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Climate Sensitivities of National Parks in the Rocky Mountains

Rocky Mountain National Park, Colorado. Beneath the sunlit face of Notchtop Mountain, ice and snow wrap the shoreline of Two Rivers Lake.
NPS

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Science Report NPS/SR—2025/368

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Abstract

National Park Service units across the United States have been affected by climate change, and impacts are expected to intensify. Understanding the vulnerability of park resources, assets, and values to climate change is critical for effective and adaptive park management. Climate change vulnerability is a result of exposure, sensitivity, and adaptive capacity. This report provides information on climate sensitivity: the degree to which changes in climate drivers affect a resource, asset, or value, either adversely or beneficially. Here, we present regional-scale information for an area congruent with the Rocky Mountain and Greater Yellowstone Inventory and Monitoring (I&M) Networks, which encompasses areas from southern Colorado to the Montana–Canadian border. We provide regional trends for past, present, and projected future climate drivers, including gradual changes and extreme events. We then summarize the impacts of these climate trends on natural resources, cultural resources, visitor experience, and infrastructure. Throughout the report, we include park-specific examples illustrating sensitivities and their implications for park management. The purpose of this report series is to document current understanding of key climate trends and resource sensitivities to inform park management decisions and provide information that can be readily incorporated into planning.

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List of Terms and Acronyms

Climatic Water Deficit (CWD): A metric for estimating drought stress in plants and soil by quantifying evaporative demand relative to the supply of water. CWD expresses a difference between actual evapotranspiration (AET) and potential evapotranspiration (PET).

Eutrophication: A process by which a body of water is enriched by an excess of nutrients, which may disrupt aquatic ecology and nutrient cycling through mass algal blooms and oxygen depletion.

Invasive: An introduced or native organism that causes ecological harm typically through rapid and unchecked growth, resulting in the displacement of native species and/or natural processes.

Phenology: Natural progressions in plant and animal morphology and behavior that correspond with seasonal patterns and life-history events such as germination or migration.

Refugium: A distinct area that provides persistent habitat for a species despite loss of habitat affecting local extinction within the larger region. In the context of natural history, refugia are typically associated with relict populations that reflect past climate or other resource conditions.

Evapotranspiration: The loss of moisture from physical surfaces (evaporation) and plant tissues (transpiration). Transpiration, the loss of water from plant tissues through foliar gas exchange, is a necessary process for carbon assimilation (photosynthesis), respiration, and thermal and metabolic regulation.

Zoonotic disease: Any contagious illness that may be spread between humans and animals.

Executive Summary

This report provides information on climate sensitivity: the degree to which changes in climate drivers affect important park ecological resources, cultural resources, visitor experience, and park facilities. This report covers the general area of the Rocky Mountain and Greater Yellowstone Inventory and Monitoring (I&M) Networks, which includes areas from southern Colorado to the Montana–Canadian border.

Why Do You Need This Report?

Understanding the sensitivity of park resources, assets, and values to climate change is a critical step in climate adaptation planning. This sensitivity report can help park managers evaluate potential climate impacts and vulnerabilities and re-evaluate management goals in light of these vulnerabilities. Each report in this series describes the most impactful climate changes that are anticipated to impact parks in a specific geographic area. This report complements the NPS Climate Futures Summaries, which cover historic and projected climate trends, by providing information on how these climate trends will impact park resources, assets, and values.

Key Climate Trends

The Rocky Mountains region has already experienced gradual climate changes as well as shifts in extreme events. These changes are projected to continue to depart from historic conditions due to climate change. Across the region, average annual temperature has increased by an average 1.9°F (1.06°C) since 1980 (4.2°F or 2.3°C/century). At this rate, temperatures will have increased by more than 2°F (1.11°C) by 2030, an amount of warming considered to pose severe threats to ecosystems. Overall, precipitation is projected to increase across the region, but those increases are anticipated to be offset by increasing evapotranspiration experienced in a hotter future climate. Changes in climate are often punctuated by extreme events, with the Rocky Mountain region experiencing increasing wildfire and drought. However, impacts from flooding and extreme heat also are concerns in this region. Both gradual changes and extreme events can contribute to the expansion of insect pests, invasive species, and diseases.

Resource Sensitivities/Vulnerabilities

Natural Resources

The topographic diversity of the Rocky Mountains may promote resilience to potential changes in climate due to microclimatic diversity provided by mountainous terrain. Microclimate diversity provides a wider range of available environmental conditions which species can utilize to persist under climate change. Plant species, including traditional subsistence resources, are experiencing range shifts to higher elevations, tracking suitable climate conditions as temperatures increase in this region. While much of the flora is drought- and fire-adapted, climate change is altering the frequency, size, and severity of drought and wildfire events. As a result, landscape-scale changes including ecosystem transformation from forest to non-forest systems have occurred and are projected to become increasingly likely in the future. Multiple climate drivers, which include changing temperature, changing precipitation, and drought, interact to increase the risk of wildfire and nonnative species invasion in Rocky Mountain parks. Climate change is a global driver of biodiversity loss, including declines of aquatic and terrestrial wildlife species in the Rocky Mountain region. Cold-adapted and snow-dependent wildlife are particularly at risk in a warming world. The Rocky Mountains region contains the headwaters of multiple major rivers, which will face reduced in-stream flow due to changing snowpack. Additional hydrological resources in this region that may be impacted by climate change include mountain glaciers, wetlands, and alpine lakes.

Cultural Resources
Archeological resources historically preserved in ice patches are at risk of exposure and decomposition as ice patches melt, while others are at risk of damage and loss from climate-altered wildfire and erosion events. Historic structures may be damaged or destroyed by extreme events including fire and floods, while gradual changes in precipitation and temperature lead to loss of structural integrity. Cultural landscapes may be transformed by altered vegetation communities due to pest species including bark beetles, and museum collections are threatened by wildfire, flooding, pests, and changes in building conditions where they are housed.

Visitor Use
Climate change has and will continue to impact many aspects of visitation to parks in the region, including visitation numbers, timing of visits, visit location choice, activity participation, visitor experience quality, and visitor safety. Parks are already feeling the pressures from extended high visitation seasons due to warming temperatures in the Rocky Mountain region. Specific effects related to climate change include increasing temperatures, flooding and drought, decreasing snowpack and earlier spring runoff, wildfire and smoke, harmful algal blooms (HABs), and zoonotic and vector-borne diseases. While warmer temperatures will likely boost visits for warm-weather activities, they also will decrease snow-dependent activities and pose health risks due to heat-related illnesses. Under a high greenhouse gas emissions scenario, snowmobiling, cross-country skiing, and downhill skiing could lose 50% of current visits in the Western U.S. states. Precipitation variability affects parks in different ways, but is particularly impactful for reservoir levels and water-based recreation. Both high and low water levels can decrease visitation. Decreasing snowpack alters the timing of wildflower blooms and reduces opportunities for winter recreation. Wildfires and smoke can lead to temporary declines in visitation and impacts to viewsheds, human health, and recreation location preferences. Additionally, the spread of vector-borne diseases, such as West Nile virus, raises health concerns for park visitors.

Infrastructure
NPS units contain operational structures, recreation facilities, trails, roads, and other infrastructure that require maintenance. Extreme temperatures strain HVAC systems in park facilities, while extreme precipitation may overcome current water utility systems and drainage capacity. Extreme heat can cause cracks in roads and lead to overheating of vehicles. However, reduced snowpack and extended warm seasons may also lead to increased access to high-elevation areas of parks in the Rocky Mountain region. Some locations that have been historically popular for camping and hiking may become less desirable or safe due to wildfire. Roads and trails are also susceptible to erosion, washouts, landslides, flooding, and dead and downed trees.

Response Actions

The diverse and interrelated climate change impacts on park values described in this report highlight the importance of proactive and deliberate climate adaptation planning. The National Park Service has developed multiple resources to use in the adaptation planning process. The framework outlines a series of iterative steps to identify potential management actions, monitor and evaluate outcomes, and adjust based on new information. The framework fits within this adaptation process and helps managers identify the full range of available options to resist, accept, or direct change. These frameworks, as well as a range of other approaches and tools used by the NPS and land managers more broadly, can be used to develop place-based and context-specific actions to achieve park goals, or to redefine those goals in a changing climate.

Purpose and Intent

Parks across the NPS have been affected by climate change, and impacts are expected to intensify. Understanding the vulnerability of park resources, assets, and values to climate change is a critical step in adaptation planning to develop flexible and robust strategies for managing and protecting resources in the face of these changes (Michalak et al. 2021). Climate change vulnerability is a result of the exposure of a resource, asset, or value to climate changes, sensitivity to those changes, and, for living resources, the adaptive capacity to adjust to climate stressors. The relationships between these three factors are outlined in Figure 1.

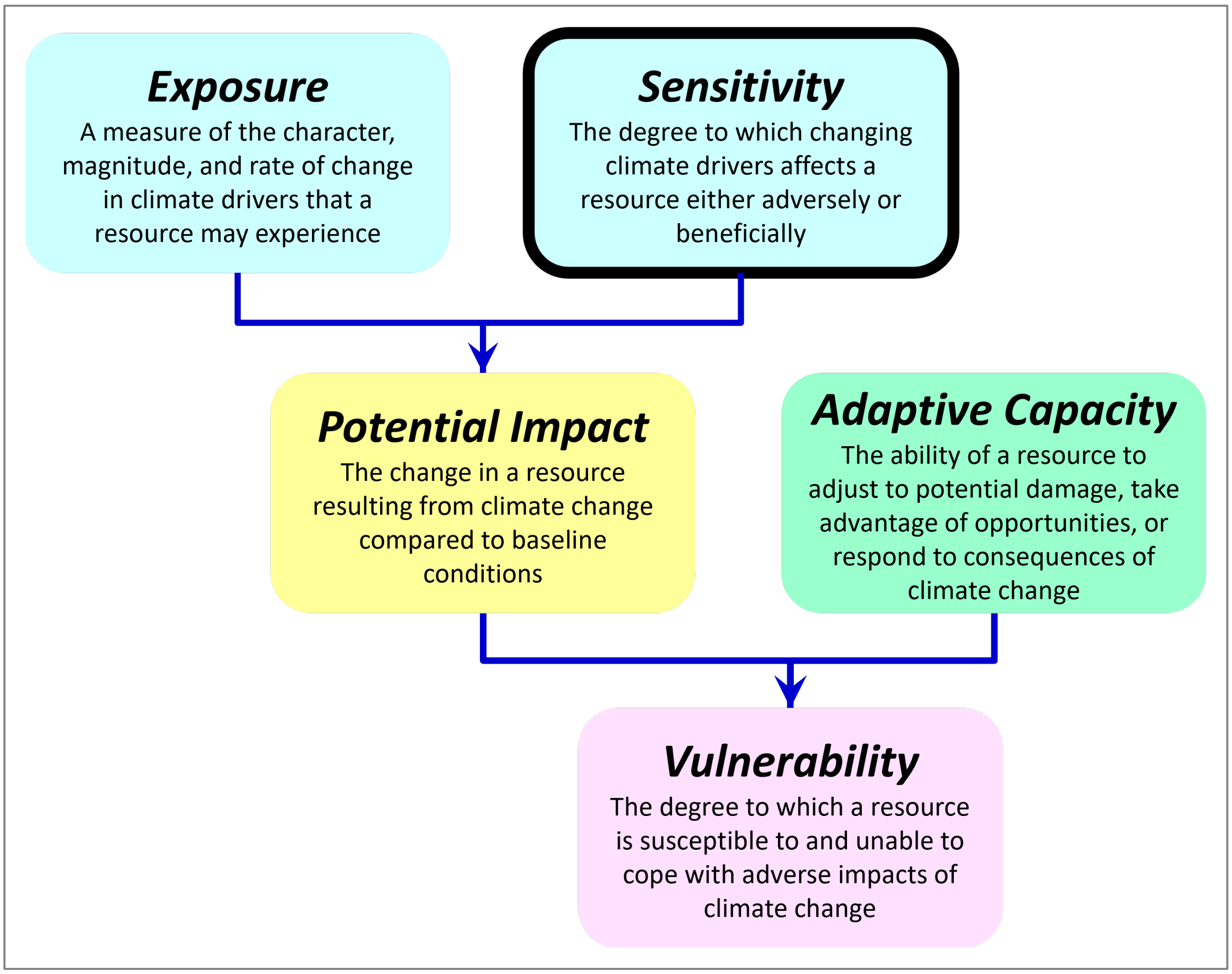

Figure 1. Components of climate vulnerability. Sensitivity, the component addressed in this report, is outlined in black.

NPS, ADAPTED FROM GLICK ET AL. (2011) AND FODEN ET AL. (2019)

NPS park-specific Climate Futures Summaries cover the historic and potential projected future trends in exposure (e.g., changes in temperature, precipitation, etc.). As a next step, this report provides information on sensitivity. Sensitivity is the degree to which changes in climate drivers (e.g., exposure) affect a resource, asset, or value either adversely or beneficially. These sensitivities are mediated by disturbances from climate extremes and the interaction of climate with other stressors.

Used together, the Climate Futures Summaries and this sensitivity report can help park managers: 1) evaluate potential climate impacts and vulnerabilities, 2) re-evaluate goals considering climate change vulnerability, and 3) identify potential adaptation options (steps 2–4 in the NPS adaptation cycle). Each report in this series describes the most critical climate changes that are anticipated to affect parks in a specific geographic area, as well as the past and projected impacts of these changes on park resources, assets, and values.

The regions align with Inventory and Monitoring (I&M) network geographies and, in some cases, combine multiple I&M networks due to climatic similarities. The most consequential climate-related hazards (e.g., fire, floods, sea level rise, drought) are generally regional in both scale and specificity. Areas covered in these reports were selected to: 1) broadly match the scale of key climate patterns and affected resources, and 2) leverage the expertise and communications between the NPS I&M networks and parks. However, we include many park-specific examples to demonstrate place-based cases of climate sensitivity. While the geographical scope of the sensitivity reports complement existing NPS programs and networks, these regions are not official DOI/NPS Regions.

Park managers who are not experts in climate change vulnerability are the primary audience for these reports, with secondary use by others. The purpose is to:

- Document current understanding of key climate trends and resource sensitivities
- Inform decisions on park management
- Provide relevant information that is easily and efficiently incorporated into park plans, presentations, and other products
- Provide information that can be leveraged by parks in the same geographic area to work and learn collaboratively
- Guide parks toward “next steps” for climate adaptation planning and management
- Provide useful background information for interpreters, park visitors, and others

Geographic Scope

This report covers the Rocky Mountains, including the [Rocky Mountain] and [Greater Yellowstone] I&M Network areas (Figure 2). This geographical area includes the following parks:

- Bear Paw Battlefield National Historic Site
- Bighorn Canyon National Recreation Area
- Florissant Fossil Beds National Monument
- Glacier National Park
- Grand Teton National Park
- Grant-Kohrs Ranch National Historic Site
- Great Sand Dunes National Park
- John D. Rockefeller Jr. Memorial Parkway
- Little Bighorn Battlefield National Monument
- Rocky Mountain National Park
- Yellowstone National Park

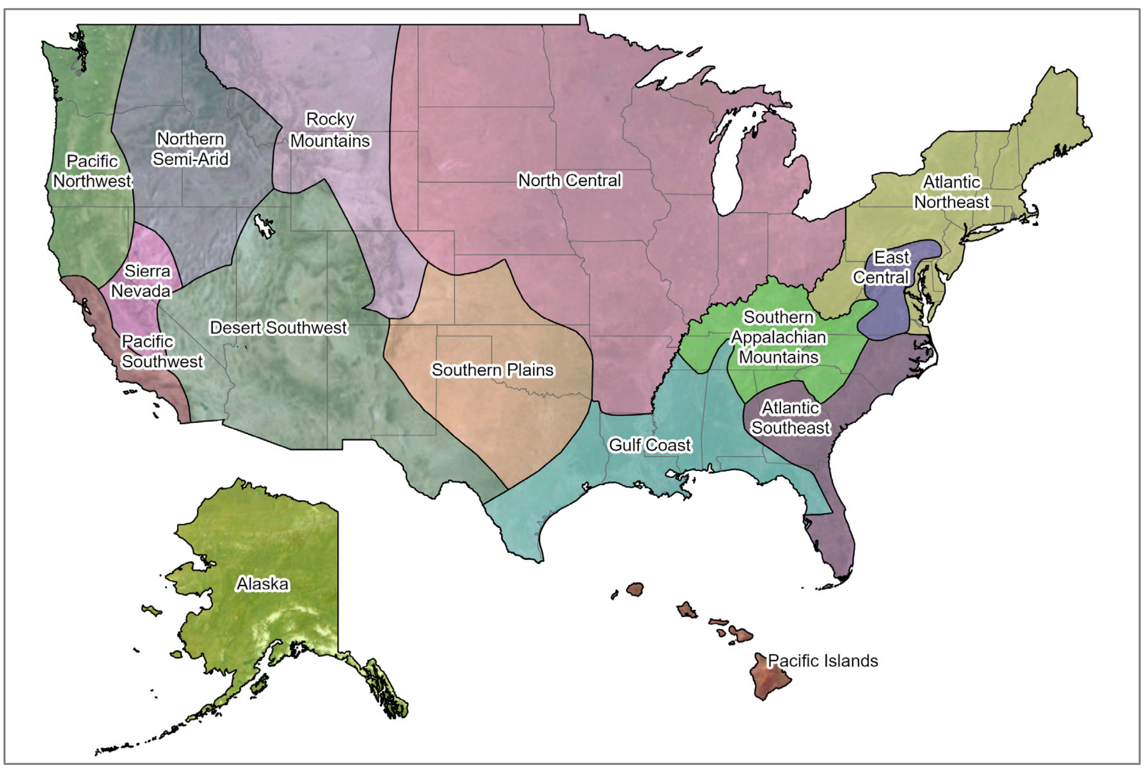

Figure 2. Map of geographic areas to be covered in report series. Black borders denote combined I&M Network areas with similar climatic profiles.

NPS / BRECKEN ROBB

Adapting to Climate Sensitivities

The diverse and interrelated climate change impacts on park values described in this report highlight the importance of proactive and deliberate climate adaptation planning. Climate change adaptation is an intentional management response to observed climate changes or plausible future changes that involves identifying, preparing for, and responding to those changes. The NPS uses multiple complementary adaptation planning frameworks, including the Planning for a Changing Climate cycle (P4CC) and the resist-accept-direct (RAD) frameworks.

NPS Adaptation Planning Cycle

NPS published Planning for a Changing Climate (P4CC) to guide service-wide climate-smart adaptation planning (NPS 2021d). The guidance helps planners and managers develop forward-looking goals and evaluate strategies and actions in light of multiple plausible futures associated with a changing climate. Figure 3 shows the P4CC adaptation cycle.

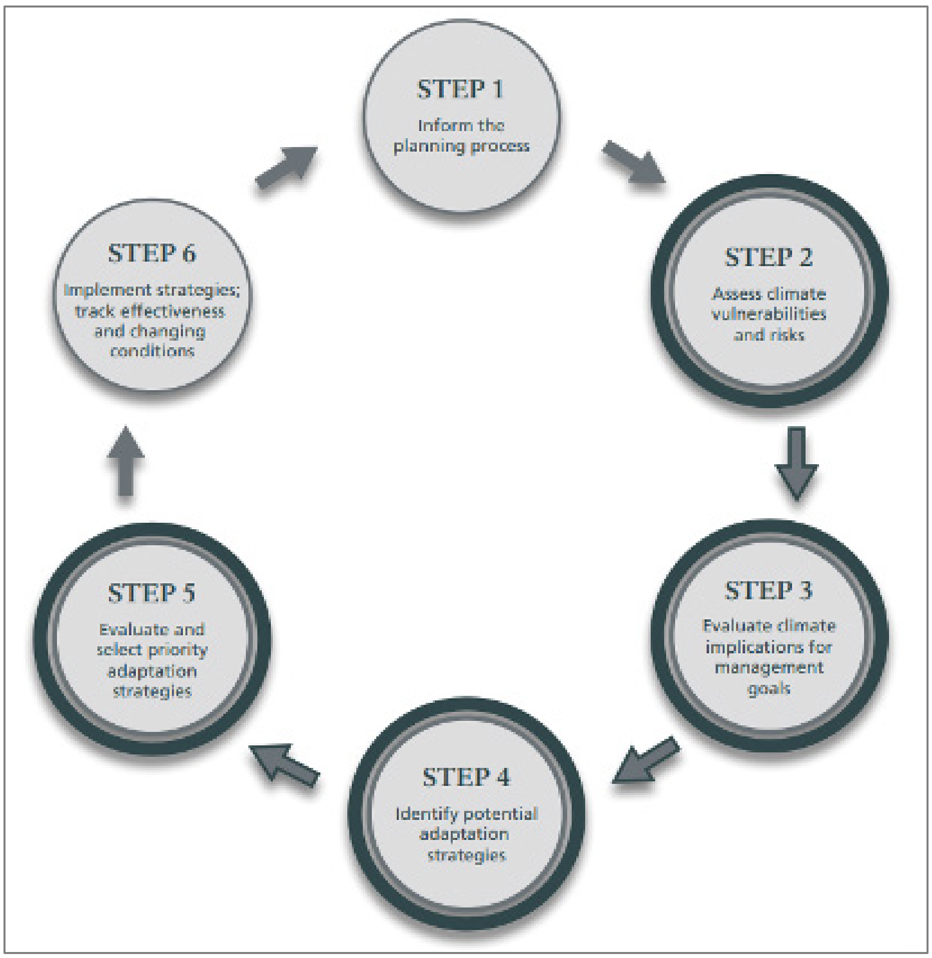

Figure 3. The NPS climate change adaptation planning process. Darker circles around steps 2–5 indicate where key principles of developing forward-looking goals and considering multiple scenarios play a critical role.
NPS

Resist-Accept-Direct Framework (RAD)

The resist-accept-direct (RAD) Framework was designed to assist managers in making decisions within ecosystems that have the potential for rapid, irreversible ecological change (Schuurman et al. 2020). The RAD framework (Figure 4) fits under Step 4 of the P4CC cycle. Its use has been expanded to consider adaptation actions for cultural resource, facility, and visitor use management. While traditional approaches to public land management in the United States have tended to focus on maintaining or restoring systems to historical baselines, the RAD framework acknowledges that climate change will result in changes beyond the historical range of variability. Therefore, the available decision space includes actions that resist changes where it may be feasible to maintain current values, actions that accept changes that are tolerable or unavoidable, and actions that direct changes toward a specific new state that is more desirable.

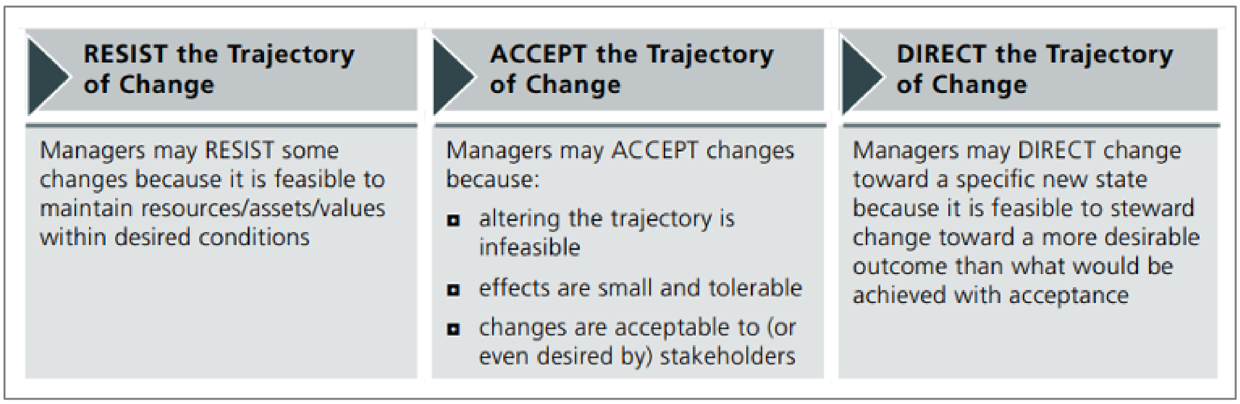

Figure 4. Resist-Accept-Direct Framework and definitions.
NPS / RESIST-ACCEPT-DIRECT (RAD)—A FRAMEWORK FOR THE 21ST-CENTURY NATURAL RESOURCE MANAGER

Summary of Climate Trends

This report focuses on climate trends and impacts generalized across the parks in the Rocky Mountain area. Climate exposure for each park is summarized in the NPS Climate Futures Summaries, and on the climate future dashboards, which describe trends in climate exposure at a finer spatial scale (Figure 5).

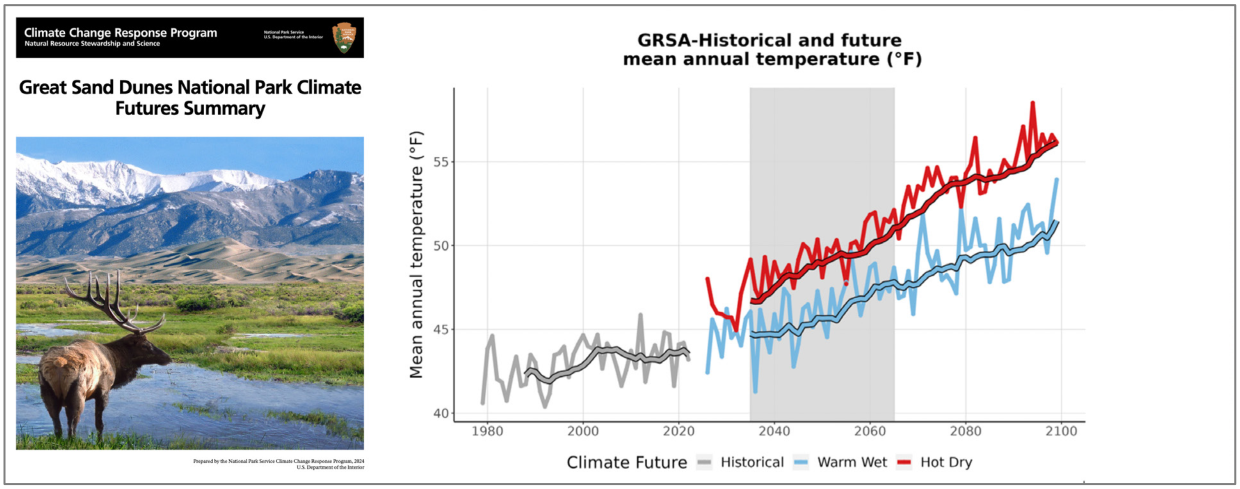

Figure 5. Example of Climate Futures Summary temperature projections for Great Sand Dunes National Park.
NPS / GREAT SAND DUNES NATIONAL PARK CLIMATE FUTURES SUMMARIES

Gradual Climate Changes

Across the region, average annual temperature has increased by about 1.9°F (1.06°C) since 1980 (4.2°F or 2.3°C/century). At this rate, temperatures will have increased by more than 2°F (1.11°C) by 2030, an amount of warming considered to pose severe threats to present ecosystems. Average precipitation is 21 inches/year, but there are large differences in precipitation across the region due to geographical variation in climate influences and elevation. Northern areas can be strongly influenced by humid air and precipitation sweeping in from the northwest, while southern areas are more subject to monsoonal rains. Much of the region experienced some degree of aridity since 2000, and in the 2000–2024 period precipitation was below average for 18 of 25 years. While some climate models project a strengthening of monsoonal influences and increased precipitation, other models project a weakening. Even when precipitation increases, the entire area is generally projected to experience gradually increasing aridity expressed as an increasing annual climatic water deficit and there will be exceptions, such as at high elevations where increased snow and glacial melt can create locally wetter areas.

The Rocky Mountain region is highly susceptible to changes in water and snowpack. These hydrological changes have wide-ranging implications as the region contains the headwaters of major rivers including the Colorado, Rio Grande, Arkansas, Platte, Yellowstone, Snake, and Missouri (Kunkel 2022; Udall and Overpeck 2017). Across the Rocky Mountains, climate change has reduced snowpack in recent decades (Miller et al. 2022; Michalak et al. 2021) and snowfall is projected to decrease below approximately 2,000m elevation (Mote et al. 2018). Rising temperatures will increase the likelihood that precipitation falls as rain rather than snow, and higher spring temperatures will continue to lead to earlier melting of the snowpack (Klos et al. 2014).

Acute Climate Changes and Extreme Events

Heatwaves

As average temperatures have increased, hot days and heat waves have become more common across the region and the number of cold days has decreased. Moving forward, heat waves are projected to increase faster than cold snaps decrease. In Colorado there were more heat waves in the first two years of the 2020s than in some entire decades in the 20th century (Bolinger et al. 2024). In most areas of Colorado the median number of heat waves is projected to increase from 1 per year during 1971–2000 to approximately 10 per year by the 2060s (Bolinger et al. 2024). Over the next 70 years, the number of days above 100°F in Montana and Wyoming are likely to double (EPA 2016a, 2016b).

Drought

Overall, the region has experienced drying and the intensity of future droughts is projected to increase in Colorado, Wyoming, and Montana (Kunkel 2022; Rocca et al. 2014). Ecological drought is defined as an episodic deficit in water availability that drives ecosystems beyond thresholds of vulnerability, impacts ecosystem services, and triggers feedbacks in natural and/or human systems (NPS 2021a). Increasing drought will occur even in parts of the region where annual precipitation increases, due to rising temperatures and resultant soil moisture loss across the Rocky Mountains (Rocca et al. 2014; NIDIS 2024). Drought conditions are closely tied to climatic water deficit, or the amount of additional water plants could use if it were available (NPS 2021c). While drought has historically been driven by lower precipitation, increasing temperatures due to climate change are leading to heat-driven drought conditions.

Wildfire

Across the region, the combined impacts of climate drivers including rising temperatures, drying, and reduced summer water availability contribute to growing wildfire risk (Rocca et al. 2014; Holden et al. 2018). While wildfire is a response to climate drivers, it can also be considered the driver of other ecological changes including ecosystem transformation, invasive species, and pests such as forest pathogens and insects. Wildfire is a natural process—and often an essential part of fire-adapted ecosystems—however climate change (in combination with land use change and historical fire suppression) is leading to increasing large, frequent, and severe wildfires (Abatzoglou and Williams 2016; Dennison et al. 2014; Parks et al. 2016). Across the Rocky Mountain region, severe wildfires have already caused ecological, human, and economic damage (Figure 6). It is projected that in the next few decades (2021–2050) area burned by wildfire in the Western United States will double compared to 1991–2020 (Abatzoglou and Williams 2016). Moisture deficits in the Rocky Mountains will lead to increased area burned, number of high fire danger days, and fire frequency by the middle-to-late 21st century (Westerling et al. 2011; Spracklen et al. 2009; Brown et al. 2004), while warmer temperatures are leading to a longer fire season length with both earlier start and later end (Rocca et al. 2014). Wildfires also are occurring at higher elevations (Alizadeh et al. 2021).

Figure 6. Howe Ridge Fire in Glacier National Park seen from across Lake McDonald on the night of August 12th, 2018, roughly 24 hours after the fire was started by a lightning strike in an area previously burned in the 2003 Roberts Fire.
NPS / GLACIER NATIONAL PARK

Extreme Precipitation and Flooding

Despite the overall drying trend, climate models project increases in heavy and extreme precipitation events in the Northern Rockies (USGCRP NCA5; Swain et al. 2025; Tabari 2020). Warmer air can hold more water vapor—about 7% more per 1.8°F (1°C) of warming—thus temperature increases effectively increase the atmospheric water demand, resulting in greater evaporation and transpiration by plants and decreased soil moisture. However, when warmer air is saturated, it acts like a huge atmospheric sponge that can be squeezed to release all that "extra" water during an extreme precipitation event. Thus, climate warming simultaneously results in both increased aridity and more extreme precipitation events. Precipitation and wildfire can interact to increase flood risk during post-fire extreme rainfall events (Touma et al. 2022).

Impacts to Park Resources

Climatic changes, including the gradual shifts in temperature and water availability and changing extremes described above, pose significant threats to resources under the protection of the NPS and valued by the public. Values covered in this report include natural resources, cultural resources, park infrastructure, and visitor experiences. Any of these values may also represent ethnographic resources, which are subsistence and ceremonial locales and sites, plants, animals, minerals, structures, objects, and rural and urban landscapes assigned cultural significance by traditional users (NPS 2002). Ethnographic resources are managed by many branches of the NPS, but are understood from the viewpoint of peoples or groups for which they have a special importance different from that enjoyed by the public (NPS 2002). These resources can be impacted by a variety of climatic changes that affect the resource itself or access to it, including changes to the abundance or distribution of living ethnographic resources (plants and animals) or to the integrity of a site or structure. For this reason, impacts to ethnographic resources are woven throughout the following sections to reflect their interconnectedness across natural and cultural resource management.

Different resources across the region may be more or less sensitive to different climate stressors. As park climates continue to depart from historical conditions, park resources may be impacted more severely and in novel ways. Park resources may also become more sensitive to climate change in the future due to novel combinations of interacting stressors. The following sections outline how climate change impacts assets managed by the NPS, describe how future climate trends may change these impacts, and highlight adaptation options available for managing impacts.

Natural Resources and Climate Change

This section describes the impacts of a changing climate on natural resources in the Rocky Mountains and highlights how the unique geographic context of the region interacts with resource vulnerability. The mountain ecosystems that characterize most of the park units in this report are disproportionately impacted by increasing temperatures at high altitudes which can accelerate rates of warming (Pepin et al. 2015). These rapid changes in temperature have direct and indirect effects on natural resources including impacts to vegetation, landscapes, wildlife, and water resources. However, mountainous landscapes also have high topographic complexity. In some cases, this complexity may promote ecological resilience by providing a wide range of climatic and ecological conditions in a relatively small area (McLaughlin et al. 2017). Michalak et al. (2021), which evaluated climate change factors to determine the relative vulnerability of NPS units across the nation, found that parks in the Western U.S. had relatively lower terrestrial vulnerability to climate change compared to the Eastern U.S. due, in part, to the high potential for climate refugia provided by relatively more mountainous terrain. Refugia are areas relatively buffered from contemporary climate change over time that enable persistence of valued physical, ecological, and socio-cultural resources (NPS 2021a).

Ecosystem Transformations

In addition to impacts on individual species, climate change can trigger landscape-scale change. Ecological transformation is the dramatic and irreversible shift in multiple ecological characteristics of an ecological system, the basis of which is a high degree of turnover in ecological communities and not just change in a single species (NPS 2021a). After wildfires, ecosystem recovery often depends on the proximity of seed sources from unimpacted forest patches. Large wildfires in Western North America have led to conifer regeneration failure in temperate and boreal forests. Additionally, recent research found that above an average summer temperature of 17°C (62.6°F), Douglas-fir regeneration will be limited regardless of how close the nearest seed source is (Kemp et al. 2019). Therefore, rising temperatures mean that ecosystem transformation of low-elevation forests in the Rocky Mountains is increasingly likely following wildfire. High-severity wildfire has been found to also homogenize flora at the regional scale in the Northern Rockies ecoregion, reducing landscape diversity (Burkle et al. 2015). When the return interval of severe wildfire becomes shorter than the time it takes for a forest to recover, stands are increasingly vulnerable to ecosystem transformation away from forest systems entirely toward grassland or shrubland. In the Greater Yellowstone ecosystem, research predicts that increased fire frequency by midcentury will impact the persistence of conifer species and lead to shifts towards lower montane woodland or non-forest vegetation (Westerling et al. 2011).

Vegetation Shifts

Across the Rocky Mountain region, climate change is expected to result in significant shifts in both the distribution and abundance of plant species due to changing mortality and regeneration rates (Kemp et al. 2019). While vegetation shifts are broadly occurring across the US, alpine plants and pollinators are particularly susceptible (Inouye 2020). Increasing temperatures and altered snowpack patterns affect the growing season of Rocky Mountain vegetation, potentially leading to phenotypic mismatches—unequal shifts in the seasonal timing of interacting species (Visser and Gienapp 2019; Monahan et al. 2016). Rising spring temperatures in Rocky Mountain National Park are projected to increase the length of the growing season for plants by up to 2 months, with the start of the growing season shifting from June to April (NPS 2021b).

As plant species shift their ranges to higher elevations to track suitable climate conditions, new plant species are arriving from lower elevations with warming temperatures. Vegetation changes will vary geographically; however, the overall trend in the Rocky Mountains is toward warmer- and drier-adapted plant species (Holsinger et al. 2019). In high-elevation ecosystems, alpine cover may shift toward coniferous forest as the tree-line moves upward, and dry coniferous forests of the U.S. West may shift toward deciduous tree species (Holsinger et al. 2019). There may be a loss of cold montane forests in parks including Grand Teton, Yellowstone, and Glacier. This loss may include whitebark pine, a species which Indigenous communities in the Crown of the Continent ecosystem have deep cultural connections to and whose range shifts may impact cultural practices and lifeways (American Forests 2017). Earlier snowmelt is leading to earlier starts to the growing season, exposing high-altitude wildflowers (Figure 7) and leading to frost damage (Inouye 2020). In addition to direct impacts, climate change may result in indirect impacts on vegetation via severe events like wildfire, non-native species invasion, or pest outbreaks.

Figure 7. Glacier National Park. Some alpine flowers like the Jones' columbine (*Aquilegia jonesii*) and alpine glacier poppy (*Papaver pygmaeum*) are dependent on the meltwater from permanent or semi-permanent snowfields. As these snowfields shrink and eventually disappear, these plants could vanish along with them. Long-term monitoring projects going back to the 1980s have already detected a significant decline in many alpine plant species.
NPS / GLACIER NATIONAL PARK

While many species in the Rocky Mountain region are drought-adapted, increasingly severe drought conditions due to a changing climate may impact vegetation. In addition to increasing the risk of wildfire, drought has been shown to increase tree mortality, alter plant phenology, and impact seed production and germination (USDA 2017). For example, wildflowers with high moisture requirements, such as the Rocky Mountain Iris, are especially limited during drought years in Rocky Mountain National Park (NPS 2012). Additionally, drought may narrow the windows of time available for successful seedling establishment in low-elevation forests of the Northern Rockies. Research has found significant increases in Douglas-fir seedling mortality due to drought, and western hemlock abundance is projected to decrease in drier areas of the Northern Rockies (Keane et al. 2018). However, some drought-adapted species such as ponderosa pine are projected to expand their ranges with increasing temperatures. For many Indigenous communities, phenology informs decision-making including the timing and location of harvesting, hunting, and ceremonial events, which may shift as the climate changes (Chisholm Hatfield et al. 2018).

Invasive Plant Species
Multiple factors including changing temperature, changing precipitation, drought, and wildfire interact to impact vegetation through species invasion (USGS 2025a, 2025b; Finch et al. 2021). Warmer temperatures allow invasive species to expand their ranges northward and upward, while disturbance events such as drought and fire may damage or kill native species thus making ecosystems more susceptible to invasion (Robinson et al. 2020; Wallingford et al. 2020). In some cases, invasive species can lead to an invasion-fire cycle in which the invasive vegetation, pests and pathogens change the flammability of the ecosystem (Tomat-Kelly and Flory 2023; Brooks 2008; Chambers et al. 2019; NPS 2025a). In Yellowstone National Park, warming enables previously low elevation weeds like cheatgrass, desert alyssum (*Alyssum desertortum*) and many others to migrate into disturbed areas of the park, where they previously could not persist. Lowered forage quality due to plant invasion can have cascading effects on ungulates (NPS 2025b).

Forest Disease and Pest-Driven Changes
Climate change is also making landscapes of the Rocky Mountain region more susceptible to diseases and pests. Drought-stressed or fire-damaged trees produce insufficient resin to fend off boring insects. In Colorado, the Western Balsam Bark Beetle was the deadliest forest pest for the second year in 2022–2023, although the number of acres impacted by the beetle decreased in 2023 (CSFS 2023). Douglas-fir beetle and mountain pine beetle impacted areas increased in acreage in 2023, threatening Douglas-fir and ponderosa pine forests in the region. Bark-beetle kill of ponderosa pine impacts ethnographic resources, for example, culturally modified trees within Indian Grove at Great Sand Dunes National Park. Indian Grove was added to the National Register of Historic Places in 2000 and contains 72 modified ponderosa pine trees peeled by Indigenous people (NPS 2024c). Peel trees and other types of culturally modified trees are at risk from pest-related tree mortality and wildfire.

In forests of the Northern Rockies, western pine beetle outbreaks can lead to tree mortality rates of 80% (Loehman et al. 2018). The combination of milder winter temperatures and low precipitation has contributed to outbreaks of beetles in Rocky Mountain National Park (NPS 2018b; Figure 8). Rising temperatures in spring and summer also have been shown to aid pine beetle outbreaks by promoting faster regeneration times which increase population sizes, meaning that outbreaks are more likely in a warming world (Loehman et al. 2018). Additionally, white pine blister rust, an invasive fungus, infects western white pine, whitebark pine, and limber pine (Loehman et al. 2018) and its rate of spread may increase under a changing climate. Glacier National Park lost a significant amount of whitebark pine in the past two decades due to white pine blister rust, and the Greater Yellowstone Area saw a loss of large cone producing whitebark pine due to recent mountain pine beetle epidemic in the mid-2000s.

Figure 8. A view of the Never Summer Mountains from the Beaver Ponds Picnic Area in western Rocky Mountain National Park, with many trees killed by mountain pine beetles.
NPS / CCRP

Fish and Wildlife

Climate change is a global driver of change in biodiversity, including declines of cold-adapted species in the Rocky Mountain region. Freshwater systems in the Rockies have experienced disproportionate biodiversity declines. Recent research found that the proportion of occupied streams by bull trout in the northern U.S. Rocky Mountains declined 18% between 1993–2018 due to rising water temperatures and decreased summer streamflow, with projected declines of 39% by 2080 (Bell et al. 2021). Comparatively, cutthroat trout are more strongly impacted by the presence of invasive rainbow trout—a species which is expanding its range in the region due to climate change and introduction by humans (Bell et al. 2021). Yellowstone cutthroat trout in Yellowstone Lake are declining due to climate change and lake trout invasion (Glassic et al. 2024).

In the Northern Rockies, habitat for terrestrial species that depend on high-elevation snowy conditions, including Canada lynx, fisher, wolverine, and snowshoe hare, will decline with decreasing snowpack (McKelvey and Buotte 2018). Some more generalist species with high mobility, including deer and elk, will likely be more resilient to increasing temperatures and changing conditions. Some amphibians in the region, such as the Columbia spotted frog and the western toad, may become increasingly vulnerable to pathogens that benefit from warmer climate conditions, including the amphibian chytrid fungus (McKelvey and Buotte 2018; Figure 9). Climate-induced vegetation changes such as the loss of cold montane conifer forest systems can impact habitat for wildlife, such as the Clark's nutcracker and grizzly and black bears. Extreme temperatures (both hot and cold) impact American pika, which rely on cool summer conditions and winter snow. While pika are metabolically very temperature sensitive and have disappeared from some areas in the Western U.S., their vulnerability is affected by multiple factors, including habitat quality and connectivity that allows them to disperse to more suitable habitat (Schwalm et al. 2015). These factors produce considerable variability in both observed and projected occupancy across national parks within their historical range. Pika populations in the Rocky Mountains, including Teton and Rocky Mountain National Parks, have been more stable than in the Great Basin, where pika have disappeared from many historic locations (NPS 2016.

Figure 9. Columbia Spotted Frog (*Rana luteiventris*).
NPS / JACOB W. FRANK

For species in the deer family including mule deer and elk, chronic wasting disease (CWD) is a fatal prion disease and circulates in wild populations (Galloway et al. 2021). Climate change does not directly cause CWD; however the indirect impacts of habitat loss resulting from climate change are predicted to increase the rate of CWD transmission by pushing independent herds closer together and challenging containment efforts (NCEL 2020).

Rivers and Streams

The Rocky Mountains contain the headwaters of multiple major rivers, and changes in water resources within the region will result in both local and downstream impacts to communities and ecosystems. Rivers and streams in the region will face reductions in in-stream flow and rising water temperatures (Overpeck and Udall 2020). Runoff efficiency (the percentage of rain and snow that becomes river water) is decreasing (Woodhouse and Pederson 2018), with recent research attributing one third of the decrease in the Upper Colorado River Basin streamflow to increasing temperature (Udall and Overpeck 2017). Earlier snowmelt is shifting peak stream flow earlier in the season, with late summer streamflow especially impacted. In the Central and Northern Rocky Mountains, peak runoff has already shifted approximately two to three weeks earlier than prior decades (Rocca et al. 2014). In the Central Rocky Mountains, 89% of non-regulated watersheds have declining August discharge rates (Leppi et al. 2012). Modeled streamflow in Montana project decreasing flows by 2080, driven partially by reduced snow-covered area and snowmelt runoff (Chase et al. 2016). Shifting precipitation patterns may result in “flashy” flows—flows that rise and fall quickly (OEHHA 2015). Increased extreme precipitation events lead to higher rates of runoff and sedimentation, which impact water quality of downstream aquatic communities. For example, rain-on-snow events occurred in Yellowstone National Park in 2022 when rapidly rising temperatures in the mountains led to snow melting and rain occurring at the same time, leading to severe flooding.

Glaciers and Ice
Climate change will alter the cryosphere, or the frozen water within Earth’s systems. Mountain glaciers are critical to regional water storage and are also sensitive to changes in both temperature and precipitation (NPS 2018a). Glacier National Park contained 150 glaciers when the park was established in 1910 and is projected to be glacier-free by the end of the century (Holsinger et al. 2019). Rocky Mountain National Park’s glaciers have been relatively less impacted due to their shaded locations and high snow accumulation (NPS 2023b). Despite conditions that have buffered Rocky Mountain National Park’s glaciers from change, warming through the end of the century will likely lead to increased glacier retreat. The park has already seen impacts of climate change on the cryosphere, including the 2022 Chaos Canyon Landslide, which resulted from increasing air temperatures that thawed permafrost and ice (NPS 2024g). Multiple parks in the region including Glacier, Grand Teton, and Rocky Mountain also contain rock glaciers—ice covered with a thick layer of rock and debris (NPS 2018c). The rock layer buffers rock glaciers from temperature increases, which may allow them to persist under a changing climate.

Wetlands
Wetlands in the Rocky Mountain region are already being impacted by climate change, as warmer temperatures coincide with reduced wetland area (Ray et al. 2019). Wetlands are critical to wetland obligate and facultative species in Rocky Mountain parks, including Grand Teton and Yellowstone, but the shallow depths and small area of palustrine wetlands may make them comparatively more sensitive to climate change than deeper aquatic habitats (Ray et al. 2019). Rising temperatures lead to increased rates of evapotranspiration in many systems, which can lower water tables or completely eliminate the supporting groundwater hydrology that maintains these systems (Ray et al. 2016). In Yellowstone, about 40% of monitored wetlands dry up in hot dry years, which results in considerable year-to-year variation in amphibian reproduction. This interannual variability can be used to project future vulnerability under continued climate change (NPS 2025c). Moreover, other stressors, such as groundwater extraction or intense herbivory, can increase the sensitivity of wetlands to climate change (Cooper et al. 2025). Reducing other stressors to support healthy wetlands can, in turn, buffer effects of climate change on a watershed by reducing the effects of floods, droughts, and wildfires (Jordan and Fairfax 2022).

Lakes

Lakes are also sensitive to changing climate conditions. In response to rising air temperatures, lakes are experiencing increasing summer surface water temperatures and more ice-free days per year. In the Southern Rockies, researchers project that mean annual lake surface temperatures will increase 0.25°C per decade, while ice-free days are predicted to increase by 5.9 days per decade. Changes in lake thermal regime can then lead to algal blooms, changes in water quality, and shifts in habitat suitability for aquatic species (Roberts et al. 2017). Additionally, warming interacts with other factors, including nutrient inputs from air pollution, and has contributed to a dramatic increase in algal growth in some high-elevation lakes in Rocky Mountain National Park since 2010 (USGS 2020). Eutrophication occurs when a body of water becomes excessively rich in nutrients, leading to ecologically disruptive growth in aquatic plants and algae and depletion of dissolved oxygen. The increased eutrophication of Loch Vale lakes in Rocky Mountain National Park indicates that even lakes relatively far removed from human development can be impacted by large-scale global changes (USGS 2020).

Cultural Resources and Climate Change

The National Park Service is the steward of many of America's most important cultural resources—the physical and spiritual reminders of the decisive times, people, and places in American history and culture. The NPS recognizes five categories of cultural resources: archeological resources, cultural landscapes, ethnographic resources, structures and installations, and museum collections.

Climatic processes such as weathering, sunlight, and moisture necessitate and pose challenges to the protection of cultural resources—even in the absence of anthropogenic climate change (NPS 2025d). Climate change is already intensifying and accelerating factors that impact cultural resources (Sesana et al. 2021). Many of these factors overlap with the changing conditions that impact natural resources described in previous sections: temperature, precipitation, moisture, wind intensity, desertification, extreme events, and the interaction between climate change and air pollution. These climate-induced or climate-amplified threats lead to the alteration, deterioration, and in some cases loss of important and irreplaceable cultural resource values. According to an NPS-wide vulnerability assessment, parks within the "Western Forested Mountains" ecoregional group were found to have very high potential vulnerability scores for non-living resources due to high levels of climate-change exposure, compared to other U.S. regions (Michalak et al. 2021).

Archeology

Archeological resources are the material evidence of human culture and activity in the past. They include artifacts, features, sites, and associated documentation. Archeological resources may be subject to erosion, slumping, subsidence, or other natural deterioration (NPS 2024a), and climate change may exacerbate these impacts in the Rocky Mountain region.

Ice patches have been increasingly recognized as reserves for archeological resources, such as animal remains and artifacts used by Indigenous peoples. Archeological reserves are most common in patches that are isolated, lower elevation, and located along gentle topography (NPS 2024d). Rising temperatures are increasing the rate of ice patch melt, exposing archeological resources to rapid decomposition and increasing risk of illegal artifact collecting (looting). In Rocky Mountain and Glacier National Parks, research teams surveyed receding ice patches and documented exposed archeological resources, including animal remains, wood specimens, and cultural items (NPS 2024d, 2024e; Figure 10). Yellowstone National Park has identified over 450 ancient ice fields that could contain archeological resources (NPS 2022).

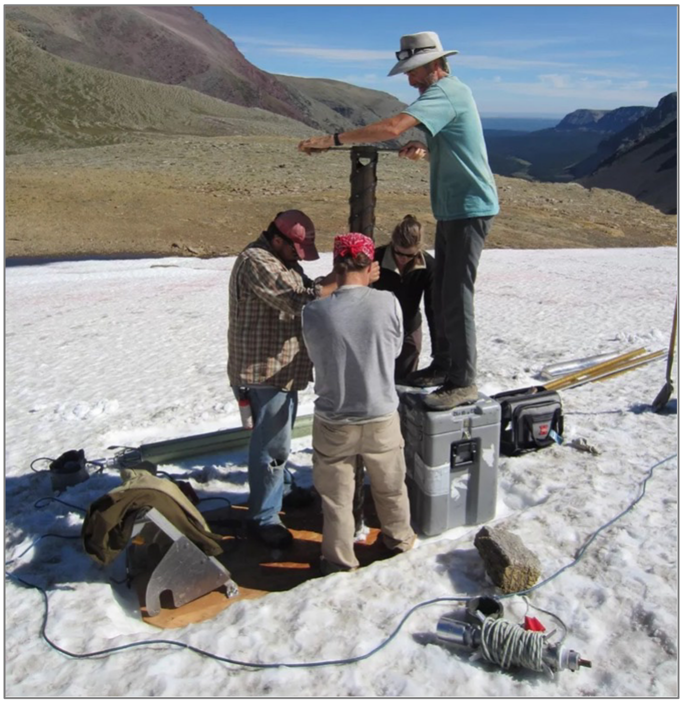

Figure 10. Ice patch archaeologists collect core samples to date the ice. The deepest parts of Glacier National Park's ice patches are over 6,000 years old.
NPS

Fire can affect archeological resources and artifacts directly through spalling—the peeling away of the rock face—which can damage or destroy rock art panels (NPS 2007). Different wildfire temperatures can impact various archeological materials. For example, at temperatures above 572°F obsidian artifacts melt, and at temperatures above 662°F chert artifacts shatter (NPS 2022). Resources most at risk are those that are on or near the surface, while those below approximately 6 inches underground are more buffered from the heat (NPS 2022). Wildfire can affect archeological resources indirectly as well. Burning of vegetation can expose artifacts and make them more susceptible to erosion and looting. Wooden archeological resources are threatened by climate change impacts including fire, wood deterioration, landslides, and insect damage.

Historic Structures and Installations
Structures and installations (e.g., roads, trails, bridges, culverts) with historic and/or cultural value are sensitive to extreme events within the Rocky Mountains including fire and storms. Structures damaged or destroyed by such events may be preserved as ruins, removed, or reconstructed and restored in accordance with NPS policy (NPS 2024a). Wildfire has led to loss of and damage to

historic structures, ranging from total loss of the structure to the cracking and splitting of construction materials (Sesana et al. 2021). While wildfire mitigation actions can help prevent damage to historic structures, some wildfire suppression actions, such as fire line construction, can also damage historic structures (Davis 2018). The impacts of wildfire on historic structures were exemplified in Glacier National Park by the loss of Sperry Chalet, a National Historic Landmark, in 2017 (NPS 2017; Figure 11).

Figure 11. The Sperry Chalet burned during the Sprague Fire on August 31, 2017. With a limited water supply, firefighters used portable water tanks, pumps and fire hoses to defend the structures.
NPS

Flooding can damage historic structures and districts due to the direct effects of water and indirect effects of subsequent landslides and debris flows (Sesana et al. 2021). Wildfire and flooding interact through post-fire erosion events where historic structures and installations may be damaged or washed away by rain events on hydrophobic surfaces (Sidman et al. 2015). Historic trails with wooden erosion control structures may lose integrity after a fire due to burning of the structures and subsequent erosion of the trail.

Historic structures can also be sensitive to gradual changes in climate. Temperature changes can increase the frequency of freeze-thaw cycles that structurally damage masonry buildings (Sesana et al. 2021). Thermoclastism—damage to stone materials caused by thermally induced expansion and contraction—leads to the deterioration of building facades (Sesana et al. 2021). Changing temperatures, in combination with air pollution, can corrode metal and masonry. Wind and wind-driven rain erodes building materials and can damage historical buildings and monuments due to increased water penetration into porous materials (Sesana et al. 2021).

Museum Objects

Museum objects are held in historic structures, modern facilities or in outdoor locations. Museum objects include prehistoric and historic objects, artifacts, works of art, archival material, and natural history specimens that are part of a museum collection. The sensitivity of these objects to a changing climate is primarily driven by the sensitivity of the building or location where they are stored. For objects within a building, changes in indoor temperature and humidity can degrade museum collections depending on the ability of the structure to regulate internal conditions (Sesana et al. 2021). Events which significantly damage the structural integrity of the building, such as flooding and fire, pose risks to museum collections inside. Modern facilities built specifically to house museum objects are the least sensitive to climate change because they were engineered with indoor climate control and protections against flooding and fire damage. Museum objects stored outdoors generally are large items like ranching or farm equipment. They can be particularly sensitive to climate change and extreme events (wildfires, storms, floods) because they lack any protection.

Cultural Landscapes and Historic Districts

The NPS defines a cultural landscape as a geographic area, including both cultural and natural resources and the wildlife or domestic animals therein, associated with a historic event, activity, or person, or exhibiting other cultural or aesthetic values (NPS 2024f). In the Rocky Mountain region, there are many cultural landscapes including Mormon Row Historic District and Murie Ranch Cultural Landscape in Grand Teton National Park, McGraw Ranch, and Moraine Park Museum and Amphitheater Cultural Landscapes in Rocky Mountain National Park, and Going-to-the-Sun Road Historic District Cultural Landscape in Glacier National Park.

While cultural landscapes are included in the Cultural Resources section of this report, these landscapes are social-ecological systems containing multiple types of values, making protection and management complex. Cultural landscapes evolved under specific climatic conditions which are now shifting under a changing climate (Aktürk and Dastgerdi 2021). While it is widely recognized that climate change will impact cultural resources, the impacts and challenges specific to cultural landscapes are not well understood. This is partially because impacts on cultural landscapes are an accumulation of impacts on individual natural and cultural resources within these landscapes, described in other sections of this report.

Flooding can damage cultural landscapes by degrading the cultural or natural features related to intangible values and reducing visitation (Sesana et al. 2021). Severe flooding may alter the historical topography and vegetation through landslide and other highly erosive events on steep slopes that then deposit sediments in flatter areas. In contrast, drought conditions can inhibit growth of culturally significant or iconic vegetation species due to water stress and pest-susceptibility. In Montana, outbreaks of mountain pine beetle have altered cultural and historic landscapes through widespread vegetation damage (Davis 2018). Changing seasonality and phenology brought on by climate change may impact the aesthetic values associated with cultural landscapes by shifting blooming times, while loss of pollinators reduces plant fertility in historic agricultural landscapes (NPS 2024b). Disturbance events, including wildfire and invasive species, can also change landscape features and damage or destroy buildings which contain cultural significance.

Visitor Use and Climate Change

Visitation to national parks has been increasing in recent years, with 332 million NPS visits in 2025—a 12% increase in visitation since 2014 (NPS 2025d). Climate change will impact multiple aspects of visitor use in parks including visitor numbers, timing of visits, visit location choice, activity participation, visitor experience quality, and visitor safety. Outdoor recreation visits to parks provide multiple non-material benefits including improved mental and physical health and educational opportunities. Understanding how these non-material benefits may be impacted or altered under a changing climate is critical for developing effective climate adaptation strategies. Not all impacts will be felt equally across demographic groups, and equitable adaptation must account for disparities in climate impacts on visitors (Miller et al. 2022).

In 2025, the NPS published a *Review of the Effects of Climate Change on Visitor Use in US Public Lands and Waters*, providing up-to-date information about climate impacts on multiple aspects of visitor use, including changing visitation levels, timing of trips, activity participation, and visitor safety (Wilkins et al. 2025; Figure 12). Across the Western U.S., climate driven changes that impact visitation include increasing temperatures, flooding and drought, decreasing snowpack and earlier spring runoff, wildfire and smoke, harmful algal blooms (HABs), and zoonotic and vector-borne diseases (EPA 2022a).

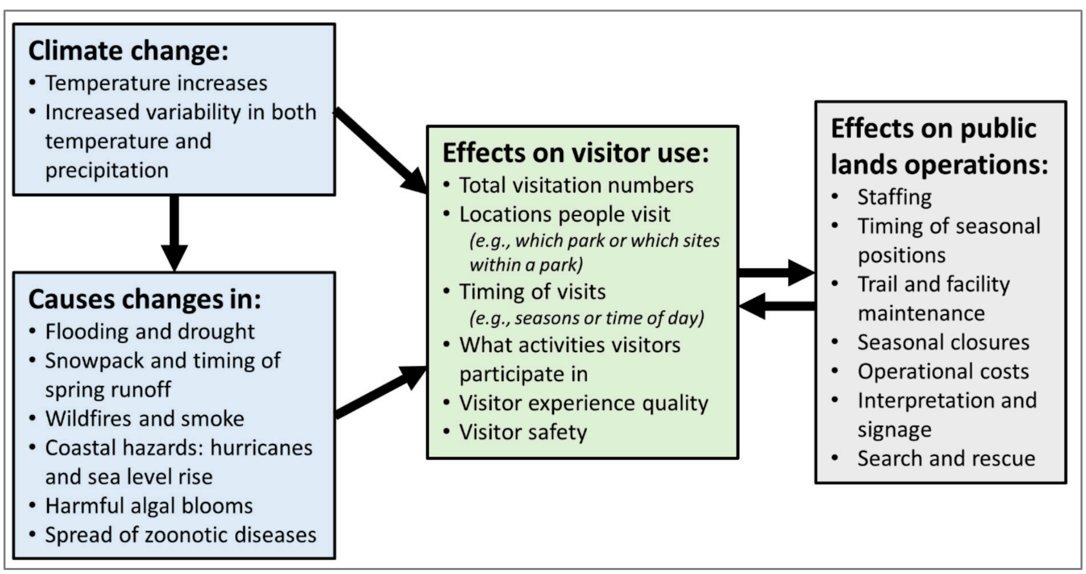

Figure 12. Conceptual diagram illustrates how climate change is affecting visitor use in public lands and waters, and how resulting changes in visitor use can affect park operations.
ADAPTED FROM WILKINS ET AL. 2025

Increasing Temperatures

Visitation generally increases as temperatures warm (up to a point, see https://www.nps.gov/subjects/climatechange/visitation.htm for information on how warming temperatures may affect visitation at a specific park). Rising temperatures can also affect activity participation. Higher temperatures in the Rocky Mountains increase total trips to participate in warm-weather activities, such as camping, biking, and fishing, but decrease total trips to participate in snow-dependent activities, such as skiing or snowmobiling (Winter et al. 2021). Additionally, warmer temperatures will shorten periods when roads and high mountain passes and trails are closed to public access due to snow (Winter et al. 2021; O'Toole et al. 2019). Rocky Mountain National Park, which manages a 2 mile section of the North Supply Access Trail (a snowmobile trail network), has seen later season openings due to lack of snowpack (Pace 2020). Longer and hotter summers may also mean higher demand for water-based recreation (Miller et al. 2022).

Warming temperatures and more days with extreme heat have the potential to negatively affect visitor health and safety through increased incidents of heat-related illness (Buttke et al. 2023). Extreme heat is currently the leading cause of weather-related deaths in the United States, and prolonged exposure to heat has been linked to heat exhaustion, heat stroke, kidney and heart disease, and pregnancy complications (Konkel 2019; HHS 2024). Physical exertion, including outdoor labor on the part of park staff and high-intensity recreation activities on the part of park visitors, is more dangerous during high-heat conditions (EPA 2022b).

As recreation opportunities decrease or are restricted in some areas, recreational use will become increasingly concentrated within areas that are relatively less impacted by changing climate. Increased concentration of visitation in certain locations may pose challenges for maintaining natural and cultural values. Hunting, fishing, and backcountry skiing are projected to decline in the Rocky Mountains (Miller et al. 2022).

Precipitation Changes, Drought and Flooding

Precipitation changes and drought have variable effects on total annual visits to mountainous national parks in the West. Variable water levels at reservoirs affect visitor access and typically decrease visitation (Wilkins et al. 2025). Severe droughts have significantly impacted visitation rates in the Northern Rocky Mountains (Steiger et al. 2024). These reductions in visitation during dry extremes may be due to a number of factors including increased risk of wildfire and heat waves associated with dry conditions, altered access to desired recreational conditions including reduced water levels, and/or management actions such as closures which intentionally reduces access in impacted areas (Jedd et al. 2018).

Decreasing Snowpack and Earlier Spring Runoff

Decreasing snowpack and earlier snowmelt in the spring can affect the timing of wildflower blooms and related wildflower viewing visits in mountainous parks (Breckheimer et al. 2020). Warmer summertime temperatures and extreme heat events can increase snow and glacial melt. Faster melt leads to flooding or variability in streamflow, which can make stream crossing dangerous or trails inaccessible for visitors (NPS 2025e). Declining snowpack is also reducing opportunities to participate in snow-dependent activities, such as cross-country skiing, downhill skiing, and snowmobiling. Almost all locations across the United States are projected to see a reduction in the winter-recreation season length under climate change, with an anticipated 50% or more reduction by 2050 in the Rocky Mountains (Wobus et al. 2017). Changes to snowpack and spring runoff can affect visitor safety, as snow density and elevation influence the prevalence and impact of avalanches (Strapazzon et al. 2021).

Wildfires and Smoke

Active wildfires and related site closures, burn scars, wildfire smoke, and air quality all have the potential to affect visitor use on public lands. Active wildfires within and close to national parks temporarily decrease visitation due to access and wildfire smoke issues (Duffield et al. 2013; Kim and Jakus 2019). Camping and backcountry skiing have decreased in some recently burned landscapes (Hesseln et al. 2004; Hesseln et al. 2003). Conditions within fire-impacted landscapes (burn scars) may affect recreation for many subsequent years, with varying effects on visitation (Schroeder and Schneider 2010). After a wildfire, recreationists may face hazards from dead, unstable, and downed trees, reduced water quality, and post-fire flooding and erosion events (NPS 2018). Forest insect outbreaks, which are being exacerbated by climate change, also result in an increase in dead or dying trees that can be hazardous to recreationalists and park staff (Melnick and Quiroz 2017).

Wildfire smoke affects visitors in three main ways: by reducing visibility, which can impair scenic viewsheds; by posing risks to human health; and by influencing aquatic recreation, as air quality can also affect water quality and water resources (Zajchowski et al. 2019). Health impacts are related to the length and amount of smoke exposure, the composition of the smoke, and an individual's health history. Fine particle pollution (PM 2.5) is the most common smoke-related public health concern; however, wildfire smoke can include a mix of other pollutants depending on the vegetation and structures burned (EPA 2019). Exposure to smoke from wildfires is associated with a range of respiratory conditions, increased emergency room visits, hospitalizations, and deaths (EPA 2019). High risk populations include wildland firefighters, people who work outside, people with existing health issues including lung and heart conditions, children, older adults, pregnant people, and people with less access to health care (CDC 2025; CDPHE 2025). Wildfires can impact human health in several direct and indirect ways, both during and after a fire event. In addition to loss of life, property, and livelihoods, exposure to wildfire events has been linked to adverse reproductive outcomes, poor mental health, and reduced psychosocial well-being (D'Evelyn et al. 2022).

Harmful Algal Blooms

In water bodies, increasing temperatures are linked to algal blooms and increasing toxic cyanobacterial outbreaks, which can make people sick and affect water recreation (Crimmins et al. 2016). HABs in reservoirs and “red tide” events in reservoirs and along seashores can cause severe gastrointestinal and respiratory illness and even death (Roberts et al. 2017). HABs are a concern for Rocky Mountain rivers, lakes, and reservoirs. HABs have the potential to decrease visitation significantly to U.S. reservoirs (Limaye et al. 2019) and already negatively affect visitor experience when present in a water body (Ferguson et al. 2018).

Zoonotic Diseases

Zoonotic and vector-borne diseases carried by mosquitos, such as West Nile virus, dengue fever, and western equine encephalitis, pose potential impacts to visitor use in a changing climate. In the Rocky Mountains, climate change also impacts health through the spread of insect- and tick-related diseases. Particular concerns in the region are mosquito-borne pathogens and tick-spread Lyme disease and Rocky Mountain spotted fever. Warming temperatures have led to tick and mosquito range expansions, as well as longer seasons of human exposure to biting insects (Deshpande et al. 2023). One species found in Rocky Mountain National Park is the Rocky Mountain wood tick (Figure 13), which can spread bacteria, viruses, and parasites that cause human disease (NPS 2025f).

Figure 13. Rocky Mountain wood tick (*Dermacentor andersoni*).
NPS / JACOB W. FRANK

Mental Health
In addition to physical health impacts, climate change can affect the mental health of visitors and staff. The trauma of experiencing extreme events, loss or damage of critical resources including housing, as well as the loss of sense of place and belonging related to changing conditions, may contribute to declines in mental health and human well-being (Hayden et al. 2023; Crimmins et al. 2016). For example, staff housing for 22 seasonal employees was destroyed in Rocky Mountain National Park by the East Troublesome Fire in 2020, impacting people's lives and livelihoods (NPS 2023c). Alongside acute events that cause distress, climate change has been described as a "hidden stressor" by the U.S. Department of Health and Human Services—a stressor that can accumulate over time and contribute to anxiety and depression, especially among youth and young adults (HHS 2024).

Infrastructure and Climate Change
NPS units contain structures, recreation facilities, trails, roads, and other types of infrastructure that are maintained to provide safe access while protecting natural and cultural resources. Climate change poses risks to NPS infrastructure in a variety of ways covered in this section.

Structures and Facilities
While many of the risks described for historic structures apply to modern buildings and facilities, there are some additional and unique considerations to account for. Extreme temperatures can increase weathering of structures and strain existing HVAC systems (EPA 2022c). The increased demand for air conditioning systems can add stress to building envelopes and, in some cases, require significant structural alterations. As HVAC systems work harder to cool buildings during extreme heat, energy consumption and costs may increase and impact park operations. Extreme precipitation presents threats to structures and facilities, including inundation of structures, structural collapse from force of floodwaters, sewage backup, accelerated decay of masonry, overflow of drainage systems, cracks in building infrastructure, destabilization of buildings and pipes, erosion of supporting ground around structures. Post-flooding risks include damp indoor conditions which increase rot, fungal and insect attack, mold and mildew, and physical deterioration of building materials including wood, brick, and stone.

Transportation Infrastructure
Climate change has and will continue to have significant impacts on transportation infrastructure within parks across the U.S. and within the Rocky Mountain parks. Changing conditions can impact transportation infrastructure safety, function, cost, and access. Extreme heat can cause cracks in roads and lead to overheating of vehicles. Heat waves negatively impact pavement performance through rutting, cracking, and buckling events (Pew Charitable Trusts 2024). Increased local flooding events can have direct effects, such as weakening roadway materials and increasing traffic. Flooding can also lead to indirect effects on roads through post-flooding erosion and mudslide events, which are high-risk on steep mountain slopes (Steiger et al. 2024). When roads and bridges are washed out by extreme events, access to certain areas of the park may be reduced or cut off, challenging emergency response and service access (EPA 2022d; Figure 14).

Figure 14. Washed-out bridge at Rescue Creek, Yellowstone National Park.
NPS / CHRIS FLESCH

In 2013, Rocky Mountain National Park experienced extreme precipitation and flooding from prolonged rains over a period of days. State Highway 34, a major route for park visitors and commuters, sustained extensive damage and was closed for months. In 2022, Yellowstone National Park experienced an unusual rain-on-snow event that resulted in exceptional flooding of the Yellowstone River, washing out roads, trails, bridges, and structures both inside and outside the park.

In addition, with climate change and the resulting "climate intensification", heavy precipitation will become a common occurrence after extreme wildfires (Touma et al. 2022), resulting in rapid runoff, increased flood hazards, and erosion with impacts to waterways and infrastructure such as bridges, water treatment facilities, trails, and structures in or near waterways. In 2021, heavy rainfall fell on recently burned forests in northern parts of Rocky Mountain National Park, causing a flash flood that carried rocks, soil, and trees down a small canyon that fed into the Cache la Poudre River. Outside of the park, four people were killed, and houses and bridges were washed away.

Recreation Infrastructure

Recreation infrastructure in parks includes campgrounds, trail systems, and day use infrastructure, with varying climate impacts to each. Some locations that have been historically popular for camping and hiking may become less desirable or safe due to wildfire. Trail bridges and erosion control structures constructed from wood have high vulnerability to wildfire and trails proximate to wildfire burn scars may be impacted by dead and downed trees. Because peak camping season and wildfire seasons overlap, campers are becoming increasingly exposed to fire and smoke (see section on Visitor Health and Safety for more information). Trails are also susceptible to erosion, washouts, landslides, and flooding. During the Yellowstone National Park floods in June of 2022, multiple campgrounds were inundated and campers were rescued from campgrounds in the Beartooth foothills along the Stillwater River (Chase et al. 2024).

Utility Infrastructure

Utility systems include services such as power, sewage disposal, and water, including the equipment and infrastructure needed to provide service. Climate change can disrupt or damage utility systems critical to park operations. Snow and ice, wildfires, and extreme wind events damage above-ground power lines, while flooding can impact underground power lines and pipelines. During windstorms, damaged power lines can, in turn, ignite wildfires. Power companies may proactively cut power to avoid wildfire ignitions during storms, which results in power outages (Erblat and Smith 2024). Changing precipitation and flood events affect water supplies, leading to secondary impacts for energy systems and emergency response. At Yellowstone National Park, it took Mammoth Hot Springs Hotel and Cabins over a year to reopen after the 2022 floods due to wastewater system repairs (NPS 2023a).

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