Chapter 8
Effects of Climate Change on Wildlife in the Northern Rockies

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Abstract Few data exist on the direct effects of climatic variability and change on animal species. Therefore, projected climate change effects must be inferred from what is known about habitat characteristics and the autecology of each species. Habitat for mammals, including predators (Canada lynx, fisher, wolverine) and prey (snowshoe hare) that depend on high-elevation, snowy environments, is expected to deteriorate relatively soon if snowpack continues to decrease. Species that are highly dependent on a narrow range of habitat (pygmy rabbit, Brewer's sparrow, greater sage-grouse) will be especially vulnerable if that habitat decreases from increased disturbance (e.g., sagebrush mortality from wildfire). Species that are mobile or respond well to increased disturbance and habitat patchiness (deer, elk) will probably be resilient to a warmer climate in most locations. Some amphibian species (Columbia spotted frog, western toad) may be affected by pathogens (e.g., amphibian chytrid fungus) that are favored by a warmer climate.

Adaptation strategies for wildlife focused on maintaining adequate habitat and healthy wildlife populations, and increasing knowledge of species' needs and climate sensitivities. Connectivity is an important conservation strategy for most species in the Northern Rockies. Maintaining healthy American beaver populations will provide riparian habitat structure and foraging opportunities for multiple species. Quaking aspen habitat, which is also important for several species, can be enhanced by allowing wildfire to burn, protecting aspen from grazing, and reducing conifer encroachment. Restoration of more open stands of ponderosa pine and mixed conifer forest through reduction of stand densities will benefit species such as flammulated owl. Excluding fire and reducing nonnative species will maintain sagebrush habitats that are required by several bird and mammal species.

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8.1 Climate-Wildlife Interactions

Temperature and moisture affect animal physiological response at short time scales via the thin boundary layer immediately above their tissues (Fig. 8.1). If you (a mammal) are wearing dark clothing on a cold, sunny day, sun energy interacts with the dark clothing, creating a warm boundary layer. Conditions beyond that thin boundary layer are physiologically irrelevant. In the shade, the warm boundary layer is replaced with one at the ambient temperature of the air, making you cold. This example demonstrates a number of basic factors that need to be considered when assessing the effects of climate change on animals. Climate is, by definition, the long-term composite of weather, which in turn is the composite of these nearly instantaneous effects in an organism's environment. Climate changes the frequency of weather events, which in turn changes the frequency of fast shifts in boundary layer conditions. But organisms do not directly respond to climate and can seek to optimize changes in climatic conditions through metabolic and behavioral plasticity.

Terrestrial animals can manipulate their environment by standing in the sun or shade, moving uphill or downhill, changing aspect, or seeking cooler/warmer conditions by digging into a burrow or the snow. Endothermic animals change their boundary layer by modifying hair or feathers, seasonally and at much shorter time scales, while minimizing energy expenditure. Endotherms can further regulate their body temperatures by expending energy; changes in climate may be expressed as increased

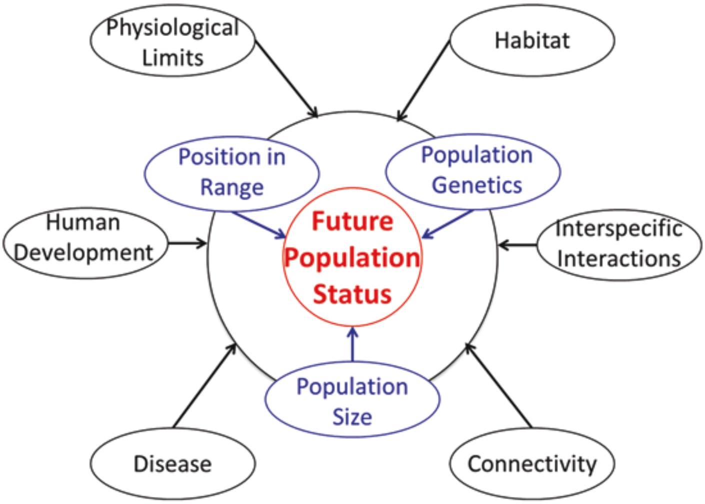

Fig. 8.1 Conceptual diagram of the effects of climate on wildlife populations in the Northern Rockies. Climate pathways (*black*) interact with population characteristics (*blue*) to affect population status (*red*)

metabolic demands. Ectotherms have no ability to regulate their body temperatures through metabolic processes; they are primarily limited to seeking appropriate temperatures by, for example, inhabiting burrows or caves (Box 8.1). It is more difficult for aquatic organisms to avoid adverse temperatures because water conducts heat efficiently, and aquatic ectotherms are particularly vulnerable. Aquatic ectotherms cannot avoid overheating when water temperatures increase, so it is more straightforward to evaluate climate change effects on fish with known warm-water limits (Chap. 4).

Because of their inherent plasticity when faced with changing temperature, terrestrial endotherms are more likely to experience effects associated with changes in precipitation amounts and types, because water produces physical features that serve as habitat. In the Northern Rockies, where winters are cold, snow provides physical habitat for which some animals have specific adaptations, such as a seasonal color change in pelage: white to match snow, brown to match a snowfree background (see discussion of snowshoe hare [*Lepus americanus*] below) (Fig. 8.2).

Box 8.1 How Animals Respond to Temperature: Endotherms vs. Ectotherms

Endotherms (warm-blooded animals) maintain a constant body temperature, and cold or excessive heat requires them to burn more calories to maintain a core temperature, allowing them to function in a wide variety of environmental conditions. Endotherm physiology responds directly to temperature change, and effectiveness and sustainability of physiological response are determined by the quantity and quality of available food.

Ectotherms (cold-blooded animals), which include fish, reptiles, and amphibians, react not by feeling cold and metabolizing energy to maintain core temperature, but by having their metabolism slow until their activity is reduced, in some cases becoming torpid. These basic metabolic differences in vertebrates must be considered in how climate change will interact with animal life history, spatial distribution, habitat quality, and food sources.

Fig. 8.2 Canada lynx diet is dominated by snowshoe hare, which undergoes seasonal pelage change from brown to white. The effectiveness of this strategy depends on synchrony with snow cover (*Left* photo by Milo Burcham, *right* photo by L. Scott Mills)

Table 8.1 Species included in the Northern Rockies Adaptation Partnership vulnerability assessment, summarized by subregion

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					
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	
Ungulates: elk, mule deer, white-tailed deer	X	X	X	X	X

Oversized feet, long legs, and light bone structure also provide benefits in snow-covered landscapes.

Deep snow provides a warm, stable environment at the interface between snow and soil, and soil temperatures can often remain above freezing throughout winter (Edwards et al. 2007). For animals that depend on a stable subnivean environment, or who have specific phenological adaptations to snow, reduced snowpack (Chap. 3) would represent a loss of critical habitat. Similarly, water bodies provide physical habitats with features that provide predator avoidance, temperature control, and sources of food. In addition, open or flowing water can provide important microclimates. For example, American pikas (*Ochotona princeps*) can be found in otherwise hot environments if water flows beneath the talus, producing cool microsites (Millar and Westfall 2010). Seeps, springs, bogs, and persistent streams can integrate longer climatic periods, so altering these features can make species that depend on them vulnerable to climate change (Table 8.1).

Climate effects on terrestrial endotherms will often be a function of changes in plant assemblages that comprise wildlife habitat (Fig. 8.1). For predators, these effects may be either direct (changes in number and location of vegetation boundaries used by predators) or indirect (changes in prey densities or prey availability to predators). If effects are associated with changes in habitat, projecting climate effects on a specific animal species will be difficult, requiring knowledge about the functional roles of ecological attributes in an animal's life history, and consequences associated with different life history strategies. Current behaviors can be studied, but may not be informative about climate change effects, and responses may be novel or difficult to anticipate.

Trophic effects include 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). For many organisms, current ranges are often strongly limited by human activities. For example, the range of greater sage-grouse is limited by conversion of native sagebrush (*Artemisia* spp.) habitat to agricultural uses (Miller and Eddleman 2001). In addition, climate change will alter the nature and location of human activities that affect wildlife. In the western United States, changes in water availability and uses will have major effects on human settlement patterns (Barnett et al. 2005), which will in turn affect habitat.

8.2 Communities and Habitat

Our understanding of wildlife ecology, particularly at broad spatial scales, is generally limited to relationships between occurrence patterns rather than direct studies of limiting factors. Although patterns of occurrence may be clear, consistent, and correlated with climate, causal mechanisms may be difficult to infer. For example, many passerine birds nest only in specific habitats, such as Brewer's sparrow (*Spizella breweri*) which is obligate to sagebrush. The pattern is clear and invariant, but the mechanistic links with sagebrush are unknown. Species such as ruffed grouse (*Bonasa umbellus*) have northern distributions, but limiting factors for its southern distribution are poorly understood (Lowe et al. 2010).

Based on observed patterns of distribution, enough information exists to identify and manage current habitat, but it cannot be assumed that measured correlations will persist in an altered climate. Assume that an animal'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, but in a future landscape, Douglas-fir may be associated with different plant and animal communities. The correlational nature of most habitat data makes it difficult to know which components are critical to habitat quality of a certain species, much less habitat quality of novel species assemblages.

The effects of climate on future habitats are expected to be strongly influenced by altered disturbance regimes. Changing disturbance dynamics (Chap. 7) modify characteristics of landscape patterns across a broad range of spatial scales. If climate change causes shifts in plant and animal distribution and abundance, a temporal mismatch may occur between decreased current habitat and increased new habitat, and will be exacerbated by periodic disturbance. Wildfire can destroy current habitat in a day, but generation of new habitat may require centuries. Fisher (*Pekania pennanti*) provides an example of uncertainties associated with projecting the effects of disturbance. This species is currently limited to mature forests in the Inland Maritime climatic zone of Idaho and Montana, and climate projections indicate that this zone will move to the east. Although climatic conditions to the east may be similar to those in areas occupied by fisher, the habitat associated with mature forest requires a century or more to grow in the projected climate zone, and a projected increase in disturbances may prevent that from occurring (Chap. 7). Therefore, it is unclear whether the projected climate will actually provide fisher habitat.

Because trajectories of species and their habitats under climate change are uncertain, we consider vulnerability assessments for animals as hypotheses to be tested. We assume that proactive management strategies will be used in the future to maintain valued species and landscape attributes, including creating resilience to disturbance. 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.

8.3 Species Sensitivity to Climate Change

A few animal species have received significant attention, generating peer-reviewed articles that analyze the effects of climate change, although this is relatively uncommon. Foden et al. (2013) identified three dimensions associated with climate change vulnerability—sensitivity, exposure, and adaptive capacity—and applied 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. 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), which considers a large number of traits associated with habitat (7 traits), physiology (6 traits), phenology (4 traits), and biotic interactions (5 traits).

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 the relative importance of disparate sources of vulnerability such as habitat and phenology or if estimated vulnerability scores have quantitative meaning (Bagne et al. 2011; Case et al. 2015). For most species, accurately identifying vulnerability (Foden et al. 2013) would be challenging given current biological understanding. Because published data on climate-species relationships are so sparse, we focus on evaluation of each trait as it relates to the biology of specific animal species.

Below are assessments for animal species identified as high priority by U.S. Forest Service Northern Region and national forest resource specialists. 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. Inferences are based on interpretation of the pertinent literature, including empirical data, modeling, and autecology. Level of detail differs greatly among species, proportional to the amount of information available.

*8.3.1 American Beaver (*Castor canadensis*)*

American beavers spend most of the winter in 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. The cost of thermodynamic regulation may be greater for juveniles because they have higher surface area-to-volume ratios than adults (Campbell et al. 2013). In Québec (Canada), beaver density was highest in areas with 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 require ponds, survival and body weight in European beavers has been linked to lower April–September precipitation (Campbell et al. 2012, 2013).

Climate can indirectly influence beavers through effects on vegetation. Climate change and climate-driven changes in streamflow may reduce early-seral tree

Fig. 8.3 Restoration of American beaver populations helps maintain cool water in mountain landscapes. Beavers create structures that help ameliorate the effects of climate change on habitat for cold-water fish species and other aquatic organisms (Photo by E. Himmel, National Park Service)

species in riparian habitats (Perry et al. 2012), thus reducing food and building materials. Beavers can be used to buffer riparian systems from drought, because beaver ponds increase the amount of open water, assisting the conservation of other animals, such as amphibians (Fig. 8.3) (Chaps. 3, 4).

*8.3.2 American Pika (*Ochotona princeps*)*

American pika is a small lagomorph that inhabits rocky alpine areas in western North America (Smith and Weston 1990). Relatively little study of pikas had occurred in the Northern Rockies until recently, with the exception of research on occupancy and abundance in the Bighorn Mountains and Wind River Range (Wyoming) (Yandow 2013). 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). Acute temperature stresses (hot and cold) and vegetation productivity appear to affect pika declines in the Great Basin (Beever et al. 2010, 2011, 2013), reinforcing surveys in Colorado of 4 pika extirpations (of 69 total sites) that occurred at the driest sites (Erb et al. 2011).

Winter snowpack insulates pikas during cold periods and provides water during summer. Surveys in the Sierra Nevada found that pika extirpations were associated with sites with higher maximum temperatures and lower annual precipitation (Millar and Westfall 2010). Individual mountain ranges act as discrete areas without pika migration between adjacent ranges across valley bottoms (Castillo et al. 2014). Connectivity of pika populations appears to be context dependent, with lower connectivity between sites that occur in hotter, drier landscapes (Henry et al. 2012; Castillo et al. 2014). Thus, recolonization may occur at distances less than 0.8 km and in areas where between-population dispersal occurs within cool, moist landscapes.

Studies in the Sierra Nevada (Millar and Westfall 2010) 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 in the near term. 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—illustrates the importance of microclimate for suitable habitat. Because pikas are sensitive to high temperatures, their populations will probably respond to climate change in the Northern Rockies. However, site-specific factors contribute to highly variable microclimates, so response to climate change will probably be minimal and vary over space and time.

*8.3.3 Canada Lynx (*Lynx canadensis*)*

Canada lynx is a mid-sized cat with adaptations that allow it to travel across soft snow, including oversized feet. Canada lynx prey nearly exclusively on snowshoe hare (*Lepus americanus*) (Fig. 8.2), which constitutes 33–100% of its diet (Mowat et al. 2000; Squires and Ruggiero 2007). Snowshoe hares also exhibit seasonal pelage change from brown to white.

Lynx are found exclusively in North America, extending across interior Canada and Alaska and northward into tundra vegetation and southward into high mountain regions in the conterminous United States (McKelvey et al. 2000). In the Northern Rockies, lynx exist in only the Clearwater River watershed, Bob Marshall Wilderness, and northwestern corner of Montana. 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), especially where disturbance processes are expected to increase.

In the Northern Rockies, 80% of dens are in mature forest and 13% in mid-seral regenerating stands (Squires et al. 2008). For winter foraging, lynx forage in mature, multilayer spruce-fir forests composed of large diameter trees with high horizontal cover, abundant snowshoe hares, and deep snow (Squires et al. 2010). Lynx select home ranges with vegetative conditions consistent with those identified for foraging and denning (Squires et al. 2013). The range of snowshoe hare is more extensive than that of lynx, extending into the mid Sierra Nevada and areas such as the Olympic Peninsula (McKelvey et al. 2000). The more extensive hare distribution, which includes areas with limited snow (e.g., the Pacific coast), is likely associated with greater genetic differentiation in snowshoe hares compared to lynx.

Variation in timing of pelage change in snowshoe hares is low in any specific location, and timing appears to be genetically controlled and linked to photoperiod (Zimova et al. 2014). Timing of pelage change is critical, because mismatches—a white hare on a dark background and vice versa—make hares susceptible to predation (Hodges 2000) (Fig. 8.2), and the ability of hares to shift timing of pelage change to match snow patterns is limited. Unless a significant change occurs in the population genetics of hares, they will be the wrong color for approximately 2 months per year in the Northern Rockies (Mills et al. 2013). Both lynx and hares require specific amounts and duration of winter snow (McKelvey et al. 2000; Schwartz et al. 2004), and in western Montana, lynx and hares use older spruce-fir forests. If climate change and associated disturbance reduce the abundance of these forests, populations of both lynx and hares could decline significantly.

*8.3.4 Fisher (*Pekania pennanti*)*

The fisher is a mid-sized, forest-dwelling mustelid whose range 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. Fishers are often associated with urban environments in the eastern United States, but this is uncommon in the West where fishers are associated with very specific habitats and populations are disjunct. Common attributes for resting sites for western fisher are steep slopes, cool microclimates, dense forest canopy cover, high volume of logs, and prevalence of large trees and snags (Aubry et al. 2013).

In the West, fishers are associated with specific habitat conditions, especially forested areas with low monthly snowfall (<13 cm) (Krohn et al. 1995), and appear to avoid both deep snowpack (Raine 1983) and dry habitats (Schwartz et al. 2013). In the Northern Rockies, fisher habitat is best in areas with high annual precipitation, low relief, and mid-range values for mean temperature in the coldest month (Olson et al. 2014). In the near term, habitat currently occupied by fisher might improve in areas that are currently occupied (primarily central Idaho) but quality will decline sharply by 2090, and new habitat may be created in northwestern Montana (Olson et al. 2014).

Given that fishers are associated with mature forests, long time lags may exist between the loss of current habitat and formation of new habitat in areas that are currently 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. Projections in Olson et al. (2014) provide an optimistic view of habitat availability under climate change, especially because it is uncertain if fisher would disperse into new habitat if and when it occurs.

*8.3.5 Moose (*Alces alces*)*

Moose is an example of a well-studied animal that has a northern distribution but whose dependency on boreal environments may not be obvious. The distribution of moose is limited by food supply, climate, and habitat (Murray et al. 2006, 2012). The species is intolerant of heat, but well adapted to cold; high summer temperatures increase metabolism and heart and respiration rates, and reduce body weight (Renecker and Hudson 1986). These temperature thresholds represent physiological thresholds that, when exceeded, represent heat stress that increases the energy expenditure needed to stay cool.

Because of the behavioral plasticity discussed above, moose may be able to avoid being exposed to high mid-day 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. In northern Minnesota, moose populations were not viable, largely because of disease and parasite-related mortality (Murray et al. 2006). However, in nearby southern Ontario (Canada), moose populations had favorable growth rates (Murray et al. 2012). Warming temperatures favor white-tailed deer (*Odocoileus virginianus*) expansion into moose range, creating the potential for increased transmission of deer parasites to moose (Lankester 2010). For moose, separating direct and indirect climate effects is difficult.

*8.3.6 Northern Bog Lemming (*Synaptomys borealis*)*

The northern bog lemming inhabits wet meadows, bogs, and fens within several overstory habitat types (Foresman 2012), typically with extensive sphagnum (*Sphagnum* spp.), willow (*Salix* spp.), or sedge. Given their dependence on wet habitats, it follows that climate changes that decrease the amount of surface water will have negative impacts on lemmings. Therefore, management practices that maintain surface water may be beneficial, although documented studies of climate and management effects are lacking.

*8.3.7 Pronghorn (*Antilocapra americana*)*

The pronghorn (*Antilocapra americana*) is an ungulate native to the prairies, shrublands, and deserts of the western United States, occupying a broad range of climatic conditions from southern Canada to Mexico. Pronghorns 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.

*8.3.8 Pygmy Rabbit (*Brachylagus idahoensis*)*

The pygmy rabbit is one of the smallest leporids in the world and is endemic to big sagebrush (*Artemisia tridentata*), which provides food and cover. In southeastern Idaho, pygmy rabbits were associated with higher woody cover and height than other areas, with fewer grasses and more forbs. Sagebrush was 51% of summer diet and 99% of winter diet (Green and Flinders 1980). Areas used by pygmy rabbits accumulate relatively high snowpack, and rabbits use the subnivean environment to access food and avoid predators. 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).

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 decreased in density with proximity (<100 m) to edges. Big sagebrush is sensitive to fire, and 100% mortality and stand replacement after burning are common (Davies et al. 2011; Chap. 6). Recruitment of mountain big sagebrush (*A. tridentata* ssp. *vaseyana*) relies on wind dispersal of seeds from adjacent seed sources and on composition of the soil seed bank. Mountain big sagebrush required 13–27 years after spring prescribed burning to return to conditions suitable for pygmy rabbit habitat (Woods et al. 2013).

Climatic variability has affected sagebrush communities and pygmy rabbits in the past (Grayson 2000), and this will probably happen again in the future. First, pygmy rabbits depend on a single species (sagebrush) and habitat condition (tall, dense stands). Second, pygmy rabbit habitat is sensitive to altered disturbance, especially wildfire. Finally, changes in winter snow depth could affect overwinter survival by altering protection provided by the subnivean environment.

*8.3.9 Townsend's Big-Eared Bat (***Corynorhinus townsendii***)*

Climate change can affect foraging, drinking water availability, and timing of hibernation in bats (Sherwin et al. 2013). Townsend's big-eared bats generally require caves for diurnal, maternal, and hibernation roosting, although they also use large tree cavities, buildings, and bridges and forage for insects along riparian and forest edge habitats (Fellers and Pierson 2002). This species does not produce concentrated urine and therefore requires daily access to water sources (Gruver and Keinath 2003).

Bioaccumulation of pesticides in fat tissue is one cause of declines in Townsend's big-eared bat populations (Clark 1988). Bats are especially sensitive to human disturbance during hibernation. In Colorado, reproductive success of *Myotis* spp. decreased during warm, dry conditions (Adams 2010), although warmer spring temperatures have led to earlier births and higher juvenile survival (Lucan et al. 2013). Higher summer precipitation may reduce reproductive success, and increased warming may reduce effectiveness of some bat echolocation calls (Luo et al. 2014).

8.3.10 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*) have broad ranges in North America, indicating a high degree of habitat flexibility. Habitat use by elk in forested areas is associated with edges that contain high quality forage and nearby forest cover. In open habitats, they select areas of high vegetative diversity with intermixed patches of shrubs and grasslands (Sawyer et al. 2007). Both types of habitat are favored by disturbances with spatial heterogeneity at fine scales.

Mule deer have larger home range sizes in areas with few large patches and smaller sizes in fine-grained vegetation mosaics (Kie et al. 2002). Fine-grained disturbance mosaics are optimal for white-tailed deer, especially in areas where thermal cover is important. In the Northern Rockies, thermal cover prevents heat loss

Fig. 8.4 Ungulates generally respond positively to wildfires that create patchy habitat with improved forage, as shown in this photo of an elk browsing in a recently burned lodgepole pine forest (Photo by Jeff Henry, National Park Service)

during winter, although in warmer climates, thermal cover reduces daytime heating.

Ungulates respond positively to disturbance, with wildfire intensity affecting both species composition and patchiness in the postfire landscape (Fig. 8.4). Vegetation growth after disturbance is especially 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. For example, in the Greater Yellowstone Area subregion, if climate change causes more frequent fires, then the landscape will be patchier compared to the current condition, and the distribution and abundance of forest species could change. In the long term, the effects of altered vegetation on ungulate populations are uncertain, and it is likely that there will be both positive and negative consequences.

*8.3.11 Wolverine (*Gulo gulo*)*

The wolverine 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. Wolverines den in snow, with deep snow throughout the denning period being essential (Magoun and Copeland 1998). A proxy for spring snowpack (areas where snow persisted through mid May) effectively describes den site selection, current range limits, and year-around habitat use at the southern periphery of their range (Copeland et al. 2010). Because wolverines travel within these same areas when dispersing and minimize travel through low-elevation habitat (Schwartz et al. 2009), it is possible to project 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, projecting changes in wolverine habitat and connectivity associated with future landscapes. In the Columbia and Upper Missouri River Basins, snowpack was projected to decrease 35% and 24%, respectively, for spring snow by the mid-twenty-first century, and 66% and 51%, 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). A connectivity model (Schwartz et al. 2009) in conjunction with ensemble climate model projections indicated that all remaining habitat blocks would likely be genetically isolated by the end of the twenty-first century (McKelvey et al. 2011). A continuing reduction in spring snow, a pattern that has been ongoing since the 1950s (Mote et al. 2005), will reduce the amount of suitable habitat for wolverines.

*8.3.12 Brewer's Sparrow (***Spizella breweri***)*

Brewer's sparrow is a sagebrush obligate during the nesting period, preferring tall, dense stands of sagebrush (Fig. 8.5). In many areas, Brewer's sparrows are the most abundant bird species (Norvell et al. 2014). The obligate relationship of Brewer's sparrow with sagebrush lacks causal explanations (Petersen and Best 1985). Therefore, correlative associations can be used to project climate change effects, but

Fig. 8.5 Sagebrush-obligate species such as Brewer's sparrow (shown here) may have less nesting habitat in the future if the extent of mature sagebrush habitat is reduced by wildfire (Photo by Paul Higgins, www.utahbirds.org)

we cannot speculate on the flexibility of this species to shift to other shrub species. Brewer's sparrows exhibit some flexibility in nesting locations, shifting sequential nests in response to previous predation (Chalfoun and Martin 2010).

Brewer's sparrow populations appear stable range-wide, although they have been in decline in some areas in Colorado (USGS 2013). Although Brewer's sparrows select 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). In general, the effects of climate change on Brewer's sparrows will depend on changes in the distribution, abundance, composition, and structure of sagebrush communities. Increased wildfire is expected to reduce the distribution, abundance, and age of sagebrush stands in a warmer climate.

*8.3.13 Flammulated Owl (***Otus flammeolus***)*

The flammulated owl is a small nocturnal owl that is migratory but breeds in montane areas across much of western North America. A cavity nester associated with mature forests with large diameter trees, it is also associated with open forests composed of multiple tree species. This species is thought to be an obligate secondary cavity nester, although it has been anecdotally observed to nest in the ground (Smucker and Marks 2013). Flammulated owls feed almost exclusively on insects, primarily Lepidoptera (Linkhart et al. 1998). During the nesting period, males are single-trip, central-place foragers, so the energetics of prey selection are important, with distance traveled and energy content of prey differing by forest type.

The extensive latitudinal range of flammulated owls, lack of specific forest associations, and generalized insect diets provide few clues about sensitivity to a warmer climate. Potential effects of climate change would most likely be through disturbance processes that remove large diameter trees. Shifts to denser forest structure would be a concern, but this is unlikely because drought and wildfire are projected to increase throughout the Northern Rockies (Chap. 5). Like other long-lived owl species, flammulated owls will require a high rate of adult survival to persist in future habitats (Noon and Biles 1990).

*8.3.14 Greater Sage-Grouse (***Centrocercus urophasianus***)*

The greater sage-grouse is the largest grouse in North America (Mezquida et al. 2006). An obligate with sagebrush habitat, its current distribution is about half of its pre-settlement range (Schroeder et al. 2004), and many populations have been steadily declining in recent decades (Connelly and Braun 1997). Declines in sage-grouse in areas still dominated by sagebrush have been attributed to sagebrush removal through land conversion, nonnative plants (Wisdom et al. 2002), energy exploration and extraction (Braun et al. 2002), grazing (Beck and Mitchell 2000), and altered fire regimes (Connelly et al. 2000). West Nile virus has also been a stressor (Naugle et al. 2004).

A recent climate change assessment for greater sage-grouse concluded that the cumulative effects of projected climate change on sagebrush and West Nile virus transmission would reduce suitable sage-grouse habitat in the Northern Rockies and northern Great Plains (Schrag et al. 2011). Because sage-grouse require large areas of mature sagebrush, future increases in wildfire are expected to significantly reduce habitat. Another assessment, focused on southeastern Oregon, concluded that in the near term, loss of sagebrush from wildfire and cheatgrass (*Bromus tectorum*) invasion will lead to habitat deterioration in future decades (Creutzburg et al. 2015). However, the same study also projected that native shrub-steppe communities would increase by around 2070, leading to habitat improvement.

*8.3.15 Harlequin Duck (***Histrionicus histrionicus***)*

Harlequin ducks in the intermountain West breed and summer on fast-flowing mountain streams and winter on rocky coastal areas. 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. In Glacier National Park, harlequin duck reproductive success declined with higher and less predictable streamflows (Hansen 2014), conditions that are expected to be more common in a warmer climate (Chap. 3).

*8.3.16 Mountain Quail (***Oreortyx pictus***)*

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. In the northwestern United States, its range extends into deep canyons such as Hells Canyon of the Snake River, where populations have been declining (Pope and Crawford 2004). Population studies have focused on survival, but connections to climate-related change are minimal. Climate-related variables are, however, important to survival, with lower survival being linked to both hot, dry conditions and cold winter weather (Stephenson et al. 2011).

*8.3.17 Pygmy Nuthatch (***Sitta pygmaea***)*

The pygmy nuthatch, a tiny bird found throughout western North America, is a cavity nester, often associated with ponderosa pine forests, but also found in other forest types such as quaking aspen (*Populus tremuloides*). 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).

The pygmy nuthatch nests in cavities in both live and dead trees, and population responses to disturbance are modest. For example, population densities across a variety of thinning and fuel treatments remained constant except in thin-and-burn treatments, where densities increased over 500% (Hurteau et al. 2008). In another study, nuthatches showed a negative response one year after wildfire, but a neutral response in subsequent years (Saab et al. 2007). Given its apparent neutral response to disturbance, flexibility in habitat, and wide latitudinal range, it is difficult to project whether pygmy nuthatch will respond positively or negatively to climate change. Conversion of forest to non-forest can reduce habitat, but climate change is unlikely to cause significant population reductions.

*8.3.18 Ruffed Grouse (***Bonasa umbellus***)*

The ruffed grouse has a primarily boreal distribution that includes peninsular extensions into the Rocky Mountains and Appalachian Mountains. Ruffed grouse are commonly found in aspen forest, which provides important food sources (Stauffer and Peterson 1985), and 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. Although higher temperature is 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 leads to decreased extent of aspen in the Northern Rockies, reduced habitat would have detrimental effects on ruffed grouse populations. Fortunately, good options exist to mitigate these changes through silviculture that favors aspen over conifers, and through active manipulation of stand densities and ages.

*8.3.19 Columbia Spotted Frog (***Rana luteiventris***)*

Columbia spotted frogs breed in montane ponds throughout western North America. The effects of climate change on these frogs are unclear. In Utah, they were 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), and throughout their range, populations in large stable water bodies were healthy, whereas those in 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 persistent water supplies, and are capable of rapid population expansion into restored wetlands (Hossack et al. 2013). However, the amphibian chytrid fungus (*Batrachochytrium dendrobatidis*, or Bd), is prevalent in many populations (Russell et al. 2010), and warmer water would favor Bd in most systems (see section on western toad below). Although the fungus is common, the population-level effects of infection are unclear.

*8.3.20 Western Toad (*Anaxyrus boreas*)*

The western toad is a montane amphibian broadly distributed across the western United States; in the southern Rocky Mountains, the subspecies boreal toad (*A. b. boreas*) is recognized. Western toads have declined in some locations, particularly at the southern extent of their range (Corn et al. 2005). This species suffers from Bd, which is often fatal. Laboratory studies of Bd have found that it grows optimally at 17–25 °C, and colonies are killed at 30 °C (Piotrowski et al. 2004). Although Bd can grow in temperatures as cold as 4 °C, warmer water 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, low-elevation sites (Muths et al. 2008). A warmer climate may allow Bd to spread to higher elevations and become even more widespread, although the susceptibility of western toads is uncertain, because increased mortality is not always associated with high infection rates.

8.4 Adapting Wildlife and Wildlife Management to Climate Change

Adaptation to climate change for wildlife resources in the Northern Rockies focused on maintaining adequate habitat and healthy wildlife populations, and increasing knowledge of species needs and climate sensitivities. In each workshop conducted by the Northern Rockies Adaptation Partnership (Chap. 1), participants identified major habitats in their subregion, then developed adaptation strategies for species they regarded as important and for which they believed viable management options exist. Here, we summarize adaptation options according to major habitats.

Riparian habitats are important across the Northern Rockies. The primary strategy for improving riparian habitat resilience is maintaining healthy American beaver populations. Beaver complexes can buffer riparian systems against low and high streamflows, and provide habitat structure and foraging opportunities for multiple species.

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 Greater Yellowstone Area, ruffed grouse was identified as strongly tied to aspen habitats. Reduced distribution and abundance of aspen is projected for some locations (especially lower elevation) in a warmer climate (Chap. 5). The most common tactics for promoting aspen resilience are allowing wildfire to burn or using prescribed fire in older aspen stands, protection from grazing, and reducing conifer encroachment in stands of any age.

Dry ponderosa pine forests are common in the Central Rockies and Eastern Rockies subregions, providing habitat for cavity-nesting birds such as the flammulated owl. These habitats have experienced encroachment by Douglas-fir as a result of fire exclusion, increasing vulnerability of pine to future fires. Tactics for promoting ponderosa pine resilience include reducing competition from Douglas-fir through understory burning and cutting, protecting mature stands, and planting ponderosa pine where it is no longer common.

The Western Rockies and Central Rockies subregions support *older, mesic forests* because they experience a maritime climate influence. These forests, which provide habitat for fisher, may have younger age classes (caused by increased disturbance; Chap. 7) and different species composition in a warmer climate (Chap. 5). Adaptation strategies include restoring historical structure, conserving current structure, and promoting potential future mesic forest habitats.

Mountain sagebrush-grassland habitat occurs in all subregions except the Grassland. In the Western Rockies subregion, these habitats have less of a sagebrush component, occur in steep mountain canyons, and support populations of mountain quail. In a warmer climate, these habitats could lose some of their forb component, making them vulnerable to increased abundance of nonnative species (Chap. 6). Specific tactics for restoring historical habitat and maintaining current habitat include assertively reducing sagebrush mortality from fire, controlling nonnative species, and restoring formerly cultivated lands.

Sagebrush habitats are common in the Eastern Rockies, Greater Yellowstone Area, and Grassland subregions, supporting greater sage-grouse, Brewer's sparrow, greater prairie chicken [*Tympanuchus cupido*], sharp-tailed grouse [*T. phasianellus*) and pygmy rabbit, among other species. Tactics for maintaining adequate sagebrush habitat include reducing sagebrush mortality from fire, controlling nonnative species, preventing fragmentation, and restoring degraded habitat. 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.

In all subregions, independent of specific habitats, *a better understanding of species requirements and mechanisms of climate change effects* is needed. In addition, connectivity and the potential for disease may affect multiple habitats and species, although climate sensitivities of diseases are not well understood. There was wide agreement on the need to better understand the mechanisms of climate sensitivities relative to 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 following fire. The influence of low-snow years on wolverine denning success is an example of a mechanistic relationship with climate that needs more data.

Connectivity was considered an important conservation strategy for most species in the Northern Rockies, although climate influences on connectivity are uncertain. 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 that would improve maintenance of connectivity include monitoring with genetic, tracking, and remote-sensing tools; identifying dispersal habitats; and identifying and removing barriers to connectivity.

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, monitoring disease trends in moose, and coordinating with state agencies to monitor West Nile virus.

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