the spring creates snowshoe hare pelage mismatch. Lynx adapted to deep soft snow and denser snow could give other predators a competitive advantage. Burn intensity is predicted to increase, and repeat burns can reduce tree seed source; in winter, lynx avoid high intensity burns until tree regeneration allows for branches at snow surface.

Adaptation strategy/approach: Manage vegetation for long-term lynx and hare habitat and connectivity.

Strategy objective: Promote resilience, reduce stressors, and facilitate transition.

	Specific tactic – A	Specific tactic – B	Specific tactic – C	Specific tactic – D
Tactic	Thin some young stands to create a variety of multi-storied hare habitat across the landscape to prevent boom and bust cycles.	Maintain forest cover connections between good habitat patches.	Maintain current multi-storied forest conditions, prevent large monoculture stand conditions (burning, harvest).	Analyze female home ranges to determine necessary mix of habitat patches (distribution and size).
Tactic effectiveness (risks)	Uncertain	Moderate	Moderate	Moderate
Implementation urgency	Near Term	Near Term	Near Term	Near Term
Where can tactics be applied? (geographic)	Anywhere in current range of lynx	Anywhere in current range of lynx	Anywhere in current range of lynx	Anywhere in current range of lynx
Opportunities for implementation	Forest Planning; U.S. Fish and Wildlife Service	U.S. Fish and Wildlife Service	Northern Rockies Lynx Management Direction; critical habitat rule; U.S. Fish and Wildlife Service	U.S. Fish and Wildlife Service; Rocky Mountain Research Station; Collaborative Forest Landscape Restoration Program; Southwest Crown Partnership
Cost	Moderate	Inexpensive	Moderate	Inexpensive
Barriers to implementation	Major	Major	None	None

Table 9A.4—Adaptation options that address climate change effects on wildlife in the Central Rockies subregion.

Sensitivity to climatic variability and change: Townsend's big-eared bat maternal colonies winter hibernacula are sensitive to temperature change, loss of access to habitat, and spread of white-nose syndrome.

Adaptation strategy/approach: Maintain maternal colony and hibernacula sites, and reduce non-climate stressors.

Strategy objective: Increase knowledge, promote resilience, reduce stressors, engage coordination

	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**	**Specific tactic – D**
Tactic	Identify, and protect current maternal colony sites.	Monitor environmental conditions at identified sites, compared to unoccupied sites.	Educate the public (caver groups) about spread of white-nose syndrome and stress decontamination procedures.	Maintain, or create, open wetland complexes (for insects) near maternal colony sites.
Tactic effectiveness (risks)	High	Moderate, but not an end point itself	Moderate	Unknown
Implementation urgency	Near term	Near term	Near term	Near to mid term
Where can tactics be applied? (geographic)	Range wide	Public land	Range wide	Public land
Opportunities for implementation	Local caving clubs	Local caving clubs	Local caving clubs	Mostly on private lands
Cost	Moderate	Inexpensive	Inexpensive	Variable
Barriers to implementation	Some	Some	None	Some

Table 9A.5—Adaptation options that address climate change effects on wildlife in the Central Rockies subregion.

Sensitivity to climatic variability and change: Increasing winter temperatures reduce snowpack, and snow melt occurs earlier in the spring. Wolverines are obligate snow denners.

Adaptation strategy/approach: Maintain wolverine female reproductive capacity and core habitat connection.

Strategy objective: Reduce stressors.

	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Map areas with high persistent snow potential; identify protection status and development potential to identify areas of concern and connection between mountain ranges.	Identify dispersal habitat requirements.	Conduct multi-carnivore genetic monitoring.
Tactic effectiveness (risks)	High	Variable	High
Implementation urgency	Near term	Near term	Near term
Where can tactics be applied? (geographic)	Range wide	Range wide	Range wide
Opportunities for implementation			Coordinate existing monitoring, and develop regional monitoring goals.
Cost	Inexpensive	Expensive	Expensive
Barriers to implementation	None	Some	Some

Table 9A.6—Adaptation options that address climate change effects on wildlife in the Eastern Rockies subregion.

Sensitivity to climatic variability and change: Pygmy rabbits are dependent on big-sage, which may be vulnerable to climate change, but range could expand with climate change.

Adaptation strategy/approach: Increase information on distribution and sensitivities of pygmy rabbit.

Strategy objective: Increase knowledge.

	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Produce more accurate sage distribution layer.	Update and expand knowledge of existing pygmy distribution.	Understand climate influences on pygmy rabbits.
Tactic effectiveness (risks)	Moderate	Moderate	Moderate
Implementation urgency	Near term	Near term	Near term
Where can tactics be applied? (geographic)	Eastern subregion	Eastern subregion	Eastern subregion
Opportunities for implementation		Heritage program.	Wildlife Conservation Society study at the Idaho National Lab; candidate for State Wildlife Grant funding
Cost	Moderate	Moderate	Moderate
Barriers to implementation	Some: funding priority	Some: funding priority	Some: funding priority, not on anyone’s radar screen

Table 9A.7—Adaptation options that address climate change effects on wildlife in the Eastern Rockies subregion.

Sensitivity to climatic variability and change: Pygmy rabbits are dependent on big-sage, which may be vulnerable to climate change, but range could expand with climate change.

Adaptation strategy/approach: Conserve pygmy rabbit habitat.

Strategy objective: Promote resilience.

	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Obtain conservation easements in current sagebrush areas.	Lease sagebrush.	Understand succession after fire in sagebrush in the region.
Tactic effectiveness (risks)	High	High	High
Implementation urgency	Near term	Near term	Near term
Where can tactics be applied? (geographic)	Sagebrush habitat on unprotected private land	Sagebrush habitat on private and State land	Sagebrush habitat
Opportunities for implementation	Land Reliance; partners		
Cost	Inexpensive (cost-sharing and is happening now, even though a lot of money is spent)	Inexpensive (happening now, even though a lot of money is spent)	Inexpensive to moderate
Barriers to implementation	Some: land owner willingness; political consequences	Some	Funding priorities; lack of understanding for the need for the information; difference of opinion about what we already know

Table 9A.8—Adaptation options that address climate change effects on wildlife in the Greater Yellowstone Area subregion.

Sensitivity to climatic variability and change: Bat hibernaculum temperature change linked to white-nose syndrome; alternative energy development impacts (wind power).

Adaptation strategy/approach: Maintain healthy bat populations.

Strategy objective: Reduce stressors; increase knowledge and coordination.

	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Consider summer roosting in vegetation management.	Protect hibernacula from disturbance.	Survey for hibernacula.
Tactic effectiveness (risks)	Uncertain	Moderate	Uncertain
Implementation urgency			
Where can tactics be applied? (geographic)	Greater Yellowstone Area	Greater Yellowstone Area	Greater Yellowstone Area
Opportunities for implementation			
Cost			
Barriers to implementation			

Table 9A.9—Adaptation options that address climate change effects on wildlife in the Greater Yellowstone Area subregion.

Sensitivity to climatic variability and change: Reduced stream flow, loss of riparian vegetation, incised stream channels due to flood events.			
Adaptation strategy/approach: Maintain healthy beaver populations on the landscape.			
Strategy objective: Promote resilience; reduce stressors; increase public knowledge (slow down the water).			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Inventory current and potential habitat (include multiple factors).	Restore riparian habitat (e.g., plant willows, manage grazers, raise water level).	Translocate beavers, manage trapping.
Tactic effectiveness (risks)	High	High	High
Implementation urgency			
Where can tactics be applied? (geographic)	Greater Yellowstone Area	Greater Yellowstone Area	Greater Yellowstone Area
Opportunities for implementation			
Cost			
Barriers to implementation			

Table 9A.10—Adaptation options that address climate change effects on wildlife in the Greater Yellowstone Area subregion.

Sensitivity to climatic variability and change: Habitat shifts and disease transmission in bighorn sheep from direct and indirect effects of climate change (e.g., increase in overlap with domestics, increased disease transmission, shifts in pressure from recreation).

Adaptation strategy/approach: Maintain healthy bighorn sheep populations.

Strategy objective: Increase knowledge; reduce stressors; promote resilience.

	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Monitor sheep disease trends to determine if there are climate drivers.	Identify locations and improve connectivity between seasonal ranges; maintain separation from domestic sheep.	Maintain communication among research groups and promote sharing of information and collaboration of research/management efforts.
Tactic effectiveness (risks)	Unknown	High	Moderate
Implementation urgency	Near term	Near term	Near term
Where can tactics be applied? (geographic)	Greater Yellowstone Area	Greater Yellowstone Area	Greater Yellowstone Area
Opportunities for implementation	Focus of current attention (state, federal, non-governmental organizations, universities)	Focus of current attention (state, federal, non-governmental organizations, universities)	Focus of current attention (state, federal, non-governmental organizations, universities)
Cost	Inexpensive	Moderately to expensive depending on scale	Inexpensive
Barriers to implementation	None	Some to major (social, legal, jurisdiction)	None

Table 9A.11—Adaptation options that address climate change effects on wildlife in the Greater Yellowstone Area subregion.

Sensitivity to climatic variability and change: Loss of mountain sage and grassland habitat for Brewer's sparrow.			
Adaptation strategy/approach: Maintain adequate mountain sage grassland communities for Brewer's sparrow.			
Strategy objective: Promote resilience, reduce stressors, and increase knowledge.			
	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Manage fire to maintain desired habitat (see sage-grouse conservation strategy).	Control invasive vegetation.	Restore formerly cultivated land.
Tactic effectiveness (risks)	High	Low to high depending on the invasive species	Low to high depending on site conditions
Implementation urgency			
Where can tactics be applied? (geographic)	Greater Yellowstone Area	Greater Yellowstone Area	Greater Yellowstone Area
Opportunities for implementation			
Cost			
Barriers to implementation			

Table 9A.12—Adaptation options that address climate change effects on wildlife in the Greater Yellowstone Area subregion.

Sensitivity to climatic variability and change: Water supply; habitat loss; habitat shifts; vegetation phenology shifts; human population expansion and redistribution; snowpack dynamics.

Adaptation strategy/approach: Maintain connectivity within and through the Greater Yellowstone Area (GYA), including daily, seasonal, dispersal, and range shift connectivity.

Strategy objective: Facilitate transition; engage coordination; increase knowledge

	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Monitor connectivity (genetics, tracking, remote sensing).	Compile table of connectivity (daily through range shift) vulnerability by species.	Identify and remove barriers.
Tactic effectiveness (risks)	Moderate	High	High
Implementation urgency			
Where can tactics be applied? (geographic)	Greater Yellowstone Area	Greater Yellowstone Area	Greater Yellowstone Area
Opportunities for implementation	New technologies (e.g., eDNA, remote cameras, GPS collars) make this more accessible		
Cost			
Barriers to implementation			

Table 9A.13—Adaptation options that address climate change effects on wildlife in the Greater Yellowstone Area subregion.

Sensitivity to climatic variability and change: Moose prefer colder temperatures; increased disease potential in warmer climates; increased algal growth in warmer ponds; precipitation patterns affect growth of preferred vegetation.

Adaptation strategy/approach: Maintain healthy moose habitats (e.g., riparian, aspen, spruce-fir) and populations.

Strategy objective: Reduce stressors; engage coordination.

	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Reduce mortality; coordinate with state agencies to reduce hunting quotas; coordinate to reduce highway mortality.	Increase knowledge and monitoring of disease and pests.	Improve riparian habitat: see beaver sheet.
Tactic effectiveness (risks)	Moderate	Moderate	High
Implementation urgency			
Where can tactics be applied? (geographic)	Greater Yellowstone Area	Greater Yellowstone Area	Greater Yellowstone Area
Opportunities for implementation			
Cost			
Barriers to implementation			

Table 9A.14—Adaptation options that address climate change effects on wildlife in the Greater Yellowstone Area subregion.

Sensitivity to climatic variability and change: Loss of aspen due to warmer, drier climate and lower water table.

Adaptation strategy/approach: Maintain adequate habitat structural diversity to support ruffed grouse populations.

Strategy objective: Promote resilience; increase knowledge.

	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Promote disturbance (fire, cutting) in older aspen stands.	Protect from grazing (fencing, manage grazing).	Reduce conifer competition (fire, cutting) in any age aspen stand.
Tactic effectiveness (risks)	High	High	High
Implementation urgency			
Where can tactics be applied? (geographic)	Greater Yellowstone Area	Greater Yellowstone Area	Greater Yellowstone Area
Opportunities for implementation			
Cost			
Barriers to implementation			

Table 9A.15—Adaptation options that address climate change effects on wildlife in the Greater Yellowstone Area subregion.

Sensitivity to climatic variability and change: Loss of sage and grassland habitat for greater sage-grouse.

Adaptation strategy/approach: Maintain adequate sage grassland communities, with inclusion of mesic meadows (brood rearing), for greater sage grouse.

Strategy objective: Promote resilience, reduce stressors, increase knowledge

	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**	**Specific tactic – D**
Tactic	Manage fire to maintain desired habitat (see sage-grouse conservation strategy).	Control invasive vegetation.	Restore formerly cultivated land.	Limit human disturbance (e.g., grazing, hunting, infrastructure).
Tactic effectiveness (risks)	High	Low to High depending on the invasive species	Low to high depending on site conditions	High
Implementation urgency				
Where can tactics be applied? (geographic)	Greater Yellowstone Area	Greater Yellowstone Area	Greater Yellowstone Area	Greater Yellowstone Area
Opportunities for implementation				
Cost				
Barriers to implementation				

Table 9A.16—Adaptation options that address climate change effects on wildlife in the Western Rockies subregion.

Sensitivity to climatic variability and change: Conversion to nonnatives; change in fire frequency; reduction in cover; change of available forage could affect insects, affecting mountain quail habitat.

Adaptation strategy/approach: Reduce stressors on mountain quail.

Strategy objective: Promote resilience, reduce stressors

	Specific tactic – A	**Specific tactic – B**	**Specific tactic – C**
Tactic	Reduce high-intensity burns using fuel breaks and late winter burning to reduce fuel buildup.	Maintain conifer components, including north face and higher elevation riparian stringers to retain moisture in microsites; replant; protect from burning; avoid harvesting.	Need more information on insect production and the forb component associated with moist areas; how will insects react with phenology changes?
Tactic effectiveness (risks)			
Implementation urgency			
Where can tactics be applied? (geographic)	Western Rockies subregion	Western Rockies subregion	Western Rockies subregion
Opportunities for implementation			
Cost			
Barriers to implementation			