Humboldt - Toiyabe National Forest Climate Change Vulnerability Report April 2011

"To understand the dynamics of Great Basin woodlands, knowledge of their development is necessary. At the core of current and historic woodland development is climate."

Dr. Robin Tausch, USDA FS, Rocky Mountain Research Station Supervisory Range Scientist

The Past

Through research on woodrat middens and pollen deposition records, scientists have been able to examine changes in vegetation from the late Pleistocene (the last epoch of glacial activity) through the Holocene (11,000 years ago to present time – a period of post-glacial climate stabilization and warming). Past vegetation changes associated with climate variation provide a basis for predicting future risks associated with current climate change and a growing human interaction with natural processes. The following is a short summary of climate changes and associated biological adjustments that have occurred.

"An understanding of why species remained in place during past climatic variations will improve our ability to evaluate the scale of vegetation changes likely to occur with future ecological or environmental changes,"

---Cheryl L. Nowak, Robert S. Nowak, Robin J. Tausch and Peter E. Wigand – 1994 Journal of Vegetation Science

Late Pleistocene – Approximately 25,000 to 11,000 years ago – Cold, moist conditions prevailed. Lakes and marshes, often connected by rivers were abundant in valley bottoms throughout the Great Basin. The vegetation had a fairly high diversity of herbaceous and woody species due to the presence of adequate moisture and warming conditions. Pinyon pine was mostly absent from the Great Basin and juniper was infrequent. Mesic conifers were present mostly in savanna's rather than dense stands. Fir, spruce and pine were found at elevations roughly 3000 to 6000 feet lower than present time. Toward the end of this time period, the large mammals of the Great Basin began to disappear with the warmer, drier climate (Nowack et al. 1994, Grayson 1993).

Early to Mid-Holocene – Approximately 11,000 to 5,500 years ago – Temperatures continued to warm and the climate became drier. The warmest and driest portion of the Holocene occurred from about 8,000 to 5,000 years ago. The suite of vegetative species began to look much like what we see today with sagebrush and other desert shrubs as well as bunchgrasses and forbs becoming dominant. Juniper dominated woodlands moved northward and upslope. Pinyon pine began its northward migration from refugia in the Mohave Desert through the Great Basin. Although the large Pleistocene lakes were gone, many Great Basin valleys supported marshes. Subalpine conifers began moving up the mountains in elevation, with pockets remaining in suitable habitats on the valley floors (Nowack et al. 1994, Grayson 1993).

Holocene Neoglacial – Approximately 5,500 to 2,500 years ago – A gradual increase in moisture and cooler temperatures created an increase in herbaceous grasslands and a decrease in desert shrubs. Pinyon pine and juniper continued to move north and pinyon pine populations expanded and became co-dominant with juniper in woodlands. Due to the increase in herbaceous vegetation, and possibly increased lightning storms and human activities, fire activity increased (Nowack et al.1994). During the neoglacial time period, the valley floors in upland watersheds were relatively stable (Chambers and Miller 2004, chapter 4).

Holocene Drought – Approximately 2,500 to 550 years ago – A significant drop in precipitation occurred about 2,500 years ago and temperatures which initially remained cool began to warm. Winters tended to be mild and precipitation shifted from mostly winter occurrence to spring and summer. Desert shrubs increased in dominance and pinyon pine and juniper decreased. The Fremont Indians were able to farm during this time period, but toward the end of the drought, their farming culture was abandoned in the Great Basin. The latter part of this cycle was very dry and temperatures began to cool again. Fire was more frequent, possibly due to drier conditions or the result of human manipulation of vegetation (Nowack et al. 1994).

During the Holocene Drought (1900 to 2500 YBP), there was a decline in vegetative cover due to lower precipitation, warmer temperatures, and an increase in wildfires, which resulted in significant sediment deposition in valley bottoms and in alluvial fans and stream incision (Chambers and Miller 2004, chapter 4). During this drought, most of the available sediments were stripped from the hillslopes and deposited on the valley floors and on side-valley alluvial fans (Chambers and Miller 2004, chapter 3). As a consequence of this hillslope erosion, streams are now sediment limited and have a natural tendency to incise (Chambers and Miller 2004, chapter 9).

Holocene Little Ice Age – Approximately 550 to 160 years ago – Cooling temperatures and increase precipitation resulted in glacial activity in many of the mountain ranges. The spring and summer growing seasons became shorter. The climate favored an expansion in the range of pinyon and juniper. Although the woodlands expanded, the tree densities remained lower than the densities we see now. Shrub and herbaceous communities were more prevalent than woodlands, possibly due to a somewhat higher occurrence of fires during dry periods. European settlers began exploring and later establishing agricultural, mining and trading based industries in the Great Basin (Nowack et al. 1994). Holocene drought erosion processes that created side-valley alluvial fans, continued to influence the stream channel, water table, and the location and stability of meadows (Chambers and Miller 2004, chapter 4).

Post Little Ice Age – 160 years ago to Present – The Native American culture of hunting and gathering and vegetation manipulation by fire slowly diminished. The climate began to warm and the presence of European settlers altered the existing ecological processes. The Great Basin had fluctuating populations of grazing animals such as deer, antelope, bighorn sheep and in the north, a scattering of elk. Europeans brought livestock to the Great Basin, and some of the heaviest grazing occurred within the first 100 years of settlement. Heavy grazing, along with fire suppression, farming and water diversions changed the landscape. Woodlands expanded and tree densities increased. Wildlife populations altered their yearly migrations and changed foraging habitats. The scattered riparian areas across the Great Basin were impacted by heavy livestock grazing and water development for farming and to support growing communities. Soil erosion increased, where vegetative cover was reduced (Nowack et al. 1994). In some cases, stream incision resulting from climatic shifts has been accelerated by anthropogenic disturbances (Chambers et al 1998; chapter 3).

> ***"The conservation of natural resources is the fundamental problem. Unless we solve that problem it will avail us little to solve all others."***
> Theodore Roosevelt, Address to the Deep Waterway Convention, Memphis, TN, October 4, 1907

The Present

It is difficult, if not impossible, to separate the changes brought by increased human presence and changes associated with temporal climate variation. The complexity of biological and physical processes occurring on Earth makes it difficult to attribute human activities such as intense agriculture, industrial manufacturing, urbanization and water displacement to specific changes in climate. Irrespective of the exact causes, the climate is changing, and as federal land managers, we need to assess our options and adjust land uses to minimize the impacts.

> ***"Climate change is expected to have significant impacts on the Great Basin by the mid-21st century."***
> Dr. Jeanne C. Chambers, Research Scientist, Rocky Mountain Research Station

Evidence of climate changes occurring over a very short period of time:

In the last 100 years, the region warmed by 0.5 to 1.5°C (1 to 3°F) and is projected to warm another 3.6 to 9°F (2 to 5°C) by the end of the century (Chambers and Pellant 2008).

Since about 1980, western U.S. winter temperatures have been consistently higher than long-term values and average winter snow packs have declined. Periods of higher than average precipitation have helped to offset the declining snow packs (McCabe and Wolock 2009).

Winter temperatures are increasing more rapidly than summer temperatures, particularly in the northern hemisphere, and there has been an increase in the length of the frost-free period in mid- and high-latitude regions of both hemispheres (Loehman 2010).

The onset of snow runoff in the Great Basin is currently 10–15 days earlier than 50 years ago, with significant impacts on the downstream utilization of this water (Ryan et al. 2008).

Annual precipitation (in the Northwestern and Intermountain regions) increased by 10% on average, and by as much as 30–40% in some areas (Chambers and Pellant 2008). Future precipitation is the most difficult to predict with existing Global Circulation Models. However, higher temperatures will increase evapotransporation, the Palmer Drought is predicted to increase, and the region will likely become more arid (Chambers 2011).

Since 1986, the lengthof the active wildfire season has increased by 78 days and the average burn duration of large fires has increased from 7.5 days to 37.1 days. Forest wildfire frequency is nearly four times higher and the total area burned by these fires is more than six and a half times it's previous levels.

Roughly half of the increase was due to earlier ignitions and half to later control (48% versus 52%, respectively) (Westerling et al 2008).

Spring events have been advancing by an average 2.8–3.2 days per decade. Species' range boundaries have shifted polewards with a mean velocity of 6 km per decade, as well as upward in elevation (Parmesan et al. 2011).

Greenhouse gases and climate change:

Greenhouse gases and particles in the upper atmosphere intensify warming trends, by reflecting heat back down to the Earth's surface. The term "greenhouse" is a modifier for gases and particles that trap solar energy and recycle it as heat. While this is good for growing greenhouse plants, it has huge impacts for native species not accustomed to long, warm seasons, early snowmelt and higher evapotransporation. The most widely studied greenhouse gas is carbon dioxide, but there are many others whose effects have been amplified through human activities.

Global-average CO2 concentrations have been observed to increase from levels of around 280 parts per million (ppm) in the mid-19th century to around 388 ppm by the end of 2009. CO2 concentrations can be measured in "ancient air" trapped in bubbles in ice, deep below the surface in Antarctica and Greenland; these show that present-day concentrations are higher than any that have been observed in the past 800,000 years, when CO2 varied between about 180 and 300 ppm. Various lines of evidence point strongly to human activity being the main reason for the recent increase, mainly due to the burning of fossil fuels (coal, oil, gas) with smaller contributions from land-use changes and cement manufacture. The evidence includes the consistency between calculations of the emitted CO2 and that expected to have accumulated in the atmosphere, the analysis of the proportions of different CO2 isotopes, and the amount of oxygen in the air (National Research Council).

> ***"Climate is a fundamental architect of ecosystem change."***
>
> Dr. Constance Millar, USDA Forest Service, Pacific Southwest Research Station

These observations show that about half of the CO2 emitted by human activity since the industrial revolution has remained in the atmosphere. The remainder has been taken up by the oceans, soils and plants although the exact amount going to each of these individually is less well known (National Research Council).

Concentrations of many other greenhouse gases have increased. The concentration of methane has more than doubled in the past 150 years; this recent and rapid increase is unprecedented in the 800,000 year record and evidence strongly suggests that it arises mainly as a result of human activity.

Current models do not account for nitrogen processing, and probably exaggerate the terrestrial ecosystem's potential to slow atmospheric carbon dioxide rise. These models of the carbon cycle have failed to take into account how nitrogen availability influences this equation on the global scale. Nitrogen is vital to carbon dioxide uptake in plants, and if the available nitrogen runs out, the plants won't be able to make use of the added CO2 (Univ. of Illinois 2007).

Biological changes that coincide with climatic changes:

Approximately 20% of the sagebrush ecosystem's native flora and fauna are considered imperiled, and many sagebrush-associated species are declining in numbers (Wisdom et al. 2005).

Altered disturbance regimes and climate change have resulted in major changes in plant community composition. Since the 1860s, many bunchgrass and sagebrush–bunchgrass communities, which dominated the Intermountain West, have shifted to pinyon and juniper woodland or introduced annual-dominated communities (Miller and Tausch 2000).

Many ranges have had domestic stock grazing for more than 100 years and, as a result, the plant species composition has changed greatly from that of the original ecosystems. Western rangelands previously dominated by perennial bunchgrasses have been converted, primarily through overgrazing, to annual grasslands that are susceptible to invasion by introduced forbs (Tomasa 2000).

Excessive livestock grazing and loitering in riparian meadows and woodlands has resulted in loss of vegetative cover, compaction of soils, erosion and lowering of the water table.

Since the 1860s, many bunchgrass and sagebrush–bunchgrass communities, which dominated the Intermountain West, have shifted to pinyon and juniper woodland or introduced annual-dominated communities. Concerns related to these changes in community composition are increased soil erosion changes in soil fertility, losses in forage production, changes in wildlife habitat, and alteration of pre-settlement plant communities (Miller and Tausch 2000).

Tree expansion over the last 150 years has set up the conditions for the possible decline in woodland area from large fires over the next 150 years (Tausch 1999). Pinyon and juniper communities are associated with cold desert shrub communities. The successional patterns and restoration potential of areas dominated by trees is determined by the shrub communities with which they are associated (Chambers 2011).

Introduction of more than 50 nonnative fish and invertebrate species by the public or fishery management agencies, coupled with habitat loss, have caused multiple species extinctions of native fish and invertebrates since the late 1800s (Sada and Vinyard 2002).

The negative effects of introducing elk into native ecosystems were not foreseen, and now elk are abundant in Central Nevada, and impacting aspen and high elevation habitats through removal of bark, selective foraging and wallowing in fragile ecosystems.

"If Homo sapiens is to survive, we have to understand and accept humans role in changing their environment."

Dr. Thad Box, Rangeland Scientist and Columnist for Society for Range Management

A consistent temperature-related shift has been observed across a broad range of plant and animal species (80% of species from 143 studies), including changes in species density, northward or poleward range shifts, changes in phenology, and shifts in genetic frequencies (Root et al. 2003).

Rapid expansion of invasive species can be attributed to ongoing perturbations resulting from elevated CO2 and N deposition, past and present land uses, and the direct and indirect effects of climate change (Chambers and Pellant 2008).

Many upland stream systems are in an incisional phase due to past climate changes. Anthropogenic disturbances, including overgrazing by livestock and road construction within riparian corridors, have adversely affected the ecological condition of these ecosystems and increased the rate and magnitude of stream incision (Chambers and Miller 2004).

In the Great Basin of the western United States, 7 out of 25 recensused populations of the pika (*Ochotona princeps*, Lagomorpha) were extinct since being recorded in the 1930s. Human disturbance is minimal because pika habitat is high-elevation talus (scree) slopes, which are not suitable for ranching or recreational activities. Extinct populations were at significantly lower elevations than those still present (Parmesan 2006).

Warming trends have been associated with longer seasonal survival in spruce beetle and mountain pine beetle and the fungi and nematodes that are carried by the beetles. Insects and disease along with drought and higher temperatures has impacted conifers in the western United States.

"The evidence indicates that only 30 years of warmer temperatures at the end of the twentieth century have affected the phenology of organisms, the range and distribution of species, and the composition and dynamics of communities."

Gian-Reto Waltherand others 2002

Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.
(IPCC 2007:883)

Montane meadows in the Sierra Nevada of California have experienced dramatic expansion of shrubs (*Artemisia rothrockii*) and reduction in herbaceous species cover since the introduction of livestock in the late 1800s. Increases in meadow aridity due to livestock use have been proposed as the primary factor facilitating sagebrush dominance in these areas (Berlow et al. 2002).

In the central Great Basin stream incision associated and current land uses are resulting in lowered water tables and an expansion of shrubs (*Artemisia* species) into meadow complexes (Wright and Chambers 2002). Where it occurs, stream incision is likely having similar effects in the Sierras (Chambers 2011). Repeated riparian monitoring studies in meadows in the Sierra's have shown an increase in silver sagebrush (*Artemisia cana*) and a shift toward more mesic species since the 1960's (Humboldt-Toiyabe NF data files).

In contrast with historical responses and migration processes, species in many areas today must move through a landscape that human activity has rendered increasingly impassable. As a result of the widespread loss and fragmentation of habitats, many areas which may become climatically suitable with future warming are remote from current distributions, and beyond the dispersal capacity of many species (Waklther et al. 2002).

Humboldt-Toiyabe National Forest Vulnerabilities:

High Elevation Ecosystems:

High elevation trees, such as whitebark pine, require a long cold stratification to prepare the seeds for germination (Bower et.al. 2011). Shorter winters will likely reduce seed germination in alpine and subalpine trees. Longer frost-free season and warmer temperatures will allow insects and disease to survive during mild winters and increase tree infestations and infections and cause greater mortality. Loss of whitebark pines and other high elevation conifers will affect the birds and mammals that depend on them for food and shelter (USDA 2011).

High elevation mammals, such as pika, are intolerant of warm temperatures. Pikas are not only at risk from overheating, but their food sources are also at risk from higher temperatures and early snowmelt. Pikas depend on the plant materials they gather in haystacks in the summer and retrieve from under the snow in the winter.

Some of the plants the pikas gather are poisonous, but have chemical properties that help preserve the nutrient quality of the whole haystack. The poisons in these plants leach out with freezing and moisture providing a stable winter forage. The plants gathered by pika and the stability of their storage are threatened by high temperatures and loss of forage plants.

Changes in the winter climate can expose alpine and subalpine plants and seeds to frost damage, and disease outbreaks, and displacement, and result in plant phenology that is out of sequence with pollinators (Kreyling 2010).

Elk introduced into Central Nevada have expanded their range to high altitude mountains that did not evolve with large ungulate foraging. Impacts at these elevations have altered plant community composition and structure, likely reduced ecosystem resilience to disturbance, and possibly impacted rare species.

Aquatic Ecosystems:

Changes in stream environments will parallel trends in the climate system, with streams becoming warmer, more variable in flow timing and amount, and subject to more frequent extreme events that could be synchronized across broader areas through regional flooding, droughts, and wildfires. Climate change is also likely to influence channel structure and forest and riparian communities through altered patterns and severity or intensity of wildfire, inputs of sediment and large wood, and disturbances such as debris flows (Rieman and Isaak 2010).

Due to an increase in precipitation as rain, we are likely to see higher stream flows in winter. Due to generally more arid conditions, increased evapotranspiration and warmer temperatures, summer stream flows will likely be reduced. In many low flow systems of the Great Basin, this could result in even higher water temperatues and drying of the stream systems in the summer. This will decrease connectivity for both aquatic organisms and riparian species. More variable and more extreme precipitation events could result in increased floods and exacerbate ongoing stream incision. (Chambers 2011).

Ultimately, temperature defines the gradients of performance and absolute bounds for life for most aquatic organisms as well as rates of growth and timing of key life history events or transitions. Chronic warming likely will lead to increased mortalities and shifting habitat distributions or range limits, presumably northward or upstream (Rieman and Isaak 2010).

The influences of stream hydrology may be less constraining than temperature depending on the size of the stream (many aquatic organisms, including fish, can survive in standing water), but they are still fundamentally important. Flow influences temperature and water chemistry and acts as a primary control on the supply and exchange of material such as oxygen, nutrients, organic matter and food, and metabolic wastes. Flow may directly constrain the distribution and performance of fishes based on timing and volume of run-off, water velocities, and their effects on suitability of habitats for incubation, holding, foraging and migration (Reiman and Isaak 2010).

Climate change could affect rates of embryo development and the timing of emergence with the timing of available food sources. It will also likely effect aquatic species by altering predation, competition, disease occurrence, growth rates, reproduction, migration, metabolism, forage availability and stress levels (Rieman and Isaak 2010).

Predicted future drought conditions in the southwest and across much of our region may impact trout by confining populations to smaller, upstream habitat with perennial flows, including some streams that are currently uninhabitable because of cold water temperatures. The overall effect may be a reduction in trout abundance and distribution, and an increase in susceptibility to small-population phenomena such as inbreeding and disturbance vulnerability (Young 2008).

Riparian Meadows, Springs and Seeps:

"Adaptation to changing environments through natural selection and plasticity is possible, but the speed and capacities for adaptation are not well known and may be outpaced by the rate of climate-driven environmental change "

Bruce E. Reiman and Daniel J. Isaak, Research Fisheries Scientists, Rocky Mountain Research Station

In the Great Basin ongoing stream incision has resulted in a progressive decrease in the extent of the riparian corridor and a loss of meadow complexes. Past and current climatic shifts, which are exacerbated by anthropogenic impacts, will alter species composition and vegetation patterns in riparian systems (Chambers et al. 2004, chapter 5). The rate and magnitude of stream incision has been increased with anthropogenic disturbances (Chambers and Miller 2004, chapter 9).

Reservoirs, water diversions, ditches, roads, and human land uses have had a substantial impact on the hydrology as well as biotic integrity of many riparian areas. Human land uses both within the riparian area as well as in adjacent and upland areas can and have fragmented the landscape and thereby reduced connectivity between riparian patches and between riparian and upland areas. This combined with a warmer temperatures and less snowpack has and will continue to adversely affect the movement of surface/groundwater, nutrients, and dispersal of plants and animals.

Warmer temperatures, decreased snowpack and earlier run-off have resulted in a longer period of hot season gazing by livestock. During the hot season, cattle and horses tend to stay in riparian areas for shelter and forage. The resulting effect is a loss of vegetative cover, increased soil exposure, increased soil compaction and streambank alteration, and lowering of the water table. Climate change with increasing temperature will extend the hot season, and could result in increased loss of riparian ecosystems, unless livestock are managed.

Noxious and invasive weeds have become more prevalent in riparian areas and have helped to facilitate incision and loss of water table, due to altered root structures that are less effective against fluvial erosion, and do not facilitate infiltration and ground water movement. Broadleaf pepperweed (*Lepidium latifolium*), Scotch cottonthistle (*Onopordum acanthium*), Canada thistle (*Circium arvense*), musk thistle (*Carduus nutans*), and crossflower (*Chorispora tenella*) are common riparian weeds.

Forest data shows when all riparian vegetative types are combined, they account for 1% of the vegetative types found on the Forest, but this 1% accounts for 24% of noxious weed occurrence. The fact that riparian related vegetation types support such a disproportionate amount of noxious weeds species makes management of riparian areas even more important. This is especially true in the arid state of Nevada where preserving the integrity of riparian areas that play such a critical role for wildlife, recreation, water quality, and grazing management (Glover 2010).

Riparian areas also serve as the foundation of much of the region's biological diversity. Declining conditions in riparian areas are likely to have cascading effects not only on aquatic species, but on the many upland species that use these ecosystems as their sole source of water (Chambers 2011).

Woodland Ecosystems:

On the basis of the best existing data for 130 tree species in North America and associated climate information, and assuming no limitations to individual tree growth, (McKenney and colleagues 2007) predicted that the average range for a given tree species will decrease in size by 12% and will shift northward by 700 kilometers (km) during this century (Bentz et al. 2010).

Among the most pronounced vegetation changes in the past 130 years has been the increase in both distribution and density of juniper (*Juniperus* spp.) and pinyon (*Pinus* spp.) across the Intermountain West. This dramatic increase has occurred in persistent woodlands, pinyon-juniper savannas and in wooded shrub lands (Romme et al. 2009). In the central and southern portions of the Intermountain West, particularly where pinyon is dominant, dense tree-canopied woodlands are now becoming susceptible to intense crown fires. High severity fires can lead to dominance by exotics, further altering the successional dynamics of the site (Miller and Tausch. Research on fire return intervals in pinyon-juniper woodlands indicates long fire return intervals of 300 to 600 years. However, modern fire return intervals may be getting shorter (Romme et al. 2009).

Aspen stands became established during a colder, wetter climate, and are now found in snow bank areas, cool depressions and north and east aspects. Drought and diminished snow banks have stressed aspen clones allowing insects and diseases to spread and reduce stems per acre. Many isolated aspen stands have been reduced to just a few stems. The added stresses of livestock and native and introduced wildlife species foraging and ground disturbance have further damaged aspen clones.

Cottonwood stands need periodic flooding or fire to stimulate vegetative reproduction and a large enough stand with fertile male and female trees to allow for sexual reproduction. A combination of heavy grazing use on suckers and saplings, heavy recreational use, water diversion, stream incision and lowered water table, flood control and fire suppression have resulted in diminished stands of cottonwood. In many locations on the Forest, existing cottonwood stands are mature and decadent, and male trees are no longer producing viable pollen or have died.

Rangeland Ecosystems:

Climatic stresses, such as decrease snowpack, early snowmelt, warmer air temperatures and more extensive wildfire, are effecting changes in the composition of the region's forest, rangeland, and riparian plant communities, with more xeric, drought tolerant species becoming more common (Rieman and Isaak 2010).

> ***"Inaction may be the riskiest decision of all because climate change is a long term problem that carries a huge procrastination penalty"***
>
> National Park Service Climate Change Response Strategy

Higher temperatures and increasing variability in precipitation will increase the difficulty of managing for sustainable rangelands, resulting in the potential for more litigation and political intervention. Natural population dynamics of many native and even introduced species are unlikely to respond quickly enough to changing climatic conditions to avoid widespread changes in plant communities (Chambers and Pellant 2008).

Cheatgrass (*Bromus tectorum*) is an exotic annual grass that was introduced into the Great Basin within the last 150 years. It is highly invasive in post-fire ecosystems at low to mid elevations. Wyoming big sagebrush, Basin big sagebrush, black sagebrush and some desert shrub communities have been converted to a dominance of cheatgrass with recent fires. Other annual exotics that have increased with fires are medusahead (*Taeniatherum caput-medusae*), Russian thistle (*Salsola* spp.), halogeton (*Halogeton glomerata*), tansy mustard (*Descurainia* spp.), tumblemustard (*Sisymbrium altissimum*), and alyssum (*Alyssum desertorum*).

Shifts in vegetation communities and increased wildfire frequencies, both resulting from temperature and precipitation changes, may exacerbate habitat loss and increase local extirpation for the Great Basin pygmy rabbit, a sagebrush obligate species (Larrucea and Brussard 2008).

Big sagebrush habitats throughout the western U.S. could decrease in area by 59% before the end of the 21st century, with devastating consequences for sage grouse, mule deer, pronghorn and other species that depend on these habitats (Glick 2006).

The loss of contiguous sagebrush habitat, due to increased fire occurrence and introduction of invasive plants, primarily cheatgrass, has diminished the ability of sage grouse to migrate between populations. The result is limited movement for mating, and lowered viability of the genetic pool needed for a sustainable population. A warmer climate will result in the loss of more sage grouse habitat.

Livestock grazing is a major land use across much of the region and, without highly flexible livestock management options, land degradation could accelerate, especially during drought. Similarly, many large feral and native grazers could increase the rate of degradation without proactive management (Chambers and Pellant 2008).

Arid Desert Ecosystems:

With frequent, small precipitation events and high air temperatures, biological crust organisms have a reduced period of activity before drying, and are unable to produce or repair chlorophyll a and/or protective pigments that would provide protection from radiation stress (Belnap et al. 2004).

Arid ecosystems of the western U.S. are particularly sensitive to climate change and climate variability because organisms in the region live near their physiological limits for water and temperature stress. Slight changes in temperature or precipitation regimes, or in magnitude and frequency of extreme climatic events, can significantly alter the composition, abundance, and distribution of species (Archer and Predick 2008).

At least 26 populations of desert bighorn sheep have gone extinct from mountain ranges in the desert regions of California. These extinctions occurred in conjunction with a 20% decrease in precipitation and 1ºC increase in average temperature during the last half of the 20th century (USDI NPS 2010).

The rarest plants of the Great Basin occur at the lowest elevations where they are typically restricted to specialized habitats that usually have only a few hundred foot elevation range. Valley floor taxa are more susceptible to stressors such as habitat modification or destruction and invasive species (Caicco et al. 2011).

Rare Ecosystems:

Several rare plant species are soil endemics, and when the soil has a limited range, this renders them incapable of being moved to a higher elevation to escape a warming climate.

Rare plant species could become disconnected from their pollinators by habitat fragmentation or climate changes.

Many rare plants occur in isolated habitats at high elevations. With warming conditions and diminished snow packs these plants are at risk of extinction.

With climate change, we may see more hybridization between rare species and species that are more common, due to adaptive response movement of plants and animals with the changing climate. The result might be a loss of some rare species and the eventual creation of new species. The overall impact of climate change on genetic pools will depend on the rate of change and the ability of species to move and/or adapt.

Water Resources:

Approximately 85% of the water used by humans in the Great Basin and Rocky Mountain region flows from spring melt of mountain snow packs. Warmer wintertime temperatures and earlier melt dates will deplete this virtual reservoir, leaving much less available water for natural systems and human uses. Water resources in the region are totally allocated, with 80% of available water used for agriculture. Regional human populations and water needs are expected to double in the next 40 years, taxing resources even further (Loehman 2010).

Warming temperatures, less snow and more rain could impact wild and scenic rivers and wilderness characteristics. Campgrounds close to water may be flooded and others maybe abandoned due to changes in the recreational value and experience.

Bridges, culverts and campgrounds could be increasingly vulnerable to floods caused by rain on snow events in warmer winters (USDA Forest Service 2010).

Forest roads are often located in valley bottoms making them susceptible to "road captures" in which the streams are diverted onto the roads during high flows causing stream incision and riparian area degradation. The location and maintenance of Forest roads will become increasingly important not only for maintaining and restoring the infrastructure of roads, but for maintaining and restoring stream and riparian ecosystems (Chambers et al. 2004).

Exotics and Invasives:

Invasibility of cheatgrass (*Bromus tectorum*) varies across elevation gradients on the Forest and appears to be closely related to temperature at higher elevations and to soil water availability at lower elevations. Cold soil temperatures at higher elevations limit the growth and reproduction of cheatgrass. High variability in soil water and lower average perennial herbaceous cover appear to increase invasion potential at low to mid elevations explaining the high susceptibility of more mesic Salt desert shrub and Wyoming sagebrush ecosystems to invasion by cheatgrass. Fire and removal of perennial herbaceous species increases the susceptibility to invasion due to elevated soil water and the lack of competition. However, on intact sites in relatively high ecological condition, native perennials typically increase following fire, limiting *B. tectorum* growth and reproduction (Chamber et al. 2007).

Noxious and invasive weeds are responding to increased CO2 concentrations by increasing the rate of growth and plant biomass (Ziska 2003).

"The current controversy between scientists and climate change critics over whether human-induced changes simply exacerbate "natural" climatic cycles or drive the major changes detract us from the very actions needed for humans to survive: understanding, managing, and living with change."

Dr. Thad Box, Rangeland Scientist and Columnist for Society for Range Management

Climate Change and National Forest Management:

It is the adaptability of an organism or an ecosystem to disturbance that determines its' ability to resist damaging impacts and become resilient to change. Resistant and resilient organisms and ecosystems will have a greater ability to adjust with climate change than impaired or imperiled organisms and ecosystems. The most critical action we can do now to prepare for future climate change is to reduce current stressors, maintain high-functioning ecosystems, and prioritize and restore function to impaired ecosystems.

Responsive Actions to Climate Change:

Identify and reduce stressors, such as grazing, introduction of non-native species and water diversions, into critical habitats.

Resilience

The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change.
(IPCC 2007:880)

Develop an understanding of ecological resilience to climate change and other disturbances for the diverse ecosystems on the Forest and use this information in management plans and actions (Wisdom and Chambers 2009).

Maintain or restore instream flows and natural hydrologic regimes to maximize available habitat, increase terrestrial interactions, and buffer streams against temperature increases and the loss of habitats during low flow events (Reiman and Isaak 2010).

Maintain or restore riparian, floodplain, and wetland conditions and connections with streams to maximize stream shading, bank stability, terrestrial food inputs, and recruitment of woody debris that helps form diverse habitat; enhance water storage for delayed summer discharge during warm, low flow periods (Reiman and Isaak 2010).

Disconnect roads from the drainage network, and remove roads and dikes that constrainor disconnect channels from floodplains to buffer the effects of peak flow events (Reiman and Isaak 2010).

Limit or stop introduction and expansion of non-native species to reduce potential competitors, predators, diseases, and hybridization that may constrain habitat capacity, individual growth rates, and survival (Reiman and Isaak 2010).

Eliminate or control pollutants or contaminants to reduce stresses associated with eutrophication, toxic materials, or other contaminants effects on growth, productivity, and survival (Reiman and Isaak 2010).

Remove barriers that are currently preventing or inhibiting completion of life processes for at risk species.

Maintain vegetative cover to mitigate loss of snow pack storage, earlier runoff, and reduced summer low reduce rain-on-snow flooding and delay flows. Conserve wetland and riparian areas that tend to store snow melt water for later summer base flows (Reiman and Isaak 2010).

Protect and restore critical or unique wetland habitats that can provide a buffer during vulnerable periods (Reiman and Isaak 2010).

Resistance

"In our perspective, resistance represents the capacity of important habitats, populations, or communities to absorb an environmental shift or disturbance with limited or negligible deflection in abundance, structure, or function."

Bruce E. Reiman and Daniel J. Isaak, Research Fisheries Scientists, Rocky Mountain Research Station

Restore meadows impacted with headcuts where possible, and re-establish wetland vegetation species with deep-rooting characteristics.

Minimize hot season livestock grazing at a level that allows for wetland plant species to reproduce and replenish root reserves.

Restore or maintain adequate vegetative cover in riparian areas to minimize erosion.

Utilize best management practices to reduce potential for soil compaction in moist and wet meadows.

Continue pinyon and juniper reduction projects where encroachment is impacting sagebrush ecosystems, reducing understory vegetation, and setting the stage for catastrophic fire.

Maintain forest cover to mitigate loss of snow pack storage, earlier runoff, and reduced summer low reduce rain-on-snow flooding and delay flows. Conserve forest areas that tend to store snow melt water for later summer base flows (Reiman and Isaak 2010).

Conserve and restore resilience and resistance of imperiled (sagebrush and bunchgrass and others) ecosystems by reducing cumulative stress levels. As global climate change increases heat and water stress, reducing cumulative cattle grazing intensities by altering utilization rates and/or seasons of use may be the only effective means of accomplishing these goals (Reisner 2010).

Maintain or restore high ecological conditions in all plant communities, as following resource fluctuations, invasibility is lowest on sites with relatively high cover of perennial herbaceous species (i.e., sites in high ecological condition) (Chambers et.al. 2007).

Reduce introduced exotic species and their interactions with native plant species in regions such as western North America. The interactions between exotic and native species impact the dynamics of the plant communities and confound the ability of models to predict vegetation change with future climate change (Nowack et al. 1994).

Conserve or restore genotypic and phenotypic diversity to provide for biological resilience and increase odds that some populations or representation of habitats across individuals will be adapted to future conditions or have the capacity to evolve (Reiman and Isaak 2010).

Analyze effects and adjust human activities such as camping, hunting, fishing, wood gathering, hiking and wilderness activities to minimize the impact on vulnerable species and ecosystems.

Access existing resources and ecological conditions to facilitate planning and management actions aimed at restoring and maintaining ecosystems (Chambers and Pellant 2008).

Monitor and document trends to strengthen local knowledge; test, validate, or reject models, predictions, and hypotheses. Review, revise, and refine management (Reiman and Isaak 2010).

With the public build understanding of ecological values in aquatic systems and support for the actions and tradeoffs that inevitably must be addressed (Reiman and Isaak 2010).

Restore and maintain high-quality rangelands, as emissions of CH_4 from domestic ruminant animals can be reduced as producers use improved grazing systems with higher quality forage, since animals grazing on poor-quality rangelands produce more CH_4 per unit of feed consumed (IPPC 2011).

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